Bi *et al. Food, Nutrition and Health* (2025) 2:24
https://doi.org/10.1007/s44403-025-00033-0

REVIEW

Open Access

Therapeutic, nutritional benefits, and applications of *Cistanche Deserticola* Y.C.Ma: a systematic review

Yaqiong Bi[1†], Guleng Amu[2†], Feng Gao[3], Jianxun Zhu[4], Feibiao Shan[1], Wenle Wang[1], Zeyuan Zhao[3] and Minhui Li[1,2,3,5*]

Abstract

The homology of food and medicine is one of the core ideas in traditional Chinese medicine, where Chinese medicine achieves gentle conditioning through daily diet. *Cistanche deserticola* Y.C.Ma (CD) is a representative medicinal plant under this class, with expanding potential for diversified applications in modern health and wellness while retaining its traditional therapeutic roots. It is renowned for its non-toxic nature, long-term safety, and vitality-enhancing properties. CD is widely used in tonifying the kidneys, nourishing the essence, and moistening the intestines, commonly applied in the treatment of ailments such as impotence, lumbar weakness, and constipation, particularly those related to kidney yang deficiency. The herb is abundant in bioactive compounds, including phenylethanoid glycosides, iridoids, and flavonoids, which exhibit diverse pharmacological effects such as antioxidant, anti-aging, immune-modulating, and anti-inflammatory activities. These bioactive constituents support CD's expanding use across pharmaceuticals, functional foods, cosmeceuticals, and consumer healthcare products. This review examines CD's value across its traditional applications, botanical resources, phytochemical composition, and pharmacological effects, focusing on therapeutic, nutritional, and applied dimensions. It also aimed to explore the current status, prospects and challenges of developing healthcare products based on CD by analyzing the data on the use of CD in functional food and patents. By integrating traditional wisdom with modern technologies and standardized methodologies, CD can unlock its potential in disease prevention, physical enhancement, and health management across diverse populations. The review emphasizes its role in advancing preventive care and functional nutrition, paving the way for innovative applications in health-promoting products development.

Keywords *Cistanche deserticola* Y.C.Ma, Functional plant, Patent, Therapeutic, Nutritional Benefits

Introduction

The global demographic transition toward aging populations presents unprecedented public health challenges and transformative opportunities in the twenty-first century. Over the coming decades, this trend is projected to intensify, with individuals increasingly experiencing prolonged periods of age-related multimorbidity and functional decline. These realities underscore an urgent need for integrative strategies that mitigate age-associated pathologies while enhancing regenerative capacity and systemic resilience. Emerging evidence positions nutritional intervention as a cornerstone in addressing these

†† Yaqiong Bi and Guleng Amu these authors contributed equally to this work and should be considered co-first authors.

*Correspondence:
Minhui Li
prof_liminhui@yeah.net
[1] Inner Mongolia Traditional Chinese & Mongolian Medical Research Institute, No. 1 35 Middle School Lane, Hohhot, Inner Mongolia 010010, China
[2] Inner Mongolia Hospital of Traditional Chinese Medicine, Hohhot 010020, China
[3] Inner Mongolia Medical University, Hohhot 010110, China
[4] Changchun University of Chinese Medicine, Changchun 130117, China
[5] Baotou Medical College, Baotou 014060, China

© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

challenges, with dietary patterns demonstrating significant potential to modulate environmental stressors and influence disease trajectories [1–3]. Modern food science employs fortification strategies to fill nutritional gaps and enhance health benefits by adding specific nutrients and non-nutritive bioactives to consumer products.

Concurrently, the convergence of traditional wisdom and technological innovation has catalyzed exploration into traditional Chinese medicine ingredients with dual medicinal-dietary functions. Spanning commonplace foodstuffs to specialized botanicals, these phytoactive resources are increasingly validated as sustainable anti-aging interventions. They are able to delay senescence processes, attenuate age-related disorders, and synergize with modern healthcare frameworks [4, 5].

China's medical heritage reflects a profound integration of dietary and therapeutic practices. As early as the Qin and Han dynasties (221 BCE–220 CE), the concept of the integration of medicine and food and the idea of preventive treatment were proposed in the Yellow Emperor's Classic of Internal Medicine (Huangdi Neijing). It emphasized using food therapy or medicinal diets to regulate the body, enhance immunity, and achieve disease prevention [6]. The principle of medicine food homology further solidifies this perspective, recognizing that certain natural substances can be used both as medicine and food, offering both therapeutic benefits and nutritional value [7–9]. In the development of homology-based products, traditional Chinese medicine can be applied in multiple directions, including pharmaceuticals, food for special medical purpose, functional foods, snack foods, personal care sector, and animal health products [10]. Collectively, these developments signify a paradigm shift toward precision nutrition strategies that harmonize ancestral knowledge with contemporary biomedical needs, offering scalable solutions to enhance health span within aging societies [11]. Among more than 18,000 varieties of traditional Chinese medicinal herbs [12], 114 have been included in the official directory of substances recognized as having homology of food and medicine. Over thousands of years of application, these herbs have been shown to possess both unique medicinal effects and long-term safety, providing clear guidance for developing health-promoting products aimed at specific populations.

CD, a precious herb commonly known as Rou Cong Rong, is widely used in traditional medicine and is one of the species included in the functional food directory. Historically, it has been highly valued for its remarkable effects in tonifying the kidneys, nourishing essence, and promoting bowel movements [13]. The earliest recorded use of CD can be traced back to the Divine Farmer's Classic of Materia Medica (Shennong Bencao Jing), where it was listed as a "superior herb." "Superior herbs" are described as non-toxic, safe for long-term use, capable of enhancing vitality, and promoting longevity. Subsequent medical texts throughout history have provided detailed accounts of the use of CD as a medicinal material [14]. CD primarily grows in desert regions, parasitizing the roots of shrubs such as *Haloxylon ammodendron* and *Atriplex canescens* [15]. Due to its unique parasitic nature and harsh growing conditions, its resources are relatively scarce, mainly distributed in Inner Mongolia, Xinjiang, Gansu in northwestern China and the south gobi of Mongolia [16].

In traditional medicine, CD is renowned for its ability to tonify kidney yang and moisten the intestines, primarily used to treat symptoms such as impotence, lower back and knee weakness, and cold-related constipation. Its broad range of applications covers the urinary, gastrointestinal, and reproductive systems, making it highly favored by both patients and practitioners for its effectiveness and mild nature [17]. Chemically, CD is rich in bioactive compounds such as phenylethanoid glycosides, iridoids, flavonoids, and polysaccharides. Research shows that these compounds exhibit various pharmacological effects, including immune-regulating, antioxidant, anti-aging, and growth hormone-promoting activities. Phenylethanoid glycosides (e.g., echinacoside) are considered the key active components, with strong anti-fatigue and anti-inflammatory properties.

In recent years, scholars'research on CD has focused on the exploration of its chemical composition and pharmacological effects, and these research results have laid an important scientific foundation for the application and development of CD products. Currently, CD demonstrates a wide range of potential applications in disease treatment, population nutrition and daily health management (Fig. 1). However, systematic reviews on the development of functional products and the mining of medicinal and food values of CD are still limited. In order to further promote the in-depth application of CD in the 'health-promoting products sector' for precision, it is necessary to systematize its existing research results and explore its future development direction. The aim of this review is to systematically collect information on functional foods and patents, analyze the current status of standardization and integration of CD with medicinal foods, and go over the trends of market applications and technological innovations of CD. In addition, this review also examines the potential ways to diversify the development and expand the application of CD-based health-promoting products, and deeply explores the role of CD in health management, disease prevention and physical fitness enhancement of different populations. From the current situation, it expands the industrial demand and

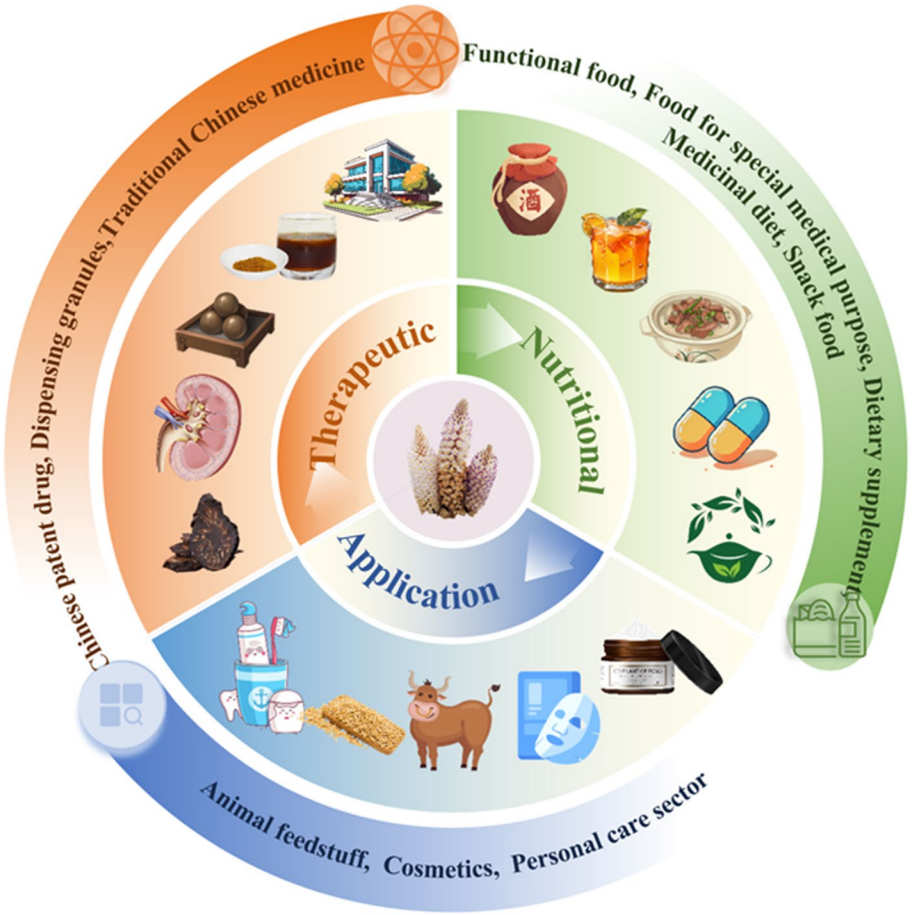


Fig. 1 Schematic overview of the *Cistanche deserticola* products

international development of health-promoting products centered on CD, a functional plant.

