

Wisdom in Qi-Huang, Leading the Future: TCM Inheritance and Global Innovation Empowered by Technology—A Review of the 2024 TCMIID® Competition on the Preservation and Innovative Development of Traditional Chinese Medicine

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Abstract

The 2024 TCMIID® Competition on the Preservation and Innovative Development of Traditional Chinese Medicine showcased the latest achievements in integrating TCM with modern technology, driving advancements in intelligent diagnosis, theoretical innovation, health management, industrial transformation, and international promotion. This review systematically analyzes the award-winning projects, summarizing their innovations in AI-powered TCM diagnostics, modernization of TCM theories, ecological wellness, green TCM industrialization, and global dissemination. The findings reveal that artificial intelligence, big data, and blockchain technologies are accelerating the intelligence, standardization, and globalization of TCM. The modernization and scientific validation of TCM theories remain critical areas for development, while personalized and precise TCM applications are increasingly incorporated into public health management. Additionally, the green TCM industry chain and ESG-driven development models are fostering sustainability in the sector. In the future, the high-quality development of TCM will rely on technological innovation, standardization, international market expansion, and green transformation, ultimately enhancing its global influence.

Keywords Preservation and innovative development of traditional Chinese medicine; technological innovation; artificial intelligence; health management; green TCM; international promotion

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1 Introduction

1.1 Background of Traditional Chinese Medicine Innovation and Development

Traditional Chinese Medicine (TCM), as a medical treasure of the Chinese nation, boasts a long history and profound cultural heritage, playing a crucial role in the development of Chinese civilization. TCM is not only an essential component of traditional Chinese medicine but also serves as a significant supplement to the global medical system. In recent years, with the development of the social economy and the improvement of people's living standards, the demand for health management has been increasing, and the unique advantages of TCM have been receiving growing attention.

Against the backdrop of the rapid development of the global health industry, the medical model is gradually shifting from disease treatment-centered to health management and preventive healthcare-oriented approaches. TCM emphasizes "preventive treatment of diseases," advocating for holistic conditioning, which aligns with modern medical development trends. Meanwhile, the rapid advancement of modern technologies such as information technology, biotechnology, and artificial intelligence has provided new opportunities for the innovative development of TCM. The application of artificial intelligence, big data analysis, blockchain, and other technologies in TCM is continuously expanding, promoting the digitalization and intelligence of TCM. Particularly in disease prediction, intelligent diagnosis and treatment, and personalized health management, the integration of TCM with modern technology demonstrates broad application prospects.

However, the modernization process of TCM also faces multiple challenges, such as the modernization and scientific validation of TCM theories, the sustainable development of Chinese herbal medicine resources, and regulatory obstacles in the international promotion of TCM. Therefore, continuous exploration is required in fundamental TCM research, clinical practice, and industrial upgrading to better adapt TCM to modern social needs and secure a more significant position in the global medical system.

1.2 National Policy Support

To promote the inheritance, innovation, and modernization of TCM, the state has successively introduced a series of policies that clarify the vital position of TCM in the national health system and propose goals such as accelerating TCM technological innovation, industrial upgrading, and international promotion.

The *Opinions of the Central Committee of the Communist Party of China and the State Council on Promoting the Inheritance, Innovation, and Development of Traditional Chinese Medicine* explicitly state the need to strengthen basic research in TCM, promote the integration of TCM with modern science and technology, enhance the scientific validation of TCM clinical efficacy, and encourage the application of TCM in disease prevention, health preservation, and wellness. The document also proposes deepening TCM education reform, improving TCM talent cultivation, and strengthening the international dissemination and cooperation of TCM.

The Industry–Academia Cooperation and Collaborative Education Project of the Ministry of Education is one of the critical national initiatives to advance the modernization and industrialization of TCM. This project encourages collaboration between universities, enterprises, and research institutions to cultivate innovative TCM talents and facilitate the transformation and application of scientific research achievements. Additionally, the project supports academic research and innovation entrepreneurship in the TCM field, providing broader development space for TCM technological innovation.

The *14th Five-Year Plan for TCM Development* further refines the objectives and tasks of TCM development, proposing to enhance TCM's role in the prevention and treatment of major diseases, promote the informatization of TCM, and advance the development and application of intelligent diagnostic and treatment equipment to enhance the international competitiveness of TCM. Moreover, the plan emphasizes promoting the standardization and regulation of TCM, strengthening the quality control of Chinese herbal medicines, and facilitating the global promotion and application of TCM.

The implementation of these policies provides strong support and guarantees for the innovative development of TCM, drives the overall upgrading of the TCM industry, and elevates the status of TCM in modern healthcare systems.

