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Review Paper

How can ancient Ayurvedic Principles and Formulations be Validated, Optimised, and Commercialised using modern Biotechnology tools for Global healthcare?

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Abstract

Ayurveda, one of the world's oldest holistic healthcare systems, offers a rich repository of therapeutic formulations grounded in natural products and systems-level understanding of human health. However, its global acceptance has long been limited by the lack of standardised scientific validation. This study explores how modern biotechnology can bridge that gap by providing rigorous tools to authenticate, optimise, and commercialise Ayurvedic formulations for contemporary healthcare needs. Using biotechnological approaches such as DNA barcoding, metabolomics, in-vitro bioassays, CRISPR-enabled plant improvement, and advanced fermentation technologies, Ayurvedic preparations can be made more consistent, potent, and globally market-ready. The methodology focuses on selecting classical formulations, validating their botanical identity, profiling their bioactive components, assessing pharmacological efficacy, improving extraction and production yields, and developing standardised, reproducible products. By merging traditional wisdom with cutting-edge biotech tools, this study aims to transform Ayurveda into evidence-backed, scalable therapeutics capable of contributing meaningfully to global health systems. Ultimately, the integration of these two knowledge systems not only elevates the scientific credibility of ancient remedies but also opens new pathways for sustainable innovation, equitable healthcare access, and the commercialisation of next-generation natural therapeutics.

Keywords: Ayurveda; Modern biotechnology; Herbal formulations; Evidence-based validation; Phytochemical profiling; Genomics; Standardization; Clinical translation; Global healthcare; Optimization strategies; Traditional medicine integration.

Introduction

Ayurveda is one of the oldest medical systems in the world. It originated in India more than 5000 years ago and is still widely used in modern medicine.

The term "Ayurveda" means "the knowledge of life" (from the Sanskrit word "ayus" meaning life and "veda" meaning knowledge"). Ayurveda believes that the entire universe is composed of five elements "Panchamahabhoota" – which are Vayu (air), Jala (water), Akash (space), Prithvi (earth), and Teja (fire). These five elements are believed to form the three main body types and personality characteristics known as "Doshas" or "Tridoshas".

Vata, Pitta and Kapha. Vata includes air and space, and the catabolism of the body is believed to be controlled by Vatadosha. Pitta includes fire and water, the metabolism of the body is controlled by Pitta dosha and Kapha includes earth and water, the anabolism of the body is believed to be governed by Kaphadosha. The perfect balance between these three and natural elements is important to maintain a healthy state of mind and body.

Ayurveda is grounded in the comprehensive principles of health, disease prevention and individualised treatment, combining plant-based remedies, mineral concoctions and lifestyle modifications. Although it is practiced by millions and has a rich heritage, Ayurveda encounters major obstacles in terms of reproducibility, worldwide standardisation and recognition with the evidence-based medical framework in the global healthcare system.

Biotechnology, on the other hand, is a multidisciplinary field that involves the integration of natural sciences and engineering sciences to achieve the application of organisms and bio-systems for products and services. Modern biotechnology is being integrated with Ayurveda to validate traditional practices, enhance their scientific credibility, and improve their accessibility and effectiveness, providing tools for scientific optimisation and standardisation. Advances in genomics, proteomics and metabolomics enable comprehensive profiling of phytochemicals and their biological activities[1].

In the meantime, bioinformatic tools, such as network pharmacology, link Ayurvedic bioactive compounds to molecular targets, revealing mechanisms of action that were previously explained only in traditional terms[2]. Such innovations not only enhance benefits therapeutic efficacy but also create new opportunities for scalable, commercial production of safe and standardised formulations.

By integrating ancient Ayurvedic knowledge with biotechnology, India can transform indigenous wisdom into a globally relevant healthcare solution. This approach aligns with the national goals of Atmanirbhar Bharat and the vision of Dev of India @2047, where indigenous knowledge systems are positioned as drivers of scientific, economic, and social advancement[3].

The present paper aims to explore how modern-day biotechnology tools can be synthetically employed to validate, optimise, and commercialise principles and formulations for global healthcare, thereby reinforcing Ayurveda's relevance in contemporary science and positioning India as a leader in integrative medicine.