Method

Patent data statistics and analysis

In this study, we retrieved all global patents related to CD from the incoPat patent database (https://www.incopat.com) through keyword-based searches, using both the medicinal name Cistanches and the botanical name *Cistanche deserticola*. To ensure specificity, patents related to *Cistanche tubulosa*, another recognized botanical source of Cistanches, were excluded from the search results. Patents were selected based on their application dates, which had to fall between January 1, 1995 and December 31, 2024. The screening was conducted using the search expression ALL = ("Cistanches" OR "*Cistanche deserticola*" NOT "*Cistanche tubulosa*") AND (AD = [19950101 TO 20241231]) for patent screening. The search results were manually reviewed and screened to eliminate patents with incomplete information and irrelevant subject matter. Using patent bibliometrics and visualization analysis, this study utilizes the incoPat database's "Keyword Filtering" and "Advanced Analysis" modules, combined with statistical tools. A comprehensive analysis is conducted on CD's patent pattern, global development trend, and efficacy application. Additionally, ArcGIS software was utilized to map the geographical distribution of patent filings, highlighting the main regions of innovation and development activity related to CD.

Functional food data statistics and analysis

This study used the Chinese term "Rou Cong Rong" (*C. deserticola* Y.C.Ma) as the main raw material of search keyword to collect data from the functional food registration platform of the State Administration for Market Regulation (SAMR; http://ypzsx.gsxt.gov.cn/specialfood/#/food). Data spanning from 1997 to 2024 were systematically retrieved and screened. The raw data table included detailed information on product names, characteristic components, main raw materials, health functions, usage methods and dosages, suitable and unsuitable

populations. To ensure data integrity, duplicate entries and products explicitly labeled as containing"Guan Hua Rou Cong Rong"(*C. tubulosa* (Schenk) Wight) were excluded. Standardization protocols were applied to unify terminology for both raw material components and health functions. For analytical visualization, heatmap analysis was performed using R programming (version 4.4.0) to elucidate patterns between botanical name of plant-derived ingredients and associated health functions.

Resource status of CD

CD is a perennial holoparasitic herb belonging to the Orobanchaceae family. It relies entirely on parasitism for survival due to its complete lack of chlorophyll and inability to perform photosynthesis. It derives essential nutrients and water by parasitizing host plants, primarily *H. ammodendron* and, as recent innovative research has revealed, *A. canescens* [18, 19]. This species is predominantly found in desert and arid regions of China (Inner Mongolia, Ningxia, Gansu, and Xinjiang), Mongolia, Iran and India [20, 21]. The fleshy stems of CD are the main medicinal part and are valued for their medicinal properties and are widely used in traditional medicine. However, overharvesting, combined with inadequate conservation measures, has led to a significant decline in wild populations. As a result, CD has been listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) [22].

In response to the urgent need for conservation and sustainable resource utilization, experimental cultivation of CD began in the 1980s. Inner Mongolia has since emerged as a key region for large-scale cultivation, renowned for both the quality and quantity of its production [23]. According to 2016 data, Alxa in Inner Mongolia, China, which contains over one million hectares of *H. ammodendron* forests, produces more than 1,000 metric tons of CD annually. [24] Recent agricultural statistics indicate that the cultivation area of it in Alxa has now expanded to over 30,000 hectares. The establishment of this large-scale cultivation system has ensured a stable and renewable supply of raw materials [25], which is critical for the development of plant-based pharmaceuticals, nutraceuticals, and functional foods. The success of these cultivation efforts underscores the potential for sustainable exploitation of CD, contributing to both biodiversity conservation and economic development in arid regions.

CD has been documented in numerous traditional Chinese medical texts over the past two thousand years for its wide range of applications. Known for its mild yet effective tonic properties, it provides balanced therapeutic effects and has long been used in classical formulations to strengthen kidney function and enhance vitality. In formulations for anti-aging and longevity, it is second only to ginseng in usage frequency [26]. Due to its tonic and health benefits comparable to those of *Panax ginseng*, it is often referred to as "desert ginseng" [27]. Unlike some supplements that may lead to what's known in traditional Chinese medicine as "Heat syndrome", CD offers balanced nutritional support and is less likely to disrupt the body's natural equilibrium. Therefore, it is more appropriate for long-term dietary intake. The earliest written record of CD used for dietary health purposes appears in the Tang Dynasty text Supplement to Materia Medica. Historically, it has been prepared with other dietary ingredients through methods such as soups, congees, stews, stir-frying, boiling, and infusions in wine or tea. Goat or sheep meat (*Capra hircus* or *Ovis aries*) is frequently used as the main ingredient in these preparations, though other components like eel (*Anguilla spp.*), Chinese yam (*Dioscorea opposite*), and goji berries (*Lycium barbarum*) are also common. Across dynasties, the use of CD has been valued not only for its flavor and nourishing effects but also for its therapeutic goals, including warming kidney yang, enhancing vigor, sustaining vitality, and improving complexion. This enduring medicinal and dietary tradition provides a robust foundation for developing CD into functional foods and health-promoting products in modern markets [28–30].

Modern research on CD

As a traditional Chinese medicinal herb, CD has attracted extensive exploration due to its rich chemical composition and diverse pharmacological activities. Thus far, researchers have isolated over 120 compounds from CD, primarily including phenylethanoid glycosides [31, 32], iridoid glycosides [33–35], lignans and their glycosides [36], polyphenols, and polysaccharides [21, 37, 38]. Additionally, it contains benzyl alcohol glycosides, monoterpenes, alkaloids, essential oils, amino acids, and inorganic trace elements [39]. These chemical constituents not only form the material basis of the pharmacological effects of CD but also play crucial roles in various biological mechanisms.

Modern pharmacological studies have demonstrated that CD exhibits multiple pharmacological activities, such as hepatoprotection [40], immunomodulation [41, 42], antioxidant, hypoglycemic [43], anti-fatigue, neuroprotection [44], improvements in reproductive [45], physical strength and cognitive function [39]. Recent studies have begun to clarify the mechanism of action and dose–response relationships of specific components. For instance, geniposidic acid, 8-epiloganic acid, echinacoside, acteoside, isoacteoside, and cistanoside A were the active components of CD. All six monomers significantly enhanced the activities of antioxidant enzymes,

including superoxide dismutase (SOD) and catalase (CAT), exhibiting concentration-dependent antioxidant effects within the range of 0.781–3.125 μmol·L^{-1}.[46]. Furthermore, cistanoside A inhibits osteoclast formation and bone resorption by suppressing mitogen-activated protein kinase (MAPK) signaling and reducing p-JNK expression, with dose-dependent effects observed at concentrations of 40–160 μmol·L^{-}.^{1} [47]. Polysaccharides derived from CD enhance the female germline stem cells (FGSCs) proliferation in the ovarian cortex and promote their differentiation via the transforming growth factor-β (TGF-β) and bone morphogenetic protein (BMP) signaling pathways, particularly through BMP4/Smad pathway. [48, 49]. Among the key constituents, phenylethanoid glycosides have been shown through a series of studies to exert hepatoprotective [40], anti-osteoporosis [50–52], and antitumor activities [53], providing a solid theoretical foundation for further exploration of the medicinal value of CD. Phenylethanoid glycosides have been found to protect neural cells through modulation of ferroptosis pathways, shedding light on their possible therapeutic applications [44].

Additionally, the nutritional value of CD is increasingly recognized. The pharmacologically active compounds, herbal extracts, and raw materials derived from CD are increasingly applied in the development of health-promoting products and traditional herbal medicines. Nutritional analysis of CD from the Alxa region in Inner Mongolia reveals that it is a high-protein, low-fat source of healthy food, rich in potassium, sodium, and other trace elements [54, 55]. These nutritional characteristics confer unique advantages in the development of health-promoting products, especially for consumers seeking high-protein, low-fat dietary options, with broad potential for applications in dietary therapy and nutritional supplementation. Moreover, CD is considered relatively safe when used in appropriate amounts. A subchronic toxicity study in SD rats showed that feeding different doses (up to 8%) of powdered CD for 90 days did not cause toxicity or abnormal changes. Under the same experimental conditions, the no-observed-adverse-effect level (NOAEL) was determined to be 7.8 g/kg body weight for male rats and 8.0 g/kg for females, further supporting its safety at appropriate dosage levels [56]. However, to ensure safety across different populations, dosage adjustments according to specific needs are recommended.

Patent status of CD health-promoting products

Global patent status of CD

At present, extensive and in-depth research on the chemical composition, pharmacological effects, pharmaceuticals, health-promoting products, and food development of CD has been conducted globally, resulting in a large number of patents. The results show that a total of 4,776 CD-related patents were identified. After filtering out utility models, design patents, and duplicated content, 4,132 patents remained for analysis. Among these, 3,952 were Chinese patents (accounting for 95.65%), while 175 patents (4.35%) originated from other countries and organizations. The patents of other countries and organizations primarily include 62 from South Korea, 41 from the World Intellectual Property Organization (WIPO), 27 from the United States, and 13 from Japan (Fig. 2). These statistics clearly demonstrate China's significant resource advantage in CD-related patents.