1.3 Overview of the 2024 Traditional Chinese Medicine Inheritance and Innovation Development Competition

The 2024 TCMIID® Traditional Chinese Medicine Inheritance and Innovation Development Competition, organized by the Chinese Society for the Inheritance and Innovation of Traditional Chinese Medicine, is an international academic competition aimed at promoting the deep integration of TCM and modern technology, facilitating the globalization of TCM, and identifying and cultivating innovative talents in the TCM field. With the theme “*Technology Empowering TCM, Innovation Driving Health Development*”, this competition encourages participants to integrate cutting-edge technologies such as artificial intelligence, big data, and precision medicine to explore new models of TCM inheritance and innovation.

This competition has attracted extensive participation from renowned universities, research institutions, and corporate teams worldwide, covering multiple countries and regions, including China, Thailand, Hong Kong, and Macau. The submitted projects span various frontier fields such as intelligent TCM diagnosis and treatment, modern TCM theoretical research, health management, sustainable development, and the international promotion of TCM.

Among the award-winning projects, outstanding works from prestigious Chinese institutions such as Beijing University of Chinese Medicine, Nanjing University of Chinese Medicine, Guangdong University of Foreign Studies, and Shandong Institute of Business and Technology were recognized. Additionally, innovative projects from international institutions like Krirk University (Thailand), Lampang Inter-tech College (Thailand), Hong Kong Metropolitan University, and the University of Macau showcased the global interest and research investment in TCM.

Notable international projects include *Heritage Harmony: TCM Worldwide* (Krirk University, Thailand), focusing on the international dissemination and cultural integration of TCM; *Research on the Design and Communication of Health-Preserving Value of Anhua Dark Tea* (Lampang Inter-tech College, Thailand), exploring the application of Chinese tea culture in the international health and wellness market; *Sustainable Development of Traditional Chinese Medicine Herb Cultivation through Environmental Management* (Hong Kong Metropolitan University), integrating sustainable development concepts to optimize ecological management of TCM herb cultivation; and *Design of Optimized Storage Structure and Environmental Monitoring System for Traditional Chinese Medicine Herbs* (University of Macau), leveraging modern technology to enhance the intelligent storage and environmental monitoring of Chinese herbal medicines.

Furthermore, the competition has fostered various TCM innovation research projects integrating modern technology, such as AI tongue diagnosis devices, artificial intelligence-assisted diagnosis and treatment systems, wearable TCM health management devices, and machine learning-based TCM intelligent analysis models, offering new perspectives for the modernization of TCM.

The 2024 TCMIID® Competition has become an essential platform for international innovation exchange in the TCM field, driving global TCM research cooperation and technological integration. In the future, the competition will continue to deepen the combination of TCM and modern technology, expand international cooperation channels, and support TCM's development in the global health system while promoting the worldwide dissemination of TCM culture.

1.4 Research Objectives and Review Methods

This study aims to systematically analyze the award-winning projects of the 2024 TCMIID® Competition, summarize their characteristics in technological innovation, theoretical breakthroughs, and clinical applications, explore the main trends in TCM development, and provide insights into future directions.

This research adopts literature analysis, case studies, and data analysis methods. First, national policy documents and recent academic research in the TCM field are reviewed to analyze the development trends in technological innovation, industrial upgrading, and international promotion. Second, award-winning projects from the competition are selected as case studies to examine their technological innovations and application values in detail and assess their feasibility and promotion prospects. Finally, data analysis methods are employed to summarize the overall trends of the competition entries and extract key elements for TCM's future development.

Through this study, valuable references are expected to be provided for technological in-

novation, industrial upgrading, and global promotion in the TCM industry, contributing to the high-quality development of TCM in the new era and making greater contributions to the global health industry.

2 Trends in the Innovation and Development of Traditional Chinese Medicine

2.1 Artificial Intelligence and Traditional Chinese Medicine Diagnosis and Treatment

The rapid development of artificial intelligence (AI) technology has provided unprecedented opportunities for innovation in Traditional Chinese Medicine (TCM) diagnosis and treatment. AI technology can be utilized for the intelligent analysis of TCM diagnostic data, enhancing the accuracy of clinical diagnosis and improving medical efficiency. The application of AI in TCM mainly involves intelligent diagnosis, data analysis, and optimization of treatment plans.

AI technology leverages machine learning and deep learning models to process digitized information from the four diagnostic methods of TCM, including tongue diagnosis, pulse diagnosis, and facial diagnosis, improving the accuracy of syndrome differentiation and treatment. Intelligent TCM diagnosis systems have already been implemented in multiple medical institutions. By utilizing big data analysis, AI can provide personalized TCM treatment plans.

