

Modern Approaches to Integrating Artificial Intelligence with Traditional and Herbal Medicine: A Review

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Abstract—Traditional and herbal medicines have gained popularity worldwide due to their holistic approach and natural remedies. Artificial Intelligence (AI) can enhance various aspects of medicinal herbs, including new drug discovery, standardisation, authentication, machine learning, data mining, and natural language processing. The development of AI has introduced new opportunities and innovations for modernising traditional and herbal medicine. Integrating AI technology into the herbal medicine industry is expected to address major challenges and further advance the sector's modernisation. This review article offers insights into contemporary concepts and the potential of AI in promoting herbal medicine research to improve healthcare outcomes. Additionally, it highlights the drawbacks and challenges of incorporating AI into herbal medicine and suggests solutions to overcome these obstacles.

Index Terms—Herbal Drugs, Artificial Intelligence, Traditional and Conventional Medicine, Natural Language Processing, Ayurveda, Algorithms, Integrative Medicine

I. INTRODUCTION

Artificial intelligence (AI) broadly refers to the field of study where cognitive functions, such as facilitating learning, reasoning, and self-correction, are performed by machine or computer systems, enabling them to behave as if they possess knowledge of human behaviour.¹ The convergence of traditional, complementary, and integrative medicine (TCIM) and artificial intelligence (AI) represents a promising frontier in healthcare. AI can revolutionise healthcare

through data-driven decision-making and personalised treatment, along with analytical plans.²

Herbal medicine, firmly established in traditional practices and indigenous knowledge systems, has received global attention for its medicinal potential and cultural value. Despite millennia of practical usage and anecdotal evidence, the scientific validation and standardisation of herbal treatments have proven difficult. However, in recent years, AI technologies have emerged, providing fresh answers to these challenges and revealing herbal medicine's untapped potential. Medicinal plants have always been studied and valued due to their significance in preserving human health. Nonetheless, identifying medicinal plants is time-consuming, tedious, and requires an experienced specialist. Therefore, there is a need for an intelligent vision-based system integrated with artificial intelligence to assist researchers in recognising herbal plants quickly and accurately. In this review, an attempt has been made to summarise the modern concepts of integrating artificial intelligence technology into the comprehensive application of herbs and traditional medicine to promote further modernisation, which is expected to overcome the major problems faced today in the herbal drug industry.¹

1. Role of Artificial Intelligence (AI) In Traditional Health Care

In healthcare, AI has emerged as a powerful tool with the potential to transform various aspects of the industry, from diagnostics and treatment planning to patient engagement and administrative tasks. The following are the various applications of artificial intelligence (AI) in traditional health care.

a. Diagnostic augmentation: AI-powered diagnostic tools can analyse patient data, including medical records and imaging results, to assist in early disease detection and differential diagnoses. Traditional practitioners can benefit from these tools to support their assessments and develop a more comprehensive view of their patients' health.

b. Personalised treatment plans: AI can analyse a patient's comprehensive health profile to recommend treatments that combine conventional medical approaches with complementary therapies, tailored to the patient's preferences and needs.

c. Predictive analytics for preventive medicine: AI excels in identifying health trends and predicting disease risks, enabling proactive interventions to prevent illnesses. By providing insights into patients' unique health trajectories, AI further supports the preventive focus of traditional health care.

d. Patient engagement and education: AI-powered virtual health assistants can enhance patient engagement by providing information, answering questions, and offering guidance on integrative therapies and practices. They can also tailor educational materials to patients' specific treatment plans and personal health goals².

2. Role of AI in Traditional and Herbal Drug Discovery

a. Traditional drug discovery

One of the most significant contributions of AI in Ayurvedic herbology is the expedited discovery of potential medicinal herbs and their therapeutic properties. AI algorithms can analyse vast repositories of ancient texts, research papers, and clinical data to identify patterns and correlations between specific herbs and their effects on various health conditions. AI-driven natural language processing techniques extracted valuable information from historical Ayurvedic texts, leading to the identification of novel herbs with potential anti-inflammatory properties. Such AI-powered discoveries can significantly enhance the Ayurvedic pharmacopoeia and broaden the range of treatment options available to practitioners.⁵

b. Herbal Drug Discovery

Artificial intelligence (AI) tools such as machine learning, deep learning, and data mining have transformed herbal medicine development, providing novel strategies to speed up the identification of bioactive chemicals and improve therapeutic effects.

