

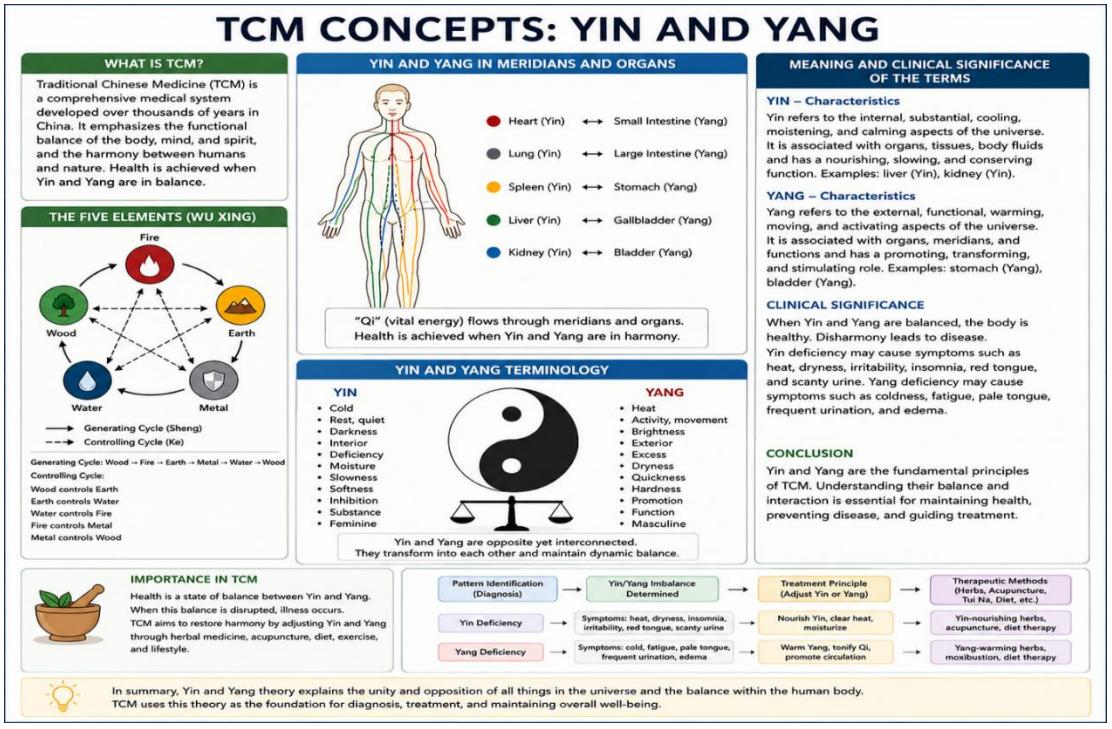
MODERN SCIENTIFIC FOUNDATIONS OF THE USE OF MEDICINAL PLANTS IN TRADITIONAL CHINESE MEDICINE

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Abstract. This review examines the modern scientific basis of medicinal plants used in Traditional Chinese Medicine (TCM), focusing on their bioactive constituents, pharmacological properties, safety aspects, and recent advances in scientific research.

Key words: Traditional Chinese Medicine (TCM); medicinal plants; **Panax ginseng**; **Astragalus membranaceus**; **Glycyrrhiza glabra**; **Ganoderma lucidum**; pharmacology; phytotherapy.

Traditional Chinese Medicine (TCM) is one of the oldest medical systems in the world, with a history spanning several thousand years. Today, medicinal plants used in TCM are extensively investigated from the perspectives of modern pharmacology, pharmacognosy, and molecular biology. Recent advances in analytical and systems biology techniques, including liquid chromatography–mass spectrometry (LC–MS), high-performance liquid chromatography (HPLC), metabolomics, genomics, and network pharmacology, have provided deeper insights into the mechanisms of action of bioactive compounds. These innovative approaches have significantly enhanced the scientific understanding of the therapeutic potential of TCM medicinal plants and have facilitated the identification of their molecular targets and pharmacological activities.