Furthermore, AI can assist TCM clinical research through data mining and pattern recognition technologies, analyzing vast amounts of TCM case studies to enhance the scientific basis of clinical decision-making. For example, AI-based TCM prescription recommendation systems can automatically match patient symptoms with appropriate herbal medicine prescriptions.

AI also plays a vital role in TCM education. Intelligent TCM learning systems utilize interactive teaching and adaptive learning technologies to provide medical students with personalized learning pathways, improving the efficiency and quality of TCM education.

With the development of 5G and cloud computing, remote medical consultation and intelligent auxiliary diagnosis systems have been further promoted. Through AI technology, TCM practitioners can offer precise remote diagnosis and treatment plans, facilitating the cross-regional sharing of TCM medical resources. This model not only addresses the shortage of primary health-care resources but also enhances the global application value of TCM.

2.2 Modern Innovation in Traditional Chinese Medicine Theory

Modern innovation in TCM theory is one of the crucial directions in promoting the modernization of TCM. In recent years, researchers have been striving to use modern scientific methods to explain classical TCM theories, improving the scientific validation and credibility of TCM.

One example is the integration of the *Five Movements and Six Qi* theory with modern meteorology, providing new perspectives for TCM preventive medicine. By collecting and analyzing climate data, researchers can predict the impact of specific climatic conditions on human health and offer corresponding TCM preventive measures.

The meridian theory in TCM has also been advanced with modern scientific research. Studies in biophysics and neuroscience suggest that meridians may be related to specific neural networks or bioelectric currents, helping to uncover the scientific basis of meridian theories.

Moreover, developments in molecular biology have opened new research directions for TCM theories. Researchers are employing genomics and proteomics to explore the mechanisms of herbal medicine on human cells and tissues, aiming to establish the scientific foundation of TCM at the molecular level.

Another major trend in TCM modernization is the establishment of standardized and quantitative TCM theoretical systems. For instance, mathematical modeling and systems biology approaches are being applied to describe TCM theories mathematically, making them more verifiable and integrable into modern medical systems.

2.3 Health Management and Traditional Chinese Medicine Wellness

With the upgrading of health awareness, TCM wellness and health management models are receiving increasing attention. Modern health management integrates TCM constitution identification, personalized wellness programs, and intelligent health monitoring technologies.

Intelligent health management systems utilize wearable devices to collect users' physiological data and provide personalized health recommendations based on TCM theories. For example, by analyzing heart rate, sleep quality, and activity data, the system can automatically suggest suitable TCM wellness methods, such as acupuncture, massage, and dietary therapy.

TCM is also playing an increasing role in chronic disease management. Personalized TCM conditioning plans based on constitution identification can help patients maintain long-term health. For instance, for patients with chronic diseases like diabetes and hypertension, AI-driven analysis of their constitution combined with TCM regulation methods can improve health management outcomes.

In recent years, as psychological health issues become more prominent, TCM emotional regulation methods have gained attention. TCM psychological therapies based on the *Five Elements* theory, such as Five Elements Music Therapy, meditation, and Qigong therapy, are increasingly being applied by researchers and clinical practitioners in psychological health management.

2.4 Modernization of the Traditional Chinese Medicine Industry

The modernization of the TCM industry encompasses herbal medicine cultivation, production processes, and market promotion. In recent years, intelligent herbal medicine cultivation, smart manufacturing, and digital supply chains have significantly enhanced the production efficiency of the TCM industry.

For example, Internet of Things (IoT)-based herbal medicine cultivation systems can monitor environmental factors such as soil moisture and light intensity in real-time and automatically adjust growth conditions to improve the quality of medicinal materials. Moreover, modernized production techniques for TCM formulations have ensured compliance with international phar-

maceutical standards, facilitating the globalization of TCM.

In digital supply chain management, the application of blockchain technology has enhanced the traceability of herbal medicines, ensuring their authenticity and safety. Blockchain-based traceability systems can monitor herbal medicines throughout the entire process, from cultivation and processing to final product sales, reducing the risks of counterfeit products.

2.5 Internationalization and Cross-Cultural Communication of Traditional Chinese Medicine

The internationalization of TCM is accelerating, with an increasing number of countries recognizing its therapeutic value and gradually incorporating it into local healthcare systems. Cross-cultural communication and international collaboration are essential for the development of TCM.

By establishing international TCM research centers and collaborating with medical institutions in Europe, Southeast Asia, and other regions, the global influence of TCM can be expanded. Meanwhile, implementing multilingual TCM education and cross-cultural communication strategies can improve the acceptance of TCM in international markets.