In-silico Medicine created a deep learning-based platform capable of producing unique chemical structures with desired features, resulting in the discovery of a new class of drugs with anti-fibrotic capabilities. Furthermore, researchers at the University of Toronto proved the effectiveness of deep learning in predicting the bioactivity of chemicals derived from herbal sources using their Chemception model.⁶

3. Artificial Intelligence (AI) In Ayurveda

One of the most critical aspects of manufacturing Ayurvedic products is accurately identifying herbs, which is the basis for creating safe and effective remedies. With the latest advances in Artificial Intelligence (AI) and machine learning, there is an exciting opportunity to transform the process of identifying herbs. Here are a few important ways in which AI can make a valuable contribution.

a. Image Recognition

In the Ayurveda field, organisations and researchers can use deep learning models to train algorithms to analyse various images of plants, herbs, and their parts, including leaves, flowers, roots, and stems, in real time. With the help of extensive databases, these AI systems can distinguish between different herbs, including those that are closely related, increasing efficiency and reducing the likelihood of misidentification leading to adulterations.

b. Spectroscopy and Chemical Analysis

With the help of AI, it is possible to analyse spectral data and chemical profiles of herbs. Using techniques such as near-infrared spectroscopy, AI algorithms can detect specific chemical markers in herbs. This enables manufacturers to verify the authenticity and quality of raw materials, ensuring consistency in product formulations and preventing spurious products.

c. Natural Language Processing (NLP)

When it comes to Ayurvedic texts, research papers, and clinical trials, NLP algorithms can analyse vast amounts of textual data and extract valuable information about the characteristics, properties, and traditional uses of herbs. With this knowledge base, AI systems can offer manufacturers comprehensive insights, which can aid in making informed decisions during the selection and formulation of herbs.

d. Disease-Specific Herb Recommendations

With the help of machine learning techniques, AI can correlate the properties of herbs with particular health conditions or diseases. This allows for the

identification of potential herb combinations and dosages that are tailored to address specific health concerns. As a result, manufacturers can create targeted Ayurvedic formulations for various ailments, which enhances the effectiveness of their products.

e. Improves Herb Agriculture Efficiency
AI-powered tools can help in the cultivation of herbs and medicinal plants by analysing soil data, monitoring crop growth, predicting weather patterns, and optimising irrigation and fertilisation of the soil. AI-powered systems can also identify and diagnose plant diseases, recommend solutions, and improve overall crop yield and quality. This brings immense potential for ethical and sustainable sourcing, rigorous quality control measures, and extensive research and development to ensure that Ayurvedic products are effective and trustworthy.

f. Herb Transparency Enhancement
Blockchain technology can help in herb identification by creating a secure and decentralised database of herb information. This can improve transparency, traceability, and efficiency in the supply chain. With blockchain, stakeholders can access real-time data on the origin, quality, and authenticity of herbs, reducing the risk of fraud and ensuring the safety and efficacy of Ayurvedic products.⁷

4. Artificial Intelligence In Ayurvedic Diagnosis

As an illustration of how AI can influence Ayurvedic diagnosis, a study was conducted where machine learning algorithms were employed to examine clinical data of individuals classified by Prakriti. The study demonstrated that AI models could accurately predict Prakriti categories based on physiological parameters and lifestyle factors. This research highlights how AI's data-driven approach can strengthen the diagnostic process in Ayurveda, thereby optimising treatment outcomes for patients. The essence of Ayurvedic diagnosis lies in understanding the interconnectedness of various factors contributing to an individual's health status. AI algorithms may excel in data analysis, but they must also take into account the subtleties and nuances that characterise Ayurvedic diagnostic practices.⁸

5. Modernisation of Chinese Medicine Using Artificial Intelligence

Traditional Chinese medicine (TCM) is the practical experience and summary of the Chinese nation for thousands of years. It shows great potential in treating various chronic diseases, complex diseases and major

infectious diseases, and has gradually attracted the attention of people all over the world.⁹

a. Traditional drug discovery

AI has contributed to traditional Chinese medicine in the process of traditional drug discovery that includes drug targets identification, lead compounds discovery, preclinical studies, clinical trials and new drug application and approval.¹⁰

b. Drug target identification and validation

Machine learning based on AI can identify and verify the target protein related to disease pathology by mining a series of biomedical databases, which plays a vital role in the initial stage of new drug discovery. Liu et al. built the multitarget-based polypharmacology prediction model by using Multi-layer Perceptron Support Vector Regression (SVR), Decision Tree Regressor (DTR), and Gradient Boost Regression (GBR) algorithms to predict 20 candidates with potential effects against drug-induced liver injury (DILI). The accuracy of the model was verified and can be used to explore the relationship between multi-target effect and overall drug efficacy.¹¹