In terms of temporal changes in patent filings over the past 30 years (Fig. 3), the overall trend can be divided into four stages. The first stage is the slow rise period (1995–2010), with the annual number of applications gradually increased from 4 to 33. The second stage is the rapid increase period (2011–2015), the number of applications increased from 96 to 452, and the global application enthusiasm is high. The third stage is the period of fluctuation and decline (2016–2023), the number of applications decreased from 404 to 96. Currently, there is an upward trend, with the number of patent applications rising to 267.

Despite the large number of patents related to CD technological innovation, their practical implementation remains limited. Among the 4,132 patents analyzed, 3,058 (74.00%) are invalid (expired, abandoned, or revoked), 644 (15.59%) are valid, and the remaining 430 (10.41%) are under review or pending approval (Fig. 4). By analyzing the time series of patent validity, it can be seen that there are obvious differences between the phases. All patents filed before 2005 have been invalided, which may be related to the change of management policy for the expiration of patent protection. Between 2006 and 2020, more than 74% of the patents also became invalid, possibly because of unpaid maintenance fees or limited commercialization efforts. In contrast, from 2021 to 2025, the proportion of expired patents declined, while the number of pending patents increased steadily. This trend reveals certain challenges within the patent system, such as overly long review periods and low efficiency in the promotion and application of patents. Although the validity or enforceability of patents may vary at different stages, their technical content consistently shows a wide range of applications and broad functional value.

Patent situation of CD in China

The distribution of CD patents across China exhibits significant regional disparities (Fig. 5). The highest concentration of patents is observed in the eastern and central regions, particularly in East China (e.g., Shandong,

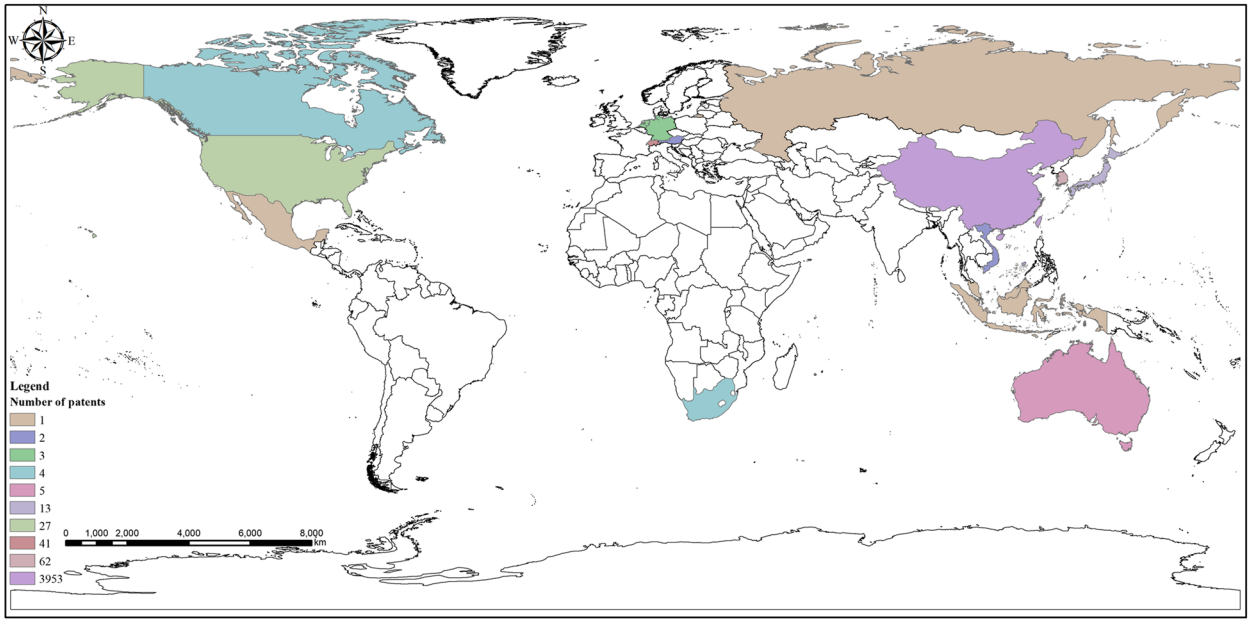


Fig. 2 Global distribution of *Cistanche deserticola* patents by countries and institutions (Countries include Malaysia, Mexico, Indonesia, Austria, Luxembourg, Vietnam, Germany, Netherlands, Canada, South Africa, Australia, Japan, the US, South Korea, and China. Institutions include major international patent offices (e.g., EAPO, EPO, WIPO), classified by headquarters location.)

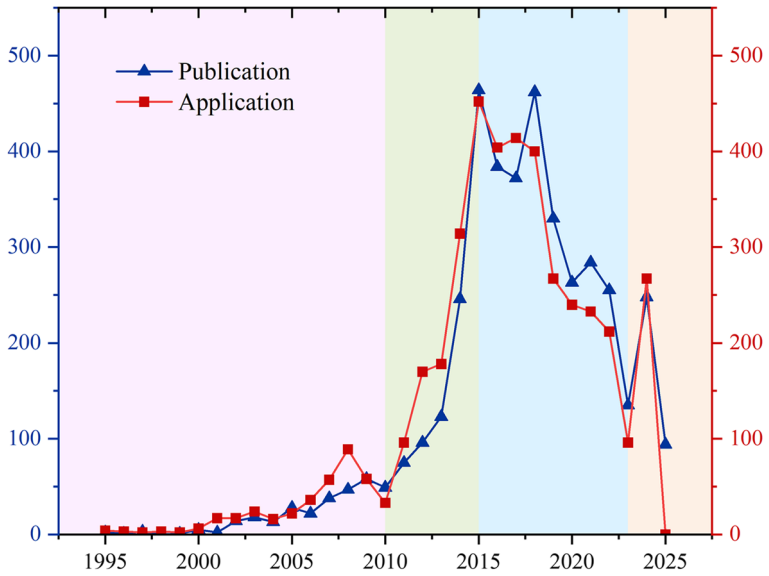


Fig. 3 Global patent application and publication trends of *Cistanche deserticola*

Jiangsu, Anhui), South China (e.g., Guangdong Province), Central China (e.g., Henan), and North China (e.g., Beijing). Each of these provinces or municipalities holds over 200 patents, highlighting their critical role in CD-related research and development. Regions with relatively few patents, such as Northwest China and Southwest China (e.g., Qinghai, Tibet), generally demonstrate lower levels of research infrastructure, industrial capacity, and market demand. Notably, major CD medicinal resource-production hubs like Inner Mongolia, Xinjiang, and Gansu show only moderate patent numbers, indicating limited synergy between resource availability and patent development. This pattern suggests that economic and technological factors, rather than natural resource