Furthermore, under the *Belt and Road* Initiative, TCM is gradually entering international healthcare systems. In the global market promotion of TCM, establishing standardized TCM systems that comply with international regulations is a key step in driving the globalization of TCM.

2.6 Green Development and ESG Strategies in Traditional Chinese Medicine

Green development has become a global consensus, and the TCM industry is actively exploring sustainable development pathways through green cultivation technologies, eco-friendly pharmaceutical processes, and ESG (Environmental, Social, and Governance) strategies.

For example, organic cultivation and ecological agriculture models reduce the environmental impact of herbal medicine farming and improve resource utilization. Additionally, TCM enterprises are adopting green manufacturing technologies to reduce carbon emissions during production, laying the foundation for sustainable development in the TCM industry.

In recent years, some TCM enterprises have initiated carbon neutrality strategies by using modern environmental protection technologies to lower energy consumption in TCM production and implementing waste recycling techniques to achieve eco-friendly manufacturing.

The green development of TCM is also reflected in eco-friendly packaging upgrades. More companies are using biodegradable materials instead of traditional plastic packaging to reduce environmental pollution. Moreover, intelligent storage and logistics systems are making the TCM supply chain more energy-efficient and reducing resource waste.

3 Analysis of Award-Winning Projects in the 2024 TCM Inheritance and Innovation Development Competition

3.1 Grand Prize Projects

The grand prize-winning projects in the 2024 TCM Inheritance and Innovation Development Competition represent the forefront of TCM inheritance and innovation. These projects focus on areas such as intelligent diagnosis and treatment, TCM theoretical innovation, ecological wellness, international promotion, and enterprise management, fully demonstrating how TCM can achieve technological empowerment and globalization in the new era.

The project *Construction and Effectiveness Evaluation of a Spinal Kyphosis Prevention and Treatment Model Based on the “TCM in Daily Life” Concept* explores how TCM interventions can be integrated into daily life, proposing a non-invasive, personalized spinal health management approach. This study combines TCM constitution identification, traditional exercises (such as Tai Chi and Ba Duan Jin), and intelligent health monitoring technology to provide a widely applicable prevention and treatment model for spinal health. Long-term follow-up research has demonstrated significant improvements in spinal health and a reduction in the incidence of spinal kyphosis, highlighting its broad potential for promotion.

The project *AI-Enabled TCM Veterinary Medicine for Diagnosis and Treatment of Common Digestive Diseases in Pigs* integrates artificial intelligence with TCM veterinary medicine, developing an efficient and precise intelligent diagnostic and treatment system for animal diseases. By utilizing deep learning algorithms, this study established a diagnostic model for common digestive diseases in pigs, providing rapid and accurate treatment plans, thereby enhancing the scientific approach of TCM veterinary medicine. Additionally, this system can be integrated with agricultural breeding management platforms, forming an intelligent breeding model that offers precise disease prevention and health management strategies for modern animal husbandry.

The project *Qihuang Smart Wellness: Combining TCM Culture with the Ecological Wellness Hub of the Yao Ethnic Group in the Guangdong-Hong Kong-Macao Greater Bay Area* merges TCM culture with modern wellness concepts, utilizing the unique resources of the Yao ethnic group to establish an ecological wellness base centered on TCM. This project not only promotes the integration of TCM with local ethnic cultures but also creates a sustainable health management model based on TCM theories. The project emphasizes personalized health management, incorporating environmental conditioning, dietary therapy, acupuncture, and massage interventions to develop a systematic TCM wellness framework.

The project *Herbal Wellness and Serene Sanctuary: Exploring the Role of TCM in Ecological Wellness and Tourism* investigates how TCM can be applied in green wellness and ecological tourism. This project proposes an innovative model that combines TCM with forest wellness, utilizing herbal bathing, dietary therapy, and acupuncture alongside natural environmental therapies to enhance physical and mental health. Furthermore, the base has developed a personalized health assessment system based on TCM theories, providing tailored wellness plans for visitors, thereby improving the precision and scientific nature of wellness services.

The project *Heritage Harmony: TCM Worldwide* aims to accelerate the globalization of TCM by creating a global knowledge-sharing and exchange platform. Through multilingual translations, digital dissemination, and online courses, this project makes TCM culture more accessible

to the international community, promoting its global adoption. In addition to online education, the project collaborates with overseas medical institutions to facilitate the legalization and standardization of TCM worldwide.

The project *Financial Analysis and Recommendations for Shijiazhuang Pharmaceutical Group* focuses on TCM enterprise management, providing scientific management solutions for the sustainable development of TCM enterprises through big data analysis and financial optimization strategies. The project thoroughly examines the company's operational status and proposes feasible recommendations such as supply chain optimization and cost control. By integrating AI technology to predict market demand, it enables enterprises to formulate precise production plans.