c. Screening of active compounds

AI is helpful to guide lead compounds discovery with pharmacological activities from natural sources such as plants and microorganisms. Moreover, AI can identify the complex components of Traditional Chinese Medicine (TCM) and explore active components more accurately and quickly. Around 74 active substances were screened, and 2128 herbal prescriptions for adjuvant treatment of gastric cancer from TCM public databases were analysed by using association rule mining (ARM).¹²

d. ADMET prediction using AI

Adverse pharmacokinetics and toxicity characteristics of candidate drugs are the common reasons for the failure of drug discovery. By carefully selecting and optimising lead compounds according to their absorption, distribution, metabolism, excretion and toxicity (ADMET) properties in the early stage of drug discovery, it is possible to greatly improve the success rate and reduce the later cost. A Swiss ADME network tool was demonstrated, which is an efficient and free resource for predicting physicochemical properties, pharmacokinetics, drug similarity and drug chemical compatibility. A valuable summary on the practical application of the Swiss ADME web tool in drug design and development was also confirmed. These

studies show the importance of AI technology in ADMET prediction¹³

6. Artificial Intelligence in Acupuncture Treatment

The involvement of AI in acupuncture treatment was investigated. A total of five studies that were related to the selection of acupoints using AI were demonstrated. It was interesting to find a study to predict acupoint patterns utilising medical records based on symptom and disease information. The average precision score was relatively high with the involvement of AI tools when compared to manual studies.¹⁴

7. Development of Traditional Indonesian Medicine Using AI

The development of traditional Indonesian herbal medicine (Jamu) products into phytopharmaceuticals or standardised herbal medicine requires a long research phase and high costs, with a risk of an extended research time. Hence, with the aid of AI, it was possible to speed up the research process and produce more active compounds with enhanced quality and effectiveness. Drug repurposing for Jamu products in Indonesia is the right concept to be combined with AI technology due to several factors, including shortening the research duration. The ability of AI to learn from existing data, both data from modern drugs and drugs derived from traditional herbal medicine, makes it possible to obtain new, more effective drugs. Another approach that can be combined is the quantitative structure-activity relationship (QSAR), which is the creation of a model that relates physicochemical properties to biological activity. This system's approach is almost identical to the mechanism approach to drugs and diseases developed to obtain more effective drugs from Jamu.¹⁵

8. AI in Predicting Herb-Drug Interactions

AI plays a pivotal role in predicting herb-drug interactions, a critical aspect of Ayurvedic medicine to ensure patient safety and treatment efficacy. AI algorithms can process and analyse complex data sets, such as molecular structures and pharmacological profiles, to forecast potential interactions between herbal remedies and conventional medications. By integrating AI-driven tools, Ayurvedic practitioners can make informed decisions about combining traditional remedies with modern pharmaceuticals, minimising the risk of adverse reactions and optimising therapeutic outcomes.¹⁶

9. Artificial Intelligence In Developing Herbal Medicine Databases

Herbal medicine databases from several countries, predicting different compounds for various diseases using AI models, will assist physicians in helping patients prevent diseases. AI tools can be used and are based on computer simulation using the established electronic database, where the specific names of herbs or herbal prescriptions are stored, and algorithms are used for finding the pattern of herbal medicine.¹⁷

10. Role of AI in Standardisation and Authentication of Herbals

AI enhances existing quality control processes and enables innovative approaches to product authentication. Pattern recognition techniques, often integrated with spectroscopic and chromatographic data, enable the identification of characteristic spectral or chromatographic fingerprints unique to authentic herbal products. AI-driven pattern recognition algorithms, such as Support Vector Machines (SVM) and Artificial Neural Networks (ANN), learn from these fingerprints to distinguish between genuine and adulterated herbal samples, enhancing product authentication and quality assurance.¹⁸

An AI-based approach for medicinal plant identification uses an intelligent vision-based system to identify herb plants. This system was produced by developing an automatic Convolutional Neural Network (CNN). The proposed Deep Learning (DL) model consists of a CNN block for feature extraction and a classifier block for classifying the extracted features. The classifier block includes a Global Average Pooling (GAP) layer, a dense layer, a dropout layer, and a softmax layer. The solution has been tested on 3 levels of definitions of images for leaf recognition of five different medicinal plants. As a result, the vision-based system achieved more than 99.3% accuracy for all the image definitions. Hence, the proposed method effectively identifies medicinal plants in real-time and is capable of replacing traditional methods.¹⁹