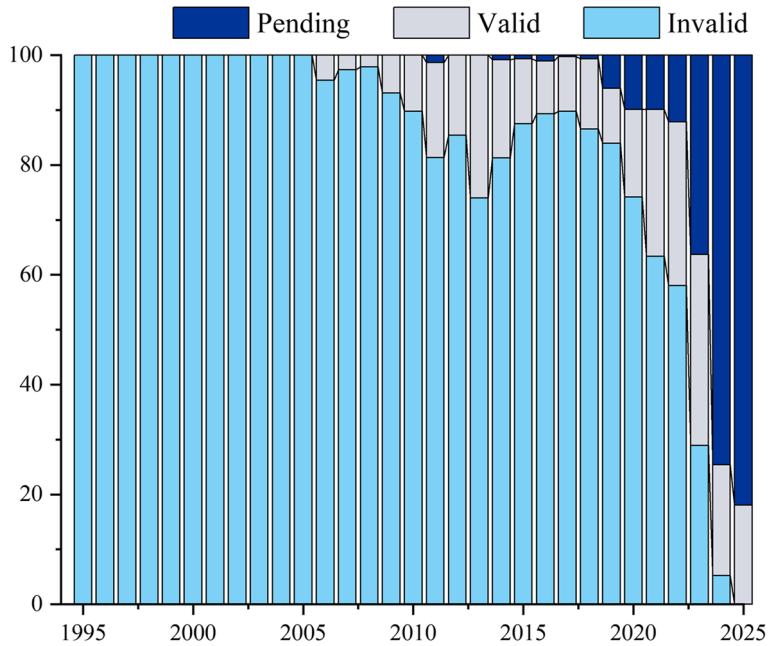


Fig. 4 Patent validity percentages related to *Cistanche deserticola*

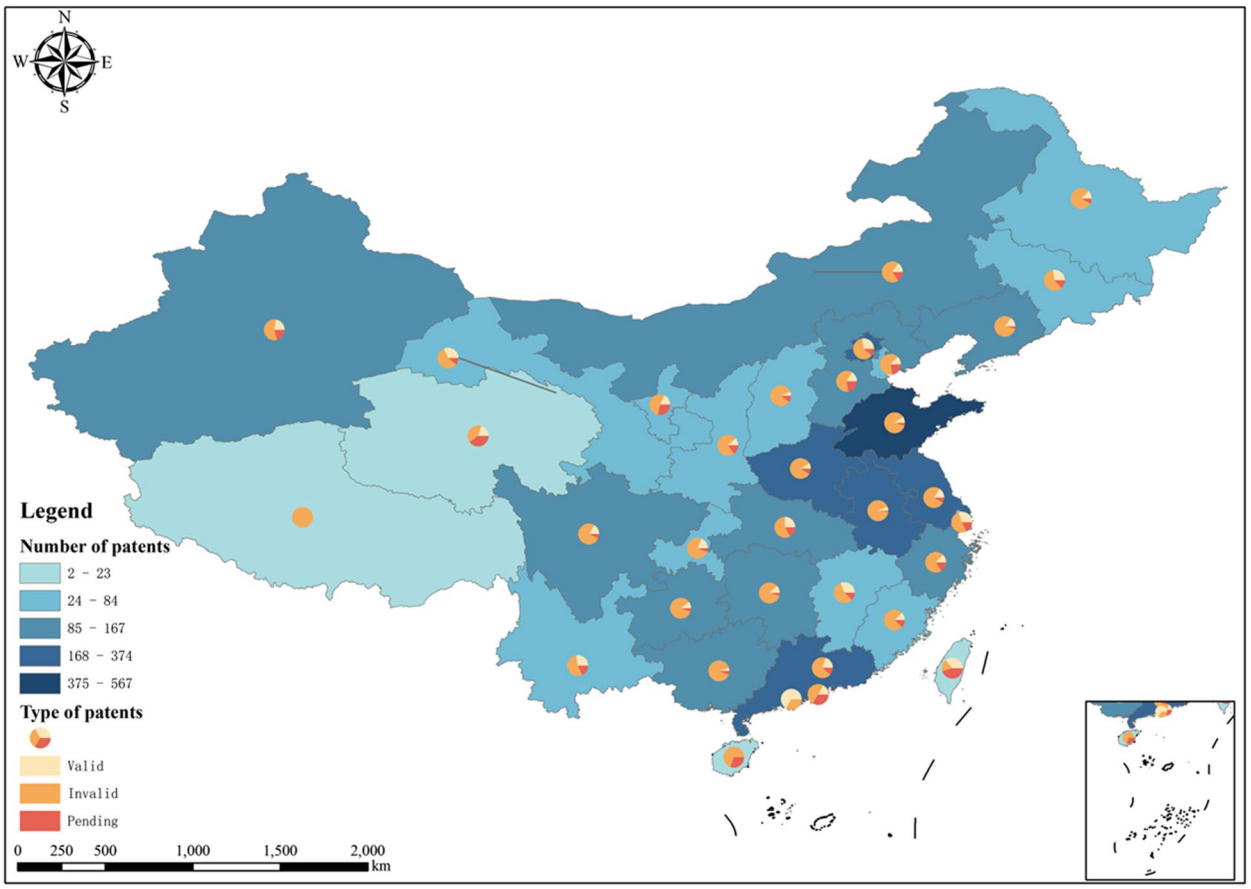


Fig. 5 Geographical distribution of *Cistanche deserticola*-related patents in China

abundance, are the primary drivers shaping both patent development and geographic distribution.

Application fields of CD patents

Pharmaceutical field

The application fields of CD-related patents are extensive, spanning pharmaceuticals, nutraceuticals, functional foods, and related industries. Analysis of International Patent Classification (IPC) codes reveals that CD not only retains its significance in traditional Chinese medicine but also demonstrates expanding potential in modern applications driven by technological advancements.

Within the pharmaceutical sector, CD-related patents dominate a substantial share. IPC data indicates that patents under codes A61K36 collectively account for over 60% of the total, reflecting diverse formulations and therapeutic uses. The formulations include both oral and topical forms such as tablets, capsules, soft capsules, granules, pills, ointments, syrups, soft creams, decoctions, patches, oral antibacterial agents, emulsions, suppositories, liniments, injections, microbial agents, and powdered injections. This variety ensures that CD can be widely utilized in different medical scenarios, meeting diverse patient needs.

At the same time, CD's applications in the pharmaceutical field span a broad spectrum, encompassing diverse disease categories. In traditional medicine, CD is widely utilized for treating constipation, menstrual irregularities, gray hair, and dysmenorrhea. It is also employed in treating urogenital conditions like erectile dysfunction, infertility, and male infertility. Additionally, it addresses metabolic disorders such as osteoporosis, gout, and hyperlipidemia. Beyond these, CD has demonstrated efficacy in treating skin conditions (e.g., hair loss, acne, melasma), infectious diseases (e.g., colds), neurological disorders (e.g., insomnia, Alzheimer's disease), cardiovascular diseases (e.g., hypertension, coronary heart disease), inflammatory conditions (e.g., rheumatoid arthritis, prostatitis, ankylosing spondylitis), and syndromes (e.g., polycystic ovary syndrome, menopause syndrome). Furthermore, it has been used in adjunctive therapies for cancers like breast cancer, lung cancer, and uterine fibroids.

Notably, a substantial proportion of patents employ CD in synergistic formulations with other medicinal herbs, enhancing holistic therapeutic benefits, amplifying clinical efficacy, and mitigating adverse reactions. This combinatorial strategy not only preserves CD's traditional medicinal philosophy of multi-component synergy but also demonstrates its adaptability to modern drug development.

Nutraceuticals and functional foods field

Nutraceuticals and functional foods represent another crucial application area for CD patents, focusing on the development and application of functional food, food for special medical purpose, dietary supplement, medicinal diet, and snack food. Based on IPC codes like A23L33, A23L1, A23F3, and A23L2, CD demonstrates great market potential with its diverse edible forms and combinations. Commonly patented applications include health supplements such as capsules, granules, soft capsules, oral liquids, and powders, primarily aimed at improving immunity, combating fatigue, regulating gut health, and delaying aging.

Additionally, CD is widely used in functional foods like tea, beverages, functional candies, nutritional biscuits, specialty breads, and plant-based drinks. In these applications, CD often serves as a health-boosting ingredient, catering to consumer demand for its beneficial effects. For example, combining CD with other medicinal herbs enhances its efficacy or addresses its limitations. When paired with *L. barbarum*, known for nourishing the liver and kidneys, CD enhances anti-aging and kidney-tonifying effects, commonly found in products like capsules and granules. Combined with *Astragalus membranaceus* var. *mongholicus* or *A. membranaceus*, which boosts immunity and fights fatigue, CD appears in functional candies and health drinks. When integrated with *P. ginseng*, which benefits individuals with low immunity or insufficient energy, the combination boosts energy and reduces fatigue, often featured in oral liquids and granules for consumers seeking enhanced vitality and anti-aging benefits. Meanwhile, in the fermented beverage and brewing industries (C12G3), CD is incorporated into medicinal wines through multi-herb formulations, offering nourishing and health-promoting benefits. These applications align with modern trends in health-oriented and functional alcoholic beverages, reflecting the integration of traditional herbal culture into contemporary lifestyles. It is worth noting that the dosage of CD in these patented combinations varies widely, often depending on the specific pairing herbs and the intended functional outcomes.

Beyond herbal combinations, CD is synergized with non-herbal functional ingredients. For instance, blending CD with soy isoflavones supports hormone balance and anti-aging applications, while combining it with prebiotics improves gut microbiota and digestion to promote gastrointestinal health. Through these diverse formulations, CD-based nutraceuticals and functional foods address growing consumer demands for comprehensive, integrative health management strategies.

Other fields

In addition to pharmaceuticals and functional foods, CD patents demonstrate promising applications in other sectors. Under IPC codes A23K1, CD is utilized in animal feed production, where extracts or powders are processed into high-value-added feeds for livestock such as cattle, sheep, and pigs, as well as poultry. These feeds enhance immune function, reproductive performance, and growth metrics in animals. This approach also offers an effective way to increase resource utilization by repurposing materials unsuitable for medicinal use, such as processing waste or non-medicinal parts, as feed additives, thereby minimizing waste while maximizing industrial value.

In the cosmetics and personal care sector (A61K8), developers leverage the antioxidant, anti-aging, and moisturizing properties of CD extracts to create diverse products like essential oils, masks, creams, shampoos, body washes, toothpaste, pillows, and medicinal bath powders. Overall, a comprehensive analysis of CD-related patents reveals its applications spanning multiple industries and fields. However, despite the large number of patents, many remain unutilized in practical settings, with market transformation and application still requiring further efforts. In the future, there remains substantial potential for innovation and product development in CD applications. Diversifying and expanding cross-field applications will not only drive industrialization but also enhance the market value of CD, fostering new opportunities through ongoing research and development (Table 1).

Development of CD in functional foods

Functional foods are food with specific health care functions, which is suitable for consumption by specific groups of people and has the function of regulating the organism without the purpose of treating diseases [57]. As legally regulated products, CD-based functional foods require mandatory review and approval of both the products themselves and their accompanying instructions by health authorities. The development and market trends of CD-based functional food reflect its growing importance in the specialty food sector. A total of 67 domestically produced functional foods with CD as the main ingredient have been officially approved. These products demonstrate significant diversity in dosage forms, ingredient combinations, and market evolution over time.