3.2 First Prize Projects

First prize-winning projects cover various fields, including modern TCM theory, health management, and enterprise management, showcasing the diverse explorations in TCM innovation.

The project *Modern Application Research of the "Five Movements and Six Qi" Theory from the Yellow Emperor's Inner Canon* employs modern meteorological data to analyze the "Five Movements and Six Qi" theory, exploring its value in disease prediction and preventive medicine. This research provides a scientific interpretation of traditional TCM theories, enhancing their scientific validity and verifiability while demonstrating their guiding significance in clinical applications.

The project *Development of an AI Tongue Diagnosis System and a Scientific Health Preservation Plan Based on Constitution Identification* integrates machine learning with tongue diagnosis technology to develop an intelligent tongue diagnosis system. This system can quickly and accurately recognize tongue characteristics and provide personalized health management recommendations, demonstrating extensive application value in intelligent health management. The study also optimizes the tongue image database and improves the accuracy of recognition algorithms.

The project *Supply Chain Management and Financial Optimization for TCM Enterprises* addresses supply chain management issues in TCM enterprises by integrating blockchain technology and intelligent supply chain management methods. This project optimizes the procurement, storage, and distribution of TCM raw materials, improving operational efficiency while proposing a sustainable smart supply chain development model.

3.3 Second and Third Prize Projects

Second and third prize-winning projects focus on sustainable development, intelligent applications, and cultural dissemination, further advancing TCM modernization across multiple domains.

Projects in the *Sustainable Development of TCM* category explore how to achieve green development in TCM cultivation, production, and application. For example, one project proposes a biomass energy-based green TCM production model to reduce reliance on fossil fuels while optimizing ecological TCM cultivation models to improve resource efficiency. Other projects investigate the use of modern biotechnology to enhance herbal medicine yield while minimizing

environmental pollution.

Projects in the *Intelligent Applications of TCM* category include IoT-based remote TCM diagnosis platforms and intelligent TCM prescription recommendation systems. These projects leverage big data analytics and AI technologies to enhance the accessibility and intelligence of TCM services. For example, one project developed an AI-powered intelligent decoction device capable of precise decoction, ensuring optimal medicinal efficacy while allowing remote management for patients to customize decoction parameters.

Projects in the *TCM Cultural Communication and Design* category use innovative methods to promote TCM culture among younger generations. One team designed an immersive TCM cultural experience center incorporating Augmented Reality (AR) and Virtual Reality (VR) technologies, allowing visitors to experience the entire TCM diagnosis and treatment process firsthand. Additionally, a series of TCM cultural short videos targeting international audiences has been launched to increase global awareness of TCM.

This section systematically analyzes the innovation points and application values of the grand prize, first prize, second prize, and third prize projects in the 2024 TCM Inheritance and Innovation Development Competition, highlighting the latest progress in the fields of intelligentization, internationalization, industrialization, and sustainable development of TCM.

4 Analysis of Innovation and Development

4.1 Breakthrough Applications of AI in Traditional Chinese Medicine

The rapid development of artificial intelligence (AI) technology has provided new breakthroughs for the modernization of Traditional Chinese Medicine (TCM). AI technology has been widely applied in TCM diagnostics, constitution identification, herbal medicine research, and health management, significantly enhancing the scientific and intelligent level of TCM.

In the field of intelligent TCM diagnosis and treatment, AI technology can precisely analyze traditional TCM diagnostic data such as tongue diagnosis, pulse diagnosis, and facial diagnosis. AI tongue diagnosis systems based on deep learning algorithms can efficiently and accurately identify tongue features and, combined with big data, analyze patients' constitutions and health conditions to provide precise health management recommendations. Additionally, AI pulse diagnosis systems utilize sensor technology and big data analysis to standardize pulse recordkeeping and automate analysis, reducing the subjectivity of physicians' experience and improving the accuracy of syndrome differentiation.

In the field of herbal medicine research, AI significantly improves the efficiency of developing compound herbal formulas. Traditional herbal formula research relies on extensive experiments and clinical verification, whereas AI can rapidly screen potential therapeutic herbal ingredients through data mining, bioinformatics analysis, and computational pharmacology, optimizing formula compatibility and increasing the success rate of new drug development. Meanwhile, AI-driven intelligent herbal compatibility systems can integrate individual patient characteristics to recommend the optimal herbal treatment plan, enhancing efficacy while reducing side effects.