11. Predictive Modelling in Herbal Medicine

Predictive modelling in herbal medicine research is a multifaceted approach facilitated by artificial intelligence (AI), enabling the assessment of efficacy, safety, and interactions of herbal compounds. Machine learning algorithms, including support vector machines, random forests, and neural networks, are

pivotal in analysing extensive datasets encompassing chemical, biological, and clinical information related to herbal compounds. These algorithms learn patterns and relationships from the data, predicting diverse pharmacological properties such as drug-likeness, bioavailability, metabolism, toxicity, and efficacy. Furthermore, molecular docking and molecular dynamics simulations elucidate the interactions between herbal compounds and molecular targets, offering insights into their mechanisms of action and pharmacological activities.²⁰

12. AI and Personalised Herbal Medicine Strategies

On the frontier of personalised medicine, AI algorithms harness vast amounts of individual health data, genetic information, and lifestyle factors to tailor treatment plans with unprecedented precision. By delving into complex datasets, AI identifies potential drug targets and optimises treatment efficacy, offering a personalised approach to herbal medicine. These algorithms further facilitate the development of customised herbal medicine cocktails, catering to the unique needs of each patient.²¹

II. CHALLENGES AND RISKS INVOLVED IN INTEGRATING AI WITH HERBALS

The integration of AI into TCIM represents an unprecedented opportunity, but it also brings forth a unique set of challenges that must be considered. One of the greatest obstacles in AI-driven research within the traditional medicine field is the scarcity of data. To accumulate data, it is essential to standardise terminology. However, compared to conventional medicine, the standardisation of terms in traditional drugs is lagging. Interpretability and transparency of AI-driven models raise concerns regarding reliability and reproducibility, particularly in regulatory contexts. Additionally, ethical considerations such as privacy protection and informed consent must be addressed when analysing sensitive healthcare data. Moreover, capturing the complexity of biological systems and herbal interventions remains challenging, requiring advancements in modelling techniques and interdisciplinary collaboration³. The integration of AI into Ayurveda is not without challenges. Preserving the essence of Ayurvedic practices while leveraging AI technology requires careful consideration. Additionally, data privacy, algorithm bias, and the risk of reducing Ayurveda to a mechanistic approach are

ethical concerns that need to be addressed. Despite the widespread popularity of AI-driven traditional and conventional medicine (TCM) discovery research, there are still some limitations and deficiencies that need to be acknowledged. For instance, while AI aids in the computer-aided design or discovery of TCM molecules, it is necessary to verify their effectiveness in the target diseases through clinical experiments⁸. TCM usually lacks a deep understanding of the molecular mechanism of drugs and adopts holistic treatment methods, which brings challenges to the application of AI. In addition, there are some problems in the database of TCM, such as different quality and poor management, which may cause false positive results in computer network analysis. The lack of high-quality and comprehensive database of Chinese herbal medicines and formulas hinders the training and verification of AI models.⁸

When applied to search engines, Artificial Intelligence looks for expert sources to find the most accurate information. Unfortunately, most of the highest-ranking sites covering a specific health condition or herb are not written by experienced herbalists. And AI can take liberties in populating information. In its current iteration, artificial intelligence sometimes fills in the gaps with falsehoods. Artificial intelligence can complement this learning type, but cannot replace it¹². Artificial intelligence collects data, analyses patterns, and provides information based on these patterns. However, this information can be misread and cannot be applied optimally without human intervention. Despite its downsides, AI has valuable applications in the field of herbal research and optimising the benefits when utilised appropriately.¹

III. DISCUSSION

Integrating AI with traditional and herbal medicine offers promising opportunities to modernise and validate age-old practices. AI techniques, such as machine learning and natural language processing, help analyse complex herbal formulations, identify bioactive compounds, and extract valuable knowledge from traditional texts. These tools also enable more efficient drug discovery and personalised treatment strategies aligned with traditional holistic approaches. However, challenges remain. The lack of standardised data, complex multi-herb compositions, and inconsistent terminologies can limit AI's effectiveness.

Ethical concerns—particularly around data ownership, cultural sensitivity, and intellectual property—must also be addressed to ensure fair and respectful use of indigenous knowledge. In summary, while the AI-traditional medicine interface is rich with potential, success depends on data quality, ethical standards, and interdisciplinary cooperation.

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