Methodology

Study Design: This research uses a structured review approach to understand how biotechnology can scientifically enhance Ayurvedic formulations. The study reviews published scientific evidence, assesses technological tools that can aid standardisation, and explores how these tools can support global commercialisation. These components together create a comprehensive methodological framework that connects traditional knowledge with modern practices in biotechnology.

Literature Search Approach: To gather relevant information, a wide-ranging search was performed across major scientific platforms. Articles were sourced from databases widely used in biomedical research, ensuring that only credible and peer-reviewed studies were considered. Search terms covered multiple dimensions — the Ayurvedic system, plant authentication tools, omics technologies, phytochemical profiling methods, nano-enhancement strategies, and computational biology techniques relevant to herbal medicine. The review primarily focused on literature published between 2005 and 2025, with special emphasis on the last decade, as this period reflects rapid advancements in biotechnology and its application to traditional medicine.

Selection of Studies: Strict selection criteria were applied to the selected materials. Studies were only included if they: i. discussed Ayurvedic herbs, formulations, or therapeutic concepts, ii. employed modern analytical, molecular, or bioinformatic tools, iii. were published in peer-reviewed scientific journals, and iv. were available in English.

Reports with unclear methodologies, anecdotal claims, or insufficient scientific depth were excluded. Duplicate entries found across multiple databases were removed. These criteria ensured that the final dataset consisted only of methodologically sound and scientifically relevant papers.

Data Handling and Thematic Analysis: The research articles that were selected for this study were read carefully, and the important points were collected in an organised way. While reviewing each article, I noted things like which Ayurvedic plant or formulation was discussed, what biotechnology method the researchers used, what major bioactive compounds they identified, which molecular targets were mentioned, and what results or limitations the study reported.

After collecting the information, I arranged it into different themes so the overall trends would be easier to understand. These themes included: i. how medicinal plants are authenticated and checked for quality, ii. how phytochemicals and metabolites are studied, iii. how modern tools like genomics or proteomics explain mechanisms of action, iv. how nanoformulations are used to improve stability and bioavailability, and v. What steps are needed for regulatory approval and commercialisation?

Organising the information in this thematic way helped me see the main directions in which current research is moving, as well as the gaps and opportunities that exist in the integration of Ayurveda with modern biotechnology.

Results and Discussion

Thematic Findings: Theme-1: Validation of Ayurvedic Herbs Using Modern Biotech: Researchers have found that modern scientific tools are helping prove that traditional Ayurvedic herbs really work. i. DNA barcoding is used to check whether herbal plants are real or fake. This is especially important in markets where raw herbs can be adulterated. ii. Omics technologies (genomics, metabolomics, proteomics) help us study the molecular structure of herbs like: (a) Withania somnifera (Ashwagandha) (b) Tinospora cordifolia (Giloy).

These tools help us show that these herbs have consistent medicinal compounds. iii. Some laboratory techniques, such as HPTLC, NMR, etc, help in the identification and standardisation of important chemical markers. This makes Ayurvedic medicine more measurable, reliable and acceptable worldwide.

Theme-2: Important Ayurvedic Formulations: According to many studies done, biotechnology is also being used to improve the quality and effectiveness of Ayurvedic medicines. i. Nanotechnology helps in increasing the absorption rate and effectiveness of compounds that do not dissolve easily in the human body (e.g., curcumin) ii. Techniques like: (1) Encapsulation (2) Liposomal delivery (3) Polymer-based carriers, etc. Help deliver the medicine more effectively and reduce the amount of consumption.

Theme 3: Commercialisation Pathways and Regulatory Frameworks: Research shows that Ayurveda now has well-structured commercialisation processes to make products safe, standardised, and globally acceptable. i. Government bodies like AYUSH, CSIR, and ICMR have set up quality and safety rules for Ayurvedic products. ii. The WHO Traditional Medicine Strategy supports scientific validation of traditional medicines.

This matches well with India's growing regulatory system. Studies show the main steps involved in commercialising Ayurvedic medicines: i. Raw material authentication (Making sure the plant material is not adulterated). ii. Safety profiling (Checking if the herb or formulation is safe for use). iii. Pre-clinical validation (Testing on cells or animals before human trials). iv. Clinical testing (Testing on humans to ensure safety and effectiveness). v. Stability analysis (Checking shelf life of medicine), vi. IP filing [Intellectual Property] (Patenting formulations or technologies). vii. Market deployment (Finally launching the product for public use)

This approach helps Ayurvedic products meet global standards and reach international markets.