AI also plays a vital role in intelligent health management. For example, wearable device-based data monitoring systems can collect real-time physiological parameters (such as heart rate, blood pressure, and sleep quality) and integrate TCM constitution identification methods to generate personalized health assessment reports, offering customized TCM wellness programs. Additionally, AI-powered intelligent consultation systems can simulate TCM diagnostic thinking to provide remote consultations and health advice for patients.

4.2 Integration of TCM Wellness and Public Health Management

TCM wellness emphasizes *preventive treatment*, aligning closely with modern public health management principles. In recent years, the integration of TCM and health management has become a new development trend, with TCM wellness theories being widely applied in chronic disease management, elderly health, sports rehabilitation, and mental health.

In chronic disease management, personalized TCM health programs have been applied to the prevention and control of hypertension, diabetes, and coronary heart disease. Personalized health management programs based on TCM constitution identification and big data analysis help patients adjust their diets, daily routines, and exercise plans, effectively controlling disease progression. For example, integrating TCM dietary therapy and meridian regulation in diabetes management has been shown to improve blood glucose levels and reduce complications.

In elderly health management, the combination of TCM and the eldercare industry is emerging. TCM eldercare institutions provide acupuncture, massage, moxibustion, and dietary therapy services, offering comprehensive health management solutions for the elderly. Furthermore, AI-driven health monitoring technology allows real-time collection and analysis of elderly health data, enabling early detection of health risks and timely intervention.

TCM is also gaining attention in sports rehabilitation and mental health management. TCM-based sports rehabilitation integrates meridian regulation and traditional exercises (such as Ba Duan Jin and Tai Chi), demonstrating significant effectiveness in muscle injury recovery and post-exercise rehabilitation. In mental health, TCM emotional therapy, through methods such as Five-Element Music Therapy, meditation, and acupuncture, has been used to alleviate anxiety and depression and improve psychological well-being.

4.3 Green TCM Industry and ESG Development

Against the backdrop of global environmental protection and sustainable development, the green TCM industry and ESG (Environmental, Social, and Governance) strategies have become crucial directions for the TCM sector. In recent years, sustainable development measures such as green cultivation technology, eco-friendly pharmaceutical processes, and low-carbon logistics systems have been widely adopted in the TCM industry.

In herbal medicine cultivation, green cultivation models are gradually being promoted. For instance, ecological farming, crop rotation, and microbial fertilizers reduce the use of chemical pesticides and fertilizers, improving the quality and yield of herbal medicine. Moreover, herbal

cultivation bases utilize Internet of Things (IoT) technology to monitor environmental parameters such as soil moisture and light exposure, optimizing cultivation conditions and enhancing resource utilization efficiency.

In pharmaceutical manufacturing, an increasing number of enterprises are adopting green manufacturing technologies, such as supercritical CO₂ extraction and membrane separation technology, to reduce solvent usage and pollution emissions while ensuring efficacy. Additionally, some enterprises have begun using biodegradable materials to replace traditional pharmaceutical packaging, minimizing plastic waste and its environmental impact.

The ESG strategies of TCM enterprises also extend to supply chain management and social responsibility. Blockchain technology is being integrated into the TCM traceability system, ensuring the safety and traceability of herbal medicine and increasing consumer trust. Meanwhile, TCM enterprises fulfill social responsibility through public welfare projects, health education, and international aid, enhancing their brand value.

4.4 New Models for Cultural Heritage and International Promotion

As a vital part of Chinese civilization, TCM faces numerous opportunities and challenges in its global promotion. In recent years, new models such as digital dissemination, multilingual education, and cross-cultural exchange have driven the international spread of TCM culture.

Digital dissemination is a key avenue for the international promotion of TCM. Short video platforms, online live broadcasts, and virtual reality (VR) technology have been utilized for TCM cultural education, enabling global audiences to understand TCM diagnosis and wellness practices intuitively. Additionally, advances in intelligent translation technology have improved the accuracy of multilingual translations of TCM classics, increasing international researchers' interest in TCM studies.

In education, many universities have launched international TCM programs, using online courses and remote practical training to cultivate overseas TCM professionals. Some medical schools have collaborated with international healthcare institutions to offer integrated TCM and Western medicine courses, helping foreign doctors acquire TCM diagnostic skills.

Cross-cultural exchange between TCM and other traditional medical systems, such as Ayurveda in India and Kampo medicine in Japan, has also deepened. The implementation of international TCM academic forums and transnational research collaborations has enhanced the global academic influence of TCM.

Additionally, the international standardization process for TCM is accelerating. The World Health Organization (WHO) has incorporated certain TCM diagnostic techniques into the International Classification of Diseases (ICD-11), providing a legal foundation for integrating TCM into global healthcare systems. Meanwhile, multiple countries are working on the localization certification of Chinese medicine, aligning it with local pharmaceutical regulations and further expanding its international market.