The evolution of CD-based functional foods (Fig. 6) demonstrates an interplay between regulatory frameworks and market dynamics. From 1997 to 2002, the industry experienced steady growth under the Wei Shi Jian Zi framework, despite challenges in regulatory oversight. Between 2003 and 2005, stricter regulatory policies led to a significant decline in approvals, reflecting

Table 1 Patent IPC major classification status

IPC	Fields	Distribution (%)	Contents
A61K36	Medicinal preparations containing material from plants or algae, or derivatives thereof	60.89	Traditional Chinese medicine with functions in promoting bowel movement, relieving fatigue, enhancing immunity, supporting reproductive health, and preventing hair loss. It is available in a variety of oral and topical formulations
C12G3	Preparation of alcoholic beverages by fermentation	5.78	Alcoholic beverages such as yellow wine, white wine, and whiskey, made with CD and other health-promoting herbs
A23L33	Food or foodstuffs specially modified to meet special dietary requirements (e.g., functional foods, food for special medical purpose, or dietary supplements)	3.73	Instant powders, fermented powders, freeze-dried powders, ointments, energy supplement tablets, enzymes, oligopeptide solutions, and other types of health-promoting products
A61K8	Cosmetic or similar toiletry preparations	2.93	Sunscreens, shampoos, serums, conditioners, body lotions, face creams, toothpastes, barrier creams, face masks, perfumes, eye creams, and bath ball products with functions such as skin repair, whitening, and hair loss prevention
A23L1	Foods or foodstuffs; their preparation or treatment	2.83	Medicinal dishes and seasonings with health benefits, including beef, noodles, sausages, eggs, chili sauce, and hot pot
A23F3	Coffee; Tea; Their substitutes; Preparations thereof	2.20	Tea and coffee beverages infused with a variety of functional herbs
A23L2	Food or foodstuffs specially modified to preserve them or to enhance their organoleptic properties	2.13	Functional beverages made with health-promoting ingredients such as oats, hawthorn, sea buckthorn, jujube, *lactobacillus*, and grapes
A23K1	Animal feedingstuffs	1.36	Functional animal feed for camels, yaks, cattle, sheep, pigs, poultry, aquatic animals, and amphibians, aiming to improve immunity and reproductive performance

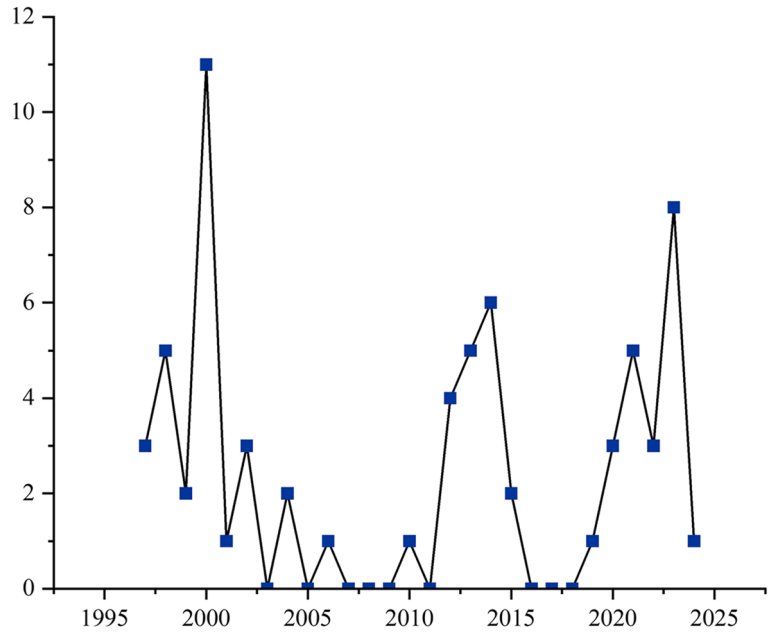


Fig. 6 Annual approval status of *Cistanche deserticola* functional foods

the industry's adjustment to higher compliance standards. The introduction of the *Technical Requirements for Functional Food Products* in 2010 and the *Administrative Measures for Registration and Filing of Functional Food* in 2016 further promoted industry standardization, albeit temporarily reducing approval numbers due to heightened entry thresholds. However, as the market adapted to these policies, approval numbers began to recover after 2019, reaching a peak in 2023. This resurgence highlights a stable regulatory environment and growing governmental support for the industry.

In terms of dosage forms, CD functional foods are available in various formats catering to diverse consumer preferences and functional needs (Fig. 7). Traditional

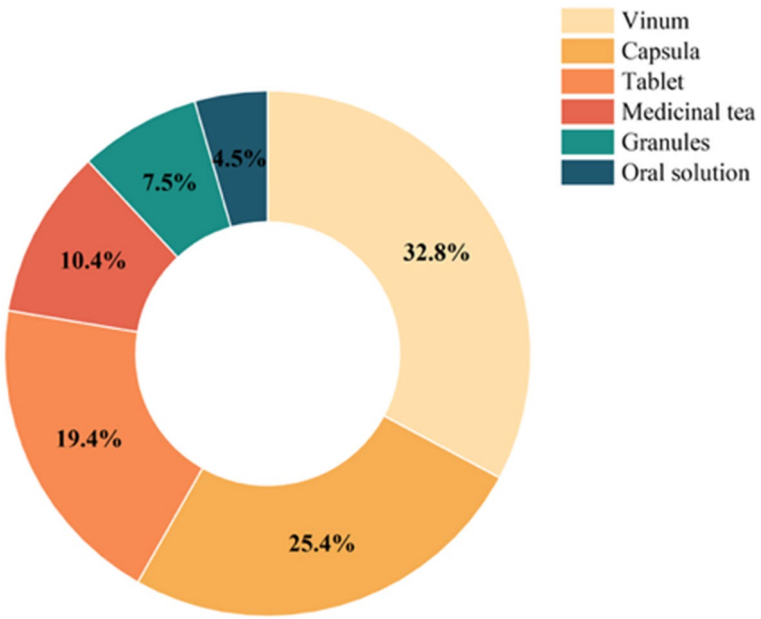


Fig. 7 Dosage forms of *Cistanche deserticola* functional foods

wine preparations remain highly popular for their ability to solubilize bioactive compounds, promoting blood circulation and warming the meridians, while also supporting long-term wellness. Tablets and capsules provide precise dosing, making them suitable for standardized and sustained intake. Granules and oral liquids offer rapid absorption, addressing the needs of consumers seeking immediate effects. In recent years, innovative formats such as solid beverages, compressed candies, raw paste products, and medicinal meal kits have emerged, targeting wider consumer groups and expanding application scenarios, demonstrating the industry's continuous innovation and adaptation to modern health demands.

The incorporation of traditional herbal pairings has further enriched the functionality and appeal of CD-based functional foods. Statistical analysis of health supplement formulations reveals that commonly used herbal combinations align with the principles of TCM. For instance, CD, *Cuscuta chinensis, Rehmannia glutinosa, L. barbarum, P. ginseng, Epimedium brevicornu, Cervus nippon*, and *C. elaphus* are fundamental components in TCM prescriptions for treating Kidney-Yang Deficiency Syndrome [57]. From the perspective of TCM, Kidney-Yang Deficiency Syndrome arises from excessive depletion of Yang energy, potentially leading to conditions such as erectile dysfunction, infertility, menstrual disorders, palpitations, insomnia, memory impairment, and neurasthenia. Patients may also experience fatigue, joint pain, dizziness, diarrhea, lower back pain, and frequent urination [58–62]. In this context, the health benefits of CD-based products align closely with the therapeutic principles of TCM. The nine primary functional effects of CD, including immunomodulation, anti-fatigue, anti-aging, antioxidant activity, promoting bowel movement, improving memory, increasing bone density, regulating blood lipids, and protecting against chemically induced liver injury, align with TCM's principles of reinforcing vital energy, nourishing the kidney, and restoring balance within the body (Fig. 8).

Additionally, the formulation of CD-based functional foods follows the TCM concept of "synergistic herbal combinations" (Fig. 9). For example, the combination of CD and *L. barbarum* is particularly effective in enhancing antioxidant capacity and anti-fatigue properties, while also supporting cognitive function and physical vitality. Both herbs are traditionally used in clinical practice for their tonic properties. Modern research indicates that the combination of these two herbs can enhance physical function and improve learning and memory capabilities, making it a natural and healthy method for boosting physical strength [63, 64]. Similarly, the pairing of CD with *E. brevicornu* is known to strengthen the kidneys and improve reproductive health, making it a popular choice for addressing issues related to impotence and infertility. These herbal compatibilities not only play the synergies of traditional combinations, but also conform to modern health trends, improving