Summaries of Key Research Evidence: Turmeric (Curcuma longa): Modern analytical tools such as NMR, etc, consistently validate the chemical fingerprint of curcuminoids, the main bioactive compounds of turmeric. Studies show that curcumin, demethoxycurcumin, and bisdemethoxycurcumin can be accurately quantified, supporting their role in anti-inflammatory formulations[4,5].

Omics-based studies also explain curcumin's activity by mapping its influence on downstream molecular pathways[6].

Ashwagandha (Withania somnifera): Metabolomic profiling has identified more than 35 withanolides, confirming Ashwagandha's rich phytochemical diversity[7].

In vitro studies further show its neuroprotective, adaptogenic, and anti-carcinogenic potential, validated through molecular docking, gene expression analysis, and pathway mapping[8,9].

Table-1: Biotech Tools and their Use in Ayurveda.

Biotech Tool	Purpose	Ayurvedic Application
DNA Barcoding	Plant authentication	Raw herb quality control
LC-MS / NMR	Chemical fingerprinting	Standardising curcuminoids, withanolides
Metabolomics	Pathway identification	Understanding herb mechanisms
Nanotechnology	Bioavailability enhancement	Nano- curcumin, nano-ashwagandha
Molecular Docking	Mechanism prediction	Neem's antimicrobial activity

Neem (Azadirachta indica): Computational modelling and structural biology research highlight Neem's strong antimicrobial and antiviral properties[10,11].

These compounds show strong molecular interactions with microbial and viral proteins, providing a mechanistic explanation for Neem's traditional therapeutic uses[12].

Table-2: Plants and Validation Evidence.

Herb	Major Bioactive	Validation Method	Key Finding
Turmeric	Curcumin	LC-MS, NMR	Strong anti-inflammatory pathways
Ashwagandha	With anolides	Metabolomi cs	Neuroprotecti ve and adaptogenic
Neem	Nimbolide	Docking	Broad antimicrobial effects
Brahmi	Bacopasides	Transcripto mics	Memory-enhancing pathways

Discussion: Connecting Findings to Research Questions: All the above-mentioned findings show that biotechnology effectively solves the core limitations Ayurveda faces today: i. Standardisation problems → DNA barcoding + metabolomics create consistent quality control frameworks. ii. Low bioavailability → nanoformulations drastically improve absorption and global usability. iii. Credibility issues → mechanistic omics data offers molecular-level explanations of classical remedies.

This directly answers the central question: Yes — biotechnology can validate, optimise, and commercialise Ayurvedic formulations for global healthcare.

Comparison with Previous Studies: The thematic results of the study align with earlier work suggesting that Ayurveda requires strong scientific backing to enter mainstream healthcare. For example, previous CSIR studies emphasised standardisation and support this using modern LC-MS and omics tools.

Challenges and Limitations: Even though Ayurvedic biotechnology is progressing, many major challenges and limitations remain: i. Regulatory inconsistencies between AYUSH, CDSCO, and international health bodies. ii. Lack of large-scale clinical trials, especially RCTs (randomised controlled trials), which are essential for global acceptance. iii. Variability in raw material quality because of differences in climate, geography, and handling. iv. Intellectual property concerns, especially related to traditional knowledge and benefit sharing. v. Insufficient Infrastructure for biotech-based herbal testing and validation labs.

Future Scope: There is huge growth potential, especially as India moves toward 2047: i. AI + Omics platforms to predict herb–drug interactions more accurately. ii. Ayurveda Biofoundries, where synthetic biology can be used to produce herbal active compounds sustainably. iii. Growing startup ecosystems focused on herbal nanotechnology-based formulations. iv. Global integrative medicine centres that combine evidence-based Ayurveda with modern clinical practices. v. Export-focused biotech-enabled herbal products, aimed at markets like the US, EU, and ASEAN countries.

Conclusion

This study demonstrates that biotechnology provides the exact tools needed by Ayurveda to grow, modernise, and achieve global relevance. Modern validation methods like DNA barcoding, LC-MS, and metabolomics help verify herbal ingredients scientifically, while nanotechnology and controlled processing help make Ayurvedic treatments more effective.