This section systematically analyzes the innovative aspects of TCM in AI-driven applications, health management, green industry development, and international dissemination, showcasing

the diverse development trends of TCM in the modern era.

5 Future Development Directions of Traditional Chinese Medicine

5.1 Deep Integration of TCM and AI

The continuous advancement of artificial intelligence (AI) technology provides unprecedented opportunities for the future development of Traditional Chinese Medicine (TCM). The deep integration of TCM and AI is mainly reflected in intelligent diagnosis, personalized treatment, data analysis, and intelligent health management.

In the field of intelligent diagnosis, AI can perform in-depth analysis of TCM diagnostic data, especially in the processing of imaging data such as tongue diagnosis, pulse diagnosis, and facial analysis. Deep learning technology significantly enhances the accuracy of syndrome differentiation. Currently, AI-based tongue diagnosis systems can analyze high-resolution images to identify features such as tongue coating color, shape, and cracks. By integrating big data analysis, these systems assess patients' health conditions. In the future, AI will play a greater role in TCM diagnostics, including AI pulse diagnosis systems, AI facial analysis, and AI-based TCM disease prediction.

For personalized treatment, AI integrates bioinformatics and TCM pharmacology to rapidly select optimal herbal combinations, greatly enhancing precision medicine in TCM. AI-powered intelligent prescription recommendation systems have been implemented in various medical institutions. These systems analyze patients' constitutions, diseases, and previous treatment plans to automatically suggest the most suitable herbal prescriptions, along with dosage adjustments, improving the scientific accuracy of TCM treatment.

Moreover, AI has extensive applications in intelligent health management. Wearable smart devices can continuously monitor physiological data such as heart rate, blood pressure, body temperature, and sleep quality. By integrating TCM constitution identification, AI can provide customized TCM wellness plans. In the future, AI-based health management systems will further integrate with home healthcare, remote diagnosis, and health monitoring, forming a comprehensive, intelligent TCM health management system for the entire lifecycle.

5.2 Standardization and Clinical Validation of TCM

The international promotion and modernization of TCM require standardization and scientific validation. Due to TCM's personalized diagnostic methods and lack of modern scientific verification, it has faced skepticism. Therefore, one of the key future directions is to establish a comprehensive standardization system and conduct clinical validation through modern medical methods.

In herbal medicine standardization, future efforts should focus on standardizing the cultivation, production, processing, and formulation of herbal medicines. For instance, developing globally recognized quality standards for herbal medicine ensures consistency in the active in-

redient content across different batches. Additionally, modernizing TCM preparation processes will move toward greater precision and efficiency, utilizing technologies such as supercritical extraction, nanotechnology, and biosynthesis to enhance the stability and bioavailability of herbal formulations.

In TCM diagnostic standardization, the future goal is to establish diagnostic standards for TCM syndromes, making syndrome differentiation more objective and quantifiable. For example, AI-driven TCM disease modeling can improve diagnostic reproducibility and enhance the scientific validity of TCM clinical research.

In clinical validation, future research trends will involve integrative medicine clinical trials to verify the efficacy of TCM treatments. Modern medical research methods such as randomized controlled trials (RCTs) and multi-center clinical studies will be employed to scientifically validate TCM treatments. Additionally, big data analysis will be used to explore the underlying mechanisms of TCM therapies.

5.3 International Certification and Market Expansion of TCM

With the growing global interest in natural therapies, the acceptance of TCM in international markets is steadily increasing. The future internationalization of TCM will focus on international certification, regulatory alignment, and market promotion.

In international certification, an increasing number of countries are incorporating TCM into mainstream healthcare systems. For example, the World Health Organization (WHO) has included TCM in the extitInternational Classification of Diseases (ICD-11), laying a foundation for its global recognition. Future efforts should focus on obtaining international certifications such as Good Manufacturing Practice (GMP), U.S. Food and Drug Administration (FDA) approval, and European Medicines Agency (EMA) authorization to enable TCM formulations to enter global markets legally.

In regulatory alignment, future strategies should involve strengthening research on international regulations for herbal medicine to ensure compliance with different countries' drug approval standards. For example, the European Union requires compliance with the extitTraditional Herbal Medicinal Products Directive (THMPD), whereas in the United States, herbal products must be regulated under the extitDietary Supplement Health and Education Act (DSHEA). Thus, the future trend is to enhance international cooperation and promote global harmonization of TCM regulatory frameworks.