The philosophical foundation of Traditional Chinese Medicine (TCM) is based on the Yin–Yang theory, the concept of ***Qi*** (vital energy), and the Five Elements theory (Wood, Fire, Earth, Metal, and Water). According to these principles, human health depends on maintaining a

dynamic balance between internal physiological processes and external environmental factors. Disruption of this balance is believed to result in the development of disease, whereas therapeutic interventions are aimed at restoring physiological harmony.Throughout history, Chinese physicians have documented thousands of medicinal plants, providing detailed descriptions of their therapeutic properties, mechanisms of action, methods of preparation, and dosage regimens. Today, this extensive body of traditional knowledge continues to serve as a valuable foundation for contemporary research in pharmaceutical sciences and pharmacognosy. In particular, the bioactive constituents of numerous medicinal plants are being investigated using advanced laboratory techniques, and their therapeutic potential is increasingly being validated through scientific studies.

Traditional Chinese Medicine (TCM) is one of the oldest medical systems in human history, with its development spanning several millennia. Initially, this medical system evolved through careful observation of natural phenomena, practical experimentation with the therapeutic properties of medicinal plants, and the accumulation of knowledge transmitted across generations. Over time, these empirical observations were systematically organized, leading to the establishment of distinctive principles of diagnosis and treatment that continue to form the foundation of TCM.In recent years, scientific interest in Traditional Chinese Medicine has increased considerably, primarily because of the rich diversity of biologically active compounds present in medicinal plants and their potential for the prevention and treatment of a wide range of diseases. Contemporary studies have demonstrated that many medicinal plants used in Chinese traditional medicine contain flavonoids, alkaloids, terpenoids, polysaccharides, and phenolic compounds, which exhibit diverse pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, and antitumor effects.Advances in analytical chemistry have substantially improved the scientific investigation of TCM medicinal plants. Modern analytical techniques, including High-Performance Liquid Chromatography (HPLC), Gas Chromatography–Mass Spectrometry (GC–MS), Nuclear Magnetic Resonance (NMR), and Liquid Chromatography–Tandem Mass Spectrometry (LC–MS/MS), enable comprehensive qualitative and quantitative analyses of the chemical composition of herbal medicines. These technologies play a crucial role in identifying bioactive constituents, determining their concentrations, and elucidating the molecular mechanisms responsible for their pharmacological activities.

Progress in molecular biology and bioinformatics has further expanded the scientific evaluation of TCM preparations. In particular, genomics, proteomics, and metabolomics have facilitated the investigation of the multifaceted biological effects of medicinal plants at the molecular level. Moreover, network pharmacology has emerged as an effective approach for explaining the multi-component and multi-target mechanisms of herbal formulations, demonstrating how different bioactive constituents simultaneously interact with multiple molecular targets. This systems-based perspective provides a scientific explanation for the complex yet effective therapeutic actions of traditional herbal prescriptions.

More recently, the application of artificial intelligence (AI) and machine learning algorithms has opened a new era in TCM research. These advanced computational technologies accelerate the screening of bioactive compounds, prediction of molecular targets, assessment of potential toxicity, and development of novel phytopharmaceuticals. Consequently, the

integration of traditional medical knowledge with modern digital technologies has significantly enhanced the efficiency and precision of pharmaceutical research and drug discovery.

Despite these remarkable advances, several challenges remain before TCM preparations can be more widely accepted in international healthcare systems. Standardization of herbal medicines, implementation of rigorous quality-control procedures, and confirmation of clinical efficacy through well-designed clinical studies remain essential priorities. The quality and therapeutic effectiveness of medicinal plant materials may be substantially influenced by their geographical origin, cultivation conditions, harvesting time, and storage practices. Therefore, establishing quality-control systems based on modern pharmaceutical standards is indispensable for ensuring the safety, consistency, and therapeutic efficacy of Traditional Chinese Medicine preparations.