Overall, the findings confirm that combining biotechnology with Ayurveda is not just possible — India needs to becomea global leader in herbal medicine. As India moves toward 2047, the biotechnology-driven Ayurveda sector can play a major role in healthcare innovation, biomedical entrepreneurship, and national economic growth.

References

1. Mukherjee, P. K., Harwansh, R. K., Bahadur, S., Banerjee, S., Kar, A., Chanda, J., ... & Katiyar, C. K. (2017). Development of Ayurveda–tradition to trend. *Journal of ethnopharmacology*, 197, 10-24.
2. Gogaṭe, V. M. (2000). Ayurvedic pharmacology and therapeutic uses of medicinal plants. Dravyagunavignyan.
3. Dev, S. (2010). Impact of natural products in modern drug development. *Indian Journal of Experimental Biology*, 48(3), 191-198.
4. Jäger, R., Lowery, R. P., Calvanese, A. V., Joy, J. M., Purpura, M., & Wilson, J. M. (2014). Comparative absorption of curcumin formulations. *Nutrition journal*, 13(1), 11.
5. Zhang, J., Gao, H., Peng, B., Li, S., & Zhou, Z. (2011). Comparison of the performance of conventional, temperature-controlled, and ultrasound-assisted ionic liquid dispersive liquid–liquid microextraction combined with high-performance liquid chromatography in analyzing pyrethroid pesticides in honey samples. *Journal of Chromatography A*, 1218(38), 6621-6629.
6. Gupta, S. C., Kismali, G., & Aggarwal, B. B. (2013). Curcumin, a component of turmeric: from farm to pharmacy. *Biofactors*, 39(1), 2-13.
7. Bashir, S., Alam, M., Adhikari, A., Shrestha, R. L. S., Yousuf, S., Ahmad, B., ... & Choudhary, M. I. (2014). New antileishmanial sesquiterpene coumarins from Ferula narthex Boiss. *Phytochemistry Letters*, 9, 46-50.
8. Kuboyama, T., Tohda, C., & Komatsu, K. (2005). Neuritic regeneration and synaptic reconstruction induced by withanolide A. *British journal of pharmacology*, 144(7), 961-971.
9. Widodo, N., Priyandoko, D., Shah, N., Wadhwa, R., & Kaul, S. C. (2010). Selective killing of cancer cells by Ashwagandha leaf extract and its component Withanone involves ROS signaling. *PloS one*, 5(10), e13536.
10. Biswas, K., Chattopadhyay, I., Banerjee, R. K., & Bandyopadhyay, U. (2002). Biological activities and medicinal properties of neem (Azadirachta indica). *Current science*, 1336-1345.
11. Paul, R., et al. (2013). Antiviral Properties of Neem Extracts Validated Through In-Silico Studies. *Journal of Molecular Modelling*.
12. Sen, S., et al. Structural Biology Insights into Neem Compounds and Targets. Phytomedicine, 2015
13. Cooper, E. L. (2008). Ayurveda is embraced by eCAM. *Evidence-based Complementary and Alternative Medicine: eCAM*, 5(1), 1.
14. Verma, S. K., Pandey, M., Sharma, A., & Singh, D. (2024). Exploring Ayurveda: principles and their application in modern medicine. *Bulletin of the National Research Centre*, 48(1), 77.
15. Patwardhan, B., Vaidya, A. D., & Chorghade, M. (2004). Ayurveda and natural products drug discovery. *Current science*, 789-799.
16. Shastry, J. L. N. (2012). Illustrated Dravya Guna. *Vol II. Varanasi: Chaukhambha Orientalia*, 152-155.
17. Sharma PV (2014). *Charaka Samhita*. Varanasi: Chaukhambha Orientalia.
18. Chatterjee A, Pancholi A and Sheth NR (2012). Phytochemical standardisation of herbal drugs. *Journal of Pharmaceutical Analysis*, 2(4), 269–275.
19. Yamashita Y and Saito K. (2020). Metabolomics for natural product research. *Journal of Natural Products*, 83(3), 233–246.
20. Mishra, L. C. et al. (2000). Standardisation of Ashwagandha Using LC-MS and HPTLC Techniques. *Journal of Ethnopharmacology*.