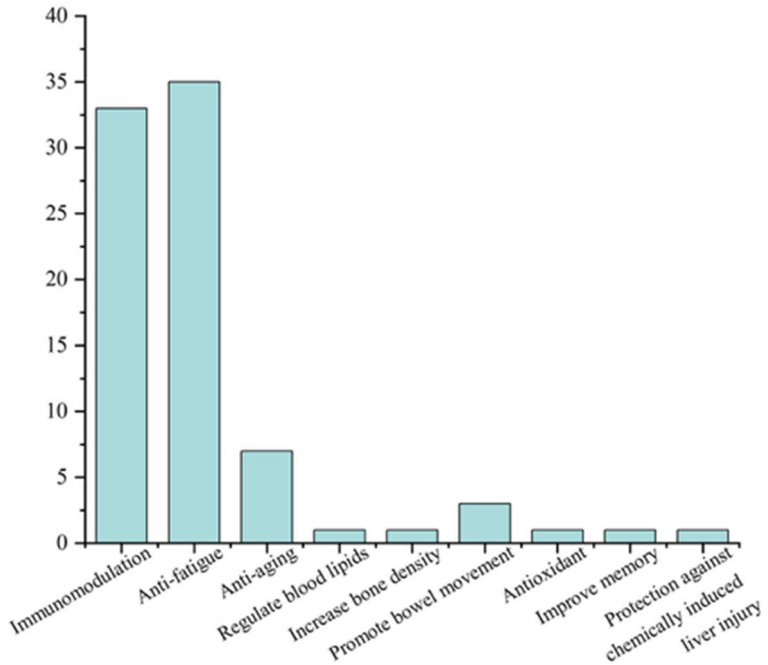


Fig. 8 Efficacy composition of *Cistanche deserticola* functional foods

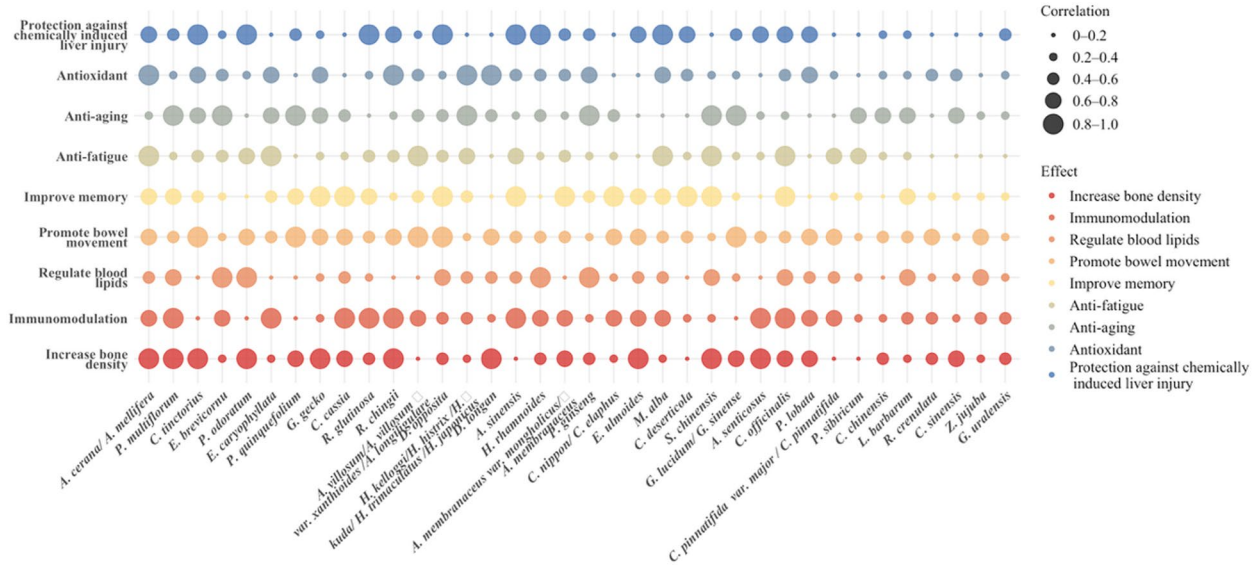


Fig. 9 Heatmap of medicinal material sources and efficacy directions

efficacy and consumer satisfaction in different types of products.

The diversity in dosage forms, the integration of functional herbal pairings, and the evolving regulatory landscape have collectively shaped the development of CD-based functional foods. These trends highlight the industry's ability to innovate while adhering to regulatory standards, establishing a solid foundation for the sustainable growth of CD in the functional food sector.

Discussion

Current status of the development of health-promoting products of CD

As a natural plant, CD has a wide range of practical values in the field of medicine and food. In recent years, the development of health-promoting products using CD as raw material has gradually expanded, covering a wide range of fields such as functional food, functional beverages, cosmetics and medicines. Most of the existing CD functional food and food products in the market are in the form of compound formula, usually combining CD raw materials or extracts with other Chinese herbs or plant ingredients to form synergistic compound products. The development of these products is guided by the theory of traditional medicine and the system of compounding, which fully reflects the profound cultural foundation of the homology theory of Chinese medicine and food.

The main active ingredients of CD include phenylethanol glycosides, polysaccharides, and flavonoids. These components are important in terms of functionality and safety, but due to the complexity and high cost of their monomer extraction and purification processes. Therefore, most companies prefer to use CD extract or powder directly for product development through compounding. This approach can ensure the health efficacy and effectively reduce the production cost, which meets the needs of enterprises and the market. However, although this experience-oriented development mode has advantages in cultural heritage, it is still insufficient in scientific verification and integration with modern technology. Some of the scientific research results have a low conversion rate in actual product development, leading to a waste of resources and research and development results. This problem is particularly prominent in the high failure rate of patent applications, which not only affects the value of innovation, but also imposes certain limitations on industrial efficiency.

Despite certain deficiencies in development technology and scientific validation, the development of CD related products as a whole still shows a positive growth trend. Beyond widespread use in China, consumers in other Asian countries such as Japan and South Korea are also familiar with and make use of the medicinal value of CD. It was included in the Japanese Pharmacopoeia (JP) in Supplement 2 of the 16th edition [65]. Some CD extracts processed by Chinese manufacturers are exported to Japan, either in extract form or as sliced herbal material. In addition, some Japanese breweries combine CD with other traditional herbs to produce medicinal liquors for commercial sale. As people's awareness of health and wellness increases and market demand continues to grow, CD products are becoming

more and more important in the health industry, and their development prospects are promising.

Limitations of market development of CD health-promoting products

Despite the achievements in the development of CD health-promoting products, there are still many problems that need to be solved in the process of marketization. The first is the lack of standardization of the industry. There is a lot of non-uniformity in the names, specifications and quality standards of herbs in functional foods and patent formulations. Resource dependency in product development has resulted in fluctuating raw material quality, which adversely affects product stability and efficacy. These factors collectively contribute to market irregularities.

Secondly, the diversification of products and conceptual confusion in the market have seriously affected the correct choice of consumers. As a medicinal plant, CD must be used with attention to both safety and proper application in order to support health or therapeutic effects. Consumers need to be aware of its usage restrictions. For example, individuals who experience chronic diarrhea or have weak digestive function should avoid using it [66]. Many people also lack a clear understanding of the functional boundaries of drugs, functional food and often have unrealistic expectations of product effects. For instance, pharmaceuticals have a clear therapeutic function, while functional food and medicinal food mainly prevent sub-health by regulating body functions, but the boundary of this distinction is not clearly understood by most consumers. Such informational gaps may not only result in product selection errors but could also pose health risks.

Furthermore, insufficient innovation constitutes another major constraint in CD product development. Patent applications and marketing strategies frequently lack robust scientific foundations and originality, coupled with non-standardized functional claims and efficacy validation processes. This leads to low consumer trust and insufficient market competitiveness. The current development of the health-promoting products industry, which is mainly in the form of compounding, has to a certain extent obscured the scientific potential of monomer active ingredients. The limited application of monomeric extracts in health-promoting products mainly stems from their classification under pharmaceutical development, which demands a higher level of technological research and development and strict clinical validation.

Policy and regulatory frameworks also present developmental challenges. Functional food registration systems, special medical purpose formula approvals, restrictive raw material catalogs, and evolving standards collectively constrain product development speed and flexibility. While these policies have restricted the rapid development of the industry to a certain extent, they have also gradually guided the industry towards greater standardization.

The international promotion of CD is also constrained by a range of factors. It is listed on CITES, which means that the international trade in its medicinal materials and products derived from it is subject to strict regulatory oversight. Although most CD-based products are developed using cultivated rather than wild-sourced materials, countries such as the United States, Canada, and New Zealand still require valid CITES permits for importation. In addition, markets like the US and the European Union impose strict quality control standards on herbal medicinal products, requiring compliance with international benchmarks such as ISO standards. These regulations extend beyond ingredient purity and contaminant limits to include standardized manufacturing processes. Strict quality control is essential across all phases of the production process, beginning with cultivation and extending through to the final product. Consumers in Europe and North America exhibit lower acceptance of traditional Chinese medicine than their Asian counterparts. They prefer dietary supplements with clearly defined single-compound ingredients, whereas Chinese multi-herbal formulas lack sufficient ingredient transparency and scientific validation for these markets. Consequently, international acceptance of CD-based herbal formulations remains limited.

Taken together, the commercialization challenges of CD health-promoting products extend beyond resource and technical limitations to encompass comprehensive issues of product design, ingredient transparency, market acceptance, and international regulatory policies. Only through enhanced scientific research, strengthened technical specifications, and alignment with target market preferences can CD products achieve broader global market penetration.

Challenges and opportunities of CD health-promoting products

The future development of CD-based medicinal and edible products will progress toward greater refinement, diversification, and scientific rigor. Modern scientific research will drive the product development towards the segmentation of different populations, health needs and functional orientation. Researchers must conduct in-depth analyses of the structural composition, mechanisms of action, and metabolic pathways of CD's bioactive components. For instance, comprehensive studies on phenylethanoid glycosides should clarify their functional

properties and dose–response relationships. Such investigations will establish a robust scientific foundation for developing stable, reliable functional products while accelerating innovative drug discovery and application.

Regarding product formats, future developments will expand beyond traditional pills and capsules in the future, and expand to ready-to-drink beverages, functional snacks, oral liquids and personalized nutritional supplements, so as to meet the diversified health needs of different consumer groups. The integration of CD with complementary ingredients such as nuts, cereals, tea, and coffee also presents vast market potential. The development of healthy snacks, functional candies, specialty breads, or plant-based beverages containing CD extracts could further expand the application scenarios and enhance product appeal. However, such innovations need to be premised on clear functional studies to ensure that the active ingredients of the products have good safety and efficacy [67, 68].

Technological innovation will serve as the cornerstone for advancing the CD industry. For example, modern biotechnology, ultra-micro pulverization technology and microencapsulation technology will inject more technological content into the development of CD products, thus enhancing the functionality and market competitiveness of the products. Concurrently, the emergence of precision nutrition therapy enables customized CD formulations, better aligning products with individualized health requirements.

The protection of origin resources and consumer education will also be important directions for future development. The sustainable development of the CD industry can be achieved by standardizing the planting, harvesting and processing processes, strengthening the rational use of resources and the protection of the ecological environment, and enhancing the construction of traceability capabilities for functional foods. Meanwhile, pharmacology and nutrition professionals and the media should strengthen the popularization of science education for consumers. They can help consumers understand the functions and scope of use of different categories of products and avoid misuse or wrong choices due to lack of information.