The therapeutic efficacy of medicinal plants used in Traditional Chinese Medicine (TCM) is closely associated with their diverse bioactive constituents. Earlier investigations primarily focused on alkaloids, flavonoids, and saponins; however, recent studies have demonstrated that high-molecular-weight biomolecules, including polysaccharides, peptides, proteins, and nucleic acids, also possess significant pharmacological properties. Among these, polysaccharides play a crucial role in enhancing immune function, reducing oxidative stress, and regulating inflammatory responses. In particular, polysaccharides isolated from *Ganoderma lucidum*, *Astragalus membranaceus*, and other medicinal plants have demonstrated remarkable immunomodulatory and antitumor activities in numerous experimental studies.

In addition, proteins and bioactive peptides present in medicinal plants participate in intracellular signaling, regulation of enzymatic activity, and modulation of immune responses. Recent advances in molecular biology have enabled researchers to elucidate the mechanisms of action of these biomolecules, thereby expanding their potential pharmaceutical applications. Furthermore, continuous improvements in technologies for the extraction, purification, and standardization of bioactive compounds have facilitated the production of high-quality phytopharmaceuticals from medicinal plants. Consequently, medicinal plants used in TCM are increasingly recognized not only as valuable components of traditional medicine but also as promising natural resources for the modern pharmaceutical industry.

Although medicinal plants employed in Traditional Chinese Medicine have been used for centuries in the treatment of various diseases, evaluating their safety and clinical efficacy according to modern scientific standards remains a major challenge. Despite their natural origin, not all medicinal plants can be regarded as inherently safe. Their chemical composition may vary considerably depending on plant species, geographical origin, environmental conditions, climatic factors, harvesting time, and post-harvest processing methods, including drying techniques. Insufficient quality control may result in significant variations in the concentration and composition of bioactive constituents. Moreover, herbal raw materials may occasionally be contaminated with heavy metals, pesticide residues, or microorganisms. Incorrect botanical identification or accidental substitution with other plant species may also compromise the safety and therapeutic efficacy of herbal preparations.Recent advances in pharmacovigilance have considerably improved the monitoring and assessment of adverse effects associated with TCM preparations. Contemporary clinical studies have demonstrated that certain medicinal plants may interact with synthetic drugs through pharmacokinetic or pharmacodynamic mechanisms when administered concurrently. Therefore, the successful

integration of TCM preparations into clinical practice requires individualized treatment strategies, appropriate dosage regimens, and careful medical supervision to ensure both safety and therapeutic effectiveness.One of the distinguishing characteristics of Traditional Chinese Medicine is the use of complex herbal formulations composed of multiple medicinal plants. Such formulations are intentionally designed to maximize the synergistic interactions among their bioactive constituents rather than relying on single active compounds. Growing scientific evidence increasingly supports the pharmacological basis of this therapeutic strategy.Through synergistic interactions, one constituent may enhance the biological activity of another, improve its bioavailability, or reduce potential adverse effects. Consequently, multi-component herbal formulations often exhibit greater therapeutic efficacy than isolated bioactive compounds. Modern pharmacokinetic studies have shown that the absorption, distribution, metabolism, and excretion of individual phytochemicals may influence one another within complex herbal formulations. From a pharmacodynamic perspective, multiple bioactive constituents can simultaneously regulate diverse molecular signaling pathways involved in disease pathogenesis. Such multi-target therapeutic actions are particularly beneficial in disorders associated with inflammation, oxidative stress, and immune dysregulation, thereby providing a strong scientific rationale for the clinical effectiveness of Traditional Chinese Medicine.

Conclusion. In conclusion, medicinal plants used in Traditional Chinese Medicine (TCM) possess considerable scientific and practical significance for modern pharmaceutical sciences and healthcare. The integration of centuries of traditional knowledge with contemporary scientific approaches provides a solid foundation for the development of a new generation of safe, effective, and standardized phytopharmaceuticals, while also expanding opportunities for the discovery of novel natural therapeutic agents. Consequently, comprehensive scientific investigation of TCM medicinal plants will not only advance the field of traditional medicine but also make a substantial contribution to the continuous improvement of modern healthcare systems.

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