In market expansion, TCM brands should integrate modern marketing strategies, utilizing digital marketing, social media promotion, and cross-border e-commerce to increase their international market share. For example, short videos, live streaming, and health education websites can be leveraged to promote TCM culture and enhance global consumer awareness. Additionally, establishing overseas TCM service centers could provide remote consultations, health management, and personalized wellness programs, further advancing the international application of TCM.

5.4 Green TCM and Environmental Sustainability

Sustainable development is a major global economic trend, and the TCM industry must also evolve towards eco-friendly and low-carbon development. Future research and innovation in TCM will focus on green cultivation, eco-friendly pharmaceutical manufacturing, and low-carbon supply chains to achieve environmentally friendly growth.

In green cultivation, future efforts should promote ecological farming, crop rotation, and pesticide-free cultivation models to reduce pesticide and fertilizer usage and protect herbal medicine growing environments. For instance, smart agriculture technologies such as drone monitoring, soil intelligent detection, and precision fertilization can improve cultivation efficiency and reduce environmental pollution.

In eco-friendly pharmaceutical manufacturing, future advancements will include the adoption of green extraction processes such as supercritical CO₂ extraction and membrane separation technology to minimize the use of organic solvents and enhance sustainability. Additionally, the adoption of biodegradable packaging materials and low-energy production models will reduce carbon emissions and enhance the sustainability of the pharmaceutical industry.

In low-carbon supply chains, blockchain technology will be used to trace the origin of herbal medicines, improving supply chain transparency. Optimization of transportation and storage methods will help reduce energy consumption. For instance, smart cold-chain logistics can ensure stable quality during transportation while minimizing energy waste.

The TCM industry must also strengthen the implementation of ESG (Environmental, Social, and Governance) strategies to balance economic growth with social responsibility. Future efforts should include promoting carbon neutrality goals, reducing carbon emissions in the production process, and participating in biodiversity conservation and public health initiatives, thereby enhancing the social influence of TCM enterprises.

This section explores the future development trends of TCM in AI-driven intelligence, standardization, international market expansion, and sustainable development. As technological innovation and international collaboration progress, TCM will continue its global expansion while optimizing production and management models to achieve a more sustainable, green, and efficient future.

6 Conclusion

The 2024 Traditional Chinese Medicine Inheritance and Innovation Development Competition has fully demonstrated the achievements of TCM in terms of both inheritance and innovation in the modern era. By deeply exploring the academic value of TCM and its integration with modern technology, the competition covered various fields such as AI-powered TCM diagnostics, modern TCM theoretical innovation, health management, ecological wellness, international promotion, and enterprise management. These contributions highlighted the unique advantages of TCM in the contemporary healthcare system.

In intelligent diagnosis, AI technology combined with the four TCM diagnostic methods

has enabled the intelligent analysis of tongue and pulse data, promoting the standardization and precision of TCM diagnostics. In theoretical innovation, classical TCM theories such as *Five Movements and Six Qi* and *TCM Constitution Identification* have been validated and applied using modern data science, providing new pathways for the scientific development of TCM. Additionally, projects related to ecological wellness and cultural dissemination have demonstrated how TCM can deeply integrate with the modern wellness and cultural industries, opening new directions for the commercialization of TCM.

The award-winning projects in this competition not only reflect breakthroughs in technological innovation in TCM but also underscore its international influence and market potential. Through multilingual promotion, international TCM education, and overseas collaborative research, the globalization of TCM is accelerating. Meanwhile, the development of the TCM industry is increasingly focused on sustainability, with green cultivation, eco-friendly pharmaceutical production, and low-carbon supply chain management driving the industry toward an environmentally friendly transformation.

Looking forward, the development of TCM will focus on several key areas. First, the deep integration of AI and TCM will continue to be a significant trend, with advancements in intelligent diagnosis, smart health management, and personalized herbal medicine recommendations. Second, the standardization and clinical validation of TCM remain critical issues, as modern scientific research methods will help validate TCM theories and treatment efficacy, increasing its acceptance in global healthcare systems. Third, international certification and market expansion efforts must be further strengthened, ensuring compliance with global medical regulations to facilitate the entry of herbal medicines into mainstream healthcare markets worldwide. Fourth, the development of a green TCM industry will become a crucial objective, with measures such as ecological cultivation, green pharmaceutical production, and low-carbon supply chain management promoting the sustainable development of the industry.

The successful hosting of the 2024 TCM Inheritance and Innovation Development Competition has not only driven technological innovation in the TCM industry but also provided new opportunities for its global development. In the future, with the further integration of AI, big data, and biotechnology, the modernization and internationalization of TCM will continue to accelerate, playing an increasingly important role in the global healthcare system.

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