Standardization and internationalization of the industry is one of the important directions for future development. It is necessary to strengthen the standardization and management of the whole industrial chain of CD planting, harvesting and processing. The naming of herbs, quality standards and efficacy assessment system should be unified to improve the controllability of product quality and enhance the recognition of the international market. At the same time, product development for the international market requires in-depth study of food safety regulations in different countries, such as the European Novel Food Regulation and the U.S. Dietary Supplement Health and Education Act (DSHEA), to ensure that the product design and export comply with international standards. This will not only enhance the competitiveness of the products in the international market, but also promote the globalization and popularization of CD products.

Policy support and international cooperation will also be important drivers for development. More policy support in terms of financial support for research and development, optimization of approval process, protection of intellectual property rights and international cooperation will help accelerate the research and development and marketization process of CD related products. Through the efforts of many parties, CD will not only continue to maintain an important position in the field of traditional Chinese medicine, but also occupy a broader market share in the modern health industry, further promoting the innovation and development of the global health industry.

Conclusion

CD is recognized as a multifunctional traditional herbal medicine with broad potential in therapeutic use, nutritional support, and general health maintenance. Patent analyses and functional food product launches highlight its growing relevance. However, efforts to develop CD-based health products continue to face obstacles, including a lack of standardization, limited scientific validation, and restricted access to international markets. Realizing its full potential will require the integration of traditional knowledge with modern scientific approaches. Critical priorities include elucidating bioactive compound mechanisms, refining extraction protocols, and designing innovative product formats aligned with evolving consumer demands. Concurrently, broadening the scope of CD utilization across industries must prioritize ecological sustainability and responsible resource stewardship. Through the integration of ancestral wisdom with technological innovation, CD could emerge as a pivotal component in preventive healthcare and functional nutrition.

Authors' contributions

Yaqiong Bi, Amuguleng, Feng Gao and Jianxun Zhu performed data collection, literature review, and data analysis. Feibiao Shan and Wenle Wang participated in critical revision of the manuscript for important intellectual content. Zeyuan Zhao designed and created the graphical illustrations. Minhui Li evaluated the experimental results and provided critical guidance throughout the research. All authors read and approved the final manuscript.

Funding

This study was supported by National Key Research and Development Program of China (No. 2024YFE0113600), Inner Mongolia Autonomous Region Science and Technology Program Project (No. 2025YFHH0228), the Ministry of

Agriculture and Rural Affairs of the People's Republic of China (No. CARS-21), and Inner Mongolia Health Commission Funding Program for Traditional Medicine Development (Chinese Medicine and Mongolian Medicine) (No. ZMY-2024208).
National Key Research and Development Program of China,2024YFE0113600,Minhui Li,Ministry of Agriculture and Rural Affairs of the People's Republic of China,CARS-21,Minhui Li,Inner Mongolia Health Commission Funding Program for Traditional Medicine Development (Chinese Medicine and Mongolian Medicine),ZMY-2024208,Yaqiong Bi

Data availability
Data will be made available on request.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Received: 17 March 2025 Revised: 17 June 2025 Accepted: 3 July 2025
Published online: 18 August 2025

References

1. Zhu H, Ou X, Qian H, et al. Focus on the nutritional intervention for healthy aging and human wellness based on the "environment-food-human" web. Front Nutr. 2024;11:1398916. https://doi.org/10.3389/fnut.2024.1398916.
2. Calimport SRG, Bentley BL, Stewart CE, et al. To help aging populations, classify organismal senescence. Science. 2019;366:576–8. https://doi.org/10.1126/science.aay7319.
3. Fraser HC, Kuan V, Johnen R, et al. Biological mechanisms of aging predict age-related disease co-occurrence in patients. Aging Cell. 2022;21:e13524. https://doi.org/10.1111/acel.13524.
4. Hennig B, Deng P. Healthful nutrition as a prevention and intervention paradigm to decrease the vulnerability to environmental toxicity or stressors and associated inflammatory disease risks. Food Front. 2020;1:13–4. https://doi.org/10.1002/fft2.6.
5. Ullah H, Khan A, Daglia M. The focus on foods for special medical purposes and food supplements in age-related disorders. Food Front. 2022;3:353–7. https://doi.org/10.1002/fft2.163.
6. Wang B (Dai M, Zhang S, Lin Y editing). Inner canon of the yellow emperor, basic questions (Huangdi Neijing, Suwen) (Pre-Qin period). Nanning: Guangxi Science and Technology Publishing House; 2016. p. 41.
7. Qu S, Yu S, Ma X, Wang R. "Medicine food homology" plants promote periodontal health: Antimicrobial, anti-inflammatory, and inhibition of bone resorption. Front Nutr. 2023;10:1193289. https://doi.org/10.3389/fnut.2023.1193289.
8. Xu J, Zhang J, Sang Y, et al. Polysaccharides from medicine and food homology materials: A review on their extraction, purification, structure, and biological activities. Molecules. 2022;27(10):3215. https://doi.org/10.3390/molecules27103215.
9. Wang L, Zhu X, Liu H, et al. Medicine and food homology substances: A review of bioactive ingredients, pharmacological effects and applications. Food Chem. 2025;463(Pt 1): 141111. https://doi.org/10.1016/j.foodchem.2024.141111.
10. Cheng JM, Xue F, Zhang YY, et al. Research and development status, technical keys and countermeasures of medicinal and food homologous products. Journal of Nanjing University of Traditional Chinese Medicine. 2023; 39(09): 814–826. https://doi.org/10.14148/j.issn.1672-0482.2023.0814.
11. Tang XY, Xie GZ, Zhou RR, et al. Development and application of "One root of medicine and food". Modern Chinese Medicine. 2020;22(09):1428–1433. https://doi.org/10.13313/j.issn.1673-4890.20200220003.
12. Huang LQ, Guo LP, Zhang XB, et al. Species of Chinese materia medica resources based on the fourth national survey of Chinese materia medica resources. China Journal of Chinese Materia Medica. 2024; *49*(13): 3409–3413. https://doi.org/10.19540/j.cnki.cjcmm.20240516.101
13. Tu PF, Jiang Y. Update classical literature research on Cistanches Herba. China Journal of Chinese Materia Medica. 2022;47(20): 5675679. https://doi.org/10.19540/j.cnki.cjcmm.20220711.101.
14. Tang SW (Shang ZJ editing). Classified materia medica (Zhenglei bencao) (Song dynasty). Beijing: Huaxia Publishing House; 1993. p. 192.
15. Editorial Committee of Flora Republicae Popularis Sinicae. Flora Republicae Popularis Sinicae. Beijing: Science Press; 2004. p. 86–7.
16. Mandakh U, Battseren M, Ganbat D, et al. Folk nomenclature of plants in *Cistanche deserticola*-associated community in South Gobi. Mongolia Plant Divers. 2020;42(6):434–42. https://doi.org/10.1016/j.pld.2020.09.008.
17. National Pharmacopoeia Committee. Pharmacopoeia of People's Republic of China: I. Beijing: The Medicine Science and Technology Press of China; 2020. p. 14141.
18. An Q. Study on cultivation technology and quality evaluation of Atriplex canescens - Cistanche deserticola. Lanzhou: Gansu Agricultural University. 2023. https://doi.org/10.27025/d.cnki.ggsnu.2023.000242.
19. Wang F, Zhuo B, Wang S, et al Atriplex canescens: A new host for *Cistanche deserticola*. Heliyon. 2021, *7*(6): e07368. https://doi.org/10.1016/j.heliyon.2021.e07368
20. Li Z, Zhang C, Ren G, et al. Ecological modeling of *Cistanche deserticola* Y.C. Ma in Alxa, China. Sci Rep. 2019, 9(1): 13134. https://doi.org/10.1038/s41598-019-48397-6
21. Xue TT, Zheng DX, Wen LM, et al. Advance in *Cistanche deserticola* Y. C. Ma. polysaccharides: Isolation, structural characterization, bioactivities and application: A review. Int J Biol Macromol. 2024; 278: 134786. https://doi.org/10.1016/j.ijbiomac.2024.134786.
22. Ma Q. Analysis on population genetic diversity of *Cistanche decerticola* Ma by ISSR. Hohhot: Inner Mongolia University; 2011.
23. Gui X. Evaluation of Origin Environment Quality and Quality of Alxa Cistanche. Hohhot: Inner Mongolia Agricultural University. 2023. https://doi.org/10.27229/d.cnki.gnmnu.2023.000229.
24. Ni Jia T, Mi Hereguli K, Ma TJ. Research progress on resource summary and nutritional and health characteristics of Cistanche deserticola. The Food Industry. 2023;44(10):28283.
25. Jiang L, Zhou B, Wang X, et al. The quality monitoring of Cistanches herba (Cistanche deserticola Ma): A Value Chain Perspective. Front Pharmacol. 2021;12: 782962. https://doi.org/10.3389/fphar.2021.782962.
26. Cheng N, Wang H, Hao H, Rahman FU, Zhang Y. Research progress on polysaccharide components of Cistanche deserticola as potential pharmaceutical agents. Eur J Med Chem. 2023;245(Pt 1): 114892. https://doi.org/10.1016/j.ejmech.2022.114892.
27. Wang T, Zhang X, Xie W. *Cistanche deserticola* Y. C. Ma, "Desert ginseng": a review. Am J Chin Med. 2012; 40(6): 1123–1141.
28. Wang ZM, Liu XQ, Li C, et al. History of Cistanche deserticola as a dietary herbal medicine. Chin Pharm J. 2017;52(07):525–9.
29. Chen CQ (Shang ZJ editing). A supplement to materia medica (Bencao Shiyi) (Tang dynasty) Volume VIII. Hefei: Anhui Science and Technology Publishing House; 2002. p. 338.
30. Zhen Q (Shang ZJ editing). Theory of Medicine Nature (Yaoxinglun) (Tang dynasty) Volume II. Hefei: Anhui Science and Technology Publishing House; 1983. p. 20.
31. Zhang JY, Li C, Che YY, et al. LTQ-Orbitrap-based strategy for traditional Chinese medicine targeted class discovery, identification and herbomics research: a case study on phenylethanoid glycosides in three different species of Herba Cistanches. RSC Adv. 2015;5(98):80816–28.
32. Song Y, Zeng K, Jiang Y, Tu P. Cistanches Herba, from an endangered species to a big brand of Chinese medicine. Med Res Rev. 2021;41(3):1539–1577. https://https://doi.org/10.1002/med.21768
33. Li W, Ding J, Liu B, et al. Phytochemical screening and estrogenic activity of total glycosides of *Cistanche deserticola*. Open Chem. 2019;17(1):279–87. https://doi.org/10.1515/chem-2019-0035.
34. Wang LW. Isolation, identification, quantification and bioactivity assessment chemical constituents of *Cistanche Deserticola* Y. C. Ma. Hohhot: Inner Mongolia University; 2016. pp. 24–27.
35. Liu WJ, Cao Y, Song QQ, et al. Chemical characterization for flowers and lignified stems of *Cistanche deserticola*. China Journal of Chinese Materia

Medica. 2018; 43(18): 3708–3714. https://doi.org/10.19540/j.cnki.cjcmm.20180612.001
36. Nan ZD, Zhao MB, Jiang Y, et al. Lignans from stems of *Cistanche deserticola* cultured in Tarim desert. China J Chin Materia Med. 2015;40(3):463–8.
37. Fu Z, Fan X, Wang X, et al. Cistanches herba: an overview of its chemistry, pharmacology, and pharmacokinetics property. J Ethnopharmacol. 2018;219:233–47.
38. Huo D, Zhang JN, Ma W, et al. Optimization of polysaccharide extraction process of Cistanches herba produced in inner Mongolia by response surface methodology. World Chinese Medicine. 2023;18(12):1667–71.
39. Zhi YJ, Zhen YQ, Tian W, et al. Research progress on chemical constituents and pharmacological effects of *Cistanche deserticola* and predictive analysis of quality markers(Q-Marker). Chinese Traditional and Herbal Drugs. 2021;52(09):2758–67.
40. Wang H, Li Y, Bian Y, et al. Potential hepatoprotective effects of Cistanche deserticola Y.C. Ma: Integrated phytochem anal using UPLC-Q-TOF-MS/MS, target network analysis, and experimental assessment. Front Pharmacol. 2022; 13: 1018572. https://doi.org/10.3389/fphar.2022.1018572.
41. Weng X, Zhao B, Feng S, Yang Y, Zhang A. Chemical composition and adjuvant properties of the macromolecules from cultivated *Cistanche deserticola* Y. C. Ma as an immunopotentiator. Int J Biol Macromol. 2022; 220: 638–658. https://doi.org/10.1016/j.ijbiomac.2022.08.072
42. He J, Lu X, Mao N, et al. *Cistanche deserticola* polysaccharide functionalized dendritic fibrous nano-silica-based adjuvant for H_9N_2 oral vaccine enhance systemic and mucosal immunity in chickens. Int J Pharm. 2024;660: 124318. https://doi.org/10.1016/j.ijpharm.2024.124318.
43. Xue TT, Zheng DX, Hou Q, et al. Optimization of extraction process, structural characterization, and antioxidant and hypoglycemic activity evaluation of polysaccharides from the medicinal and edible plant: Cistanche deserticola Y.C. Ma. Phytochem Anal. 2025. https://doi.org/10.1002/pca.3512.
44. Zhang X, Liu Z, Li Z, et al. Ferroptosis pathways: Unveiling the neuroprotective power of *Cistache deserticola* phenylethanoid glycosides. J Ethnopharmacol. 2024;333: 118465. https://doi.org/10.1016/j.jep.2024.118465.
45. Li Z, Li J, Li Y, et al. The role of Cistanches Herba and its ingredients in improving reproductive outcomes: A comprehensive review. Phytomedicine. 2024;129: 155681. https://doi.org/10.1016/j.phymed.2024.155681.
46. Li YM, Song ZT, Hou QY, et al. Quality markers of Cistanches herba based on antioxidant spectrum-effect relationship. Modern Chinese Medicine. 2024;26(02):265–275. https://doi.org/10.13313/j.issn.1673-4890.20230318001.
47. Li YY, Zhang M, Yang JJ. Cistanoside A mediates p38/MAPK pathway to inhibit osteoclast activity. Chinese Journal of Tissue Engineering Research. 2025;29(06):1144–51.
48. Qiu YK. Effect and molecular mechanism of *Cistanche deserticola* polysaccharide on promoting the differentiation of female germline stem cells through BMP4/Smad signaling pathway. Ningxia Medical Universal. 2023. https://doi.org/10.27258/d.cnki.gnxyc.2023.000013.
49. Qiu Y, Zhang Y, Ren H, et al. *Cistanche deserticola* poly▪saccharides extracted from *Cistanche deserticola* Y.C. Ma promote the differentiation of mouse female germline stem cells in vitro. J Ethnopharmacol. 2022;296:115495. https://doi.org/10.1016/j.jep.2022.115495.
50. Xu SS. Effect of Cistanche herba and echinacoside on the regulation of T lymphocytes on osteoblasts. Guangzhou University of Chinese Medicine, 2019. https://doi.org/10.27044/d.cnki.ggzzu.2019.000644
51. Wang YT, Yang ZH, Chen Y, et al. Network pharmacology exploration of the mechanism of *Cistanche deserticola* in the treatment of osteoporosis. China Pharmacy. 2019;30(5):645–51.
52. Zhen YL, Li NN, Feng J, et al. Research progress on anti-osteoporotic mechanism of phenethanol glycosides of *Cistanche deserticola*. Journal of Tianjin University of Traditional Chinese Medicine. 2022;41(02):265–72.
53. Qi XX, You SP, He ZX, et al. Effect of *Cistache deserticola* phenylethanol glycoside on proliferaion and apoptosis of HepG2 cells in vitro. Journal of Xinjiang Medical University. 2021;44(9):1041–7.
54. Xiang SQ. Analysis the nutrient composition of Cistanche deserticola and its antioxidant activity. China Food Safety Magazine. 2024;(12):96–98. https://doi.org/10.16043/j.cnki.cfs.2024.12.024.
55. Kurban G, Imerhasan M, Osman K, et al. Determination of contents of nutrition and microelement in the Uyghur traditional health protection medicinal materials Herba Cistanches. Science and Technology of Food Industry. 2009;30(09):289–91.
56. Gao Y, Qin G, Wen P, et al. Safety assessment of powdered *Cistanche deserticola* Y. C. Ma by a 90-day feeding test in Sprague-Dawley rats. Drug Chem Toxicol. 2017; 40(4): 383–389. https://doi.org/10.1080/01480545.2016.1242013
57. Li J, Li XM, Zhang LS. Development and changes of Special food supervision and related regulations in China from 1995 to 2022. Journal of Preventive Medicine Information. 2023;39(09):1138–42.
58. Yu C, Wang N, Guan S, et al. "Disease-symptom-herb" supernetwork analysis and core formula discovery of postmarketing Chinese patent medicines for treatment of kidney-*yang* deficiency. Chinese Traditional and Herbal Drugs. 2023;54(24):8153–64.
59. Shang C, Liu C, Tan Y, et al. Clinical study on zhenwu decoction combined with buyang huanwu decoction in the treatment of diabetic nephropathy with spleen and kidney yang deficiency pattern. Modern Chinese Medicine. 2022;42(5):98–101.
60. Huang Y, Liu C. Experimental research review of Chinese medicine in treatment of slow transit constipation. Chin Arch Tradit Chin Med. 2020;38(1):87–9.
61. Xu S. Effect observation of Jinkui Shenqi Wan combined with Zuo's Erectpole needle in the treatment of senior functional constipation with syndrome of deficiency of kidney yang. Chin J Coloproctol. 2022;42(7):47–9.
62. Guo S, Qi X, Yao X, et al. Metabolomics analysis based on UPLC-MS/MS in primary osteoporosis with Kidney-Yang deficiency syndrome. Chinese Journal of Osteoporosis. 2022;28(10):1410–5.
63. Ye HX, Qi YQ, He YX, et al. Study on the nootropic effects of the combination of total glycosides from Cistanche deserticola and Lycium barbarum polysaccharides in C57BL/6J mice of different Ages. Journal of Chinese Medicinal Materials. 2023;46(01):217–221. https://doi.org/10.13863/j.issn1001-4454.2023.01.038.
64. Tan LW, Hou YS, Jiang JW. Study on the Effects of *Cistanche deserticola* and *Lycium barbarum* Decoction on Exercise Endurance in Mice. Special Economic Animals and Plants. 2024;27(09):5–7.
65. Goda Y. Regulatory science of natural products. J Nat Med. 2022;76(4):732–47. https://doi.org/10.1007/s11418-022-01639-w.
66. Niu L, Wu L, Yuan Z. Textual research on the herbal medicine of roucongrong(Cistanches Herba). Journal of Liaoning University of Traditional Chinese Medicine. 2023;25(08):212–216. https://doi.org/10.13194/j.issn.1673-842x.2023.08.046.
67. Chen G, Fan Z, Jiang S, et al. Health food market status and development trend analysis. Modern Food. 2024;30(14):24–26. https://doi.org/10.16736/j.cnki.cn41-1434/ts.2024.14.008.
68. An X, Li S, Wang L, et al. The development status and countermeasures of medicine and food homologous substances for health food in China. China Fruit & Vegetable, 2024;44(05):15–19+72. https://doi.org/10.19590/j.cnki.1008-1038.2024.05.003.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.