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Review Article

ARTIFICIAL INTELLIGENCE AND CHALLENGES IN AYURVEDA PHARMACEUTICS: A REVIEW

Bale Anura[1]*, Desai Gaurav[2], Khedekar Sumod[3], Nayak Meghna[4]

*[1]Principal, Professor and HOD, Department of Kriya Sharir, [2]HOD, Department of Agada tantra vyavahara ayurved evum vidhi vaidyak, [3]I/C-HOD, Department of Kaumarbhritya-balrog (Ayu-pediatrics), [4]Intern, Gomantak Ayurveda Mahavidyalaya & Research Centre, Vazem, Shiroda, Goa, India.

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ABSTRACT

Ayurveda, the science of life is utilized for maintenance of health since ancient time. The main objective was to prolong lifespan of human subjects and also to maintain and promote their positive health and the same is the motto of Ayurveda science. Pharmaceutical branch in Ayurveda with more than five thousand permutation and combinations are used in day today practice for treatment of different ailments. This traditional medical system with established history of many centuries is becoming one of the most popular sciences with safety and efficacy. With increase demand of Ayurveda medicine and acceptance of Ayurveda in the entire world, there is requirement of modernization and use of advance techniques in Ayurveda Pharmaceutics. Now a day's newly progressed branch known as Artificial Intelligence (AI) can be used to meet increasing demands of Ayurveda medicines and to tackle challenges faced during drug manufacturing. AI can be used to combine engineering principles into the drug development to overcome challenges faced in Ayurveda Pharmaceutics. This can be achieved through applicability of AI in the various sectors of Ayurveda pharmaceutics. An attempt has been made in this article to analyze challenges with probable solutions by using Artificial Intelligence for global acceptance of Ayurveda.

INTRODUCTION

Ayurveda is one of the most approved and admired extant health systems in the world with fundamental principles and theory-based practices. Sanskrit definition of Ayurveda is the Science of Life. The theoretical foundations, rationale and epistemology of Ayurveda are reflected from the popular six *Darshanas*, mainly the logic of *Sankhya darshana* and *Nyaya-Vaishesika darshana*.[1] Its main objective is to prolong lifespan of human subjects and to maintain and promote their positive health; the same is mentioned in most of the Ayurveda classics. Surprisingly, Ayurveda has the capacity to treat many chronic conditions that are untreatable by other available medical systems, such as allergic diseases, skin problems, neuromuscular diseases, cancer, obesity, arthritis, and asthma. Unfortunately, this priceless gift from our forefathers is fading due to a lack of empirical proof of many notions. As a result, evidence-based research is need of hour for Ayurveda's global acceptance and acknowledgment, which necessitates ongoing research methodology developments. In Ayurveda, medicine is considered as first important patient management tool in the hands of a physician or a therapist. This tool has to be used precisely on the basis of various signs and symptoms and patients' examination, if not done so it is likely to cause adverse reaction who is receiving it. The information related to drugs and formulations along with diagnosis and management of disease accompanied with techniques of health maintenance through observance of proper daily and seasonal routines can be found in large number of classical and other literary works.

Pharmaceutical branch in Ayurveda with more than five thousand permutation and combinations are used in day-to-day practice for treatment of different ailments. Plant, animal or mineral product in whatever

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nature they may be, every substance has to undergo a specific processing to acquire a form of palatable drug. Such processing is termed as Ayurveda pharmaceutics i.e., *'Bhaishajya Kalpana'*. The final product which ultimately comes into use by the patient is known as a drug. The Ayurvedic formulations range widely from syrup, medicated oils, medicated soaps, capsule, creams, eye drops, freshly extracted plant juice, ointments, etc. However, there are five basic classical forms termed as '*Panchavidha kashaya kalpana*'[2] namely- *Swarasa, Kalka, Kashaya, Hima, Phanta*; from which all other drug formulations or forms are derived or developed. In ancient days and few Ayurveda physicians even in this era, prepare medicines on their own, by considering various parameters such as *Dosha* dominancy in patient, *Prakruti*- genomic constitution, *Desha*- geographical condition, condition of disease, age of the patient, strength of the patient, seasonal variations etc. With the growing popularity of Ayurvedic medicine and its acceptance around the world, there is a need for modernization and the use of advanced techniques in Ayurveda Pharmaceutics. This discipline is timeless, and it is one of the most comprehensive and useful holistic sciences that has gained popular acceptance and support.[3] *Rasashatra* branch of Ayurveda, documents monographs of 84 inorganic drugs and over 2000 compound formulations using 84 drugs and over 350 herbs. *Rasaushdhis* in the form of various *bhasmas* (single metallo-organic drugs) viz. *Abhraka* (Biotite mica), *Suvarna* (Gold- Au), *Rajata* (Silver- Ag), *Makshik*a (Chalcopyrite- $CUFeS_2$), *Galena* (PbS) and *kalpas* (metallo-herbal compound formulations) viz. *Laxmivilas rasa, Sootashekhar vati, Chandraprabha vati, Mahayogarj guggulu* etc. are praised for their low dose and fast action. They are preferred over herbal medicines to treat various known disease conditions and offer various choices for new emerging health problems as well.

Need for Updating in Pharmacopoeia

Ayurvedic Pharmacopoeia of India (API) contains standards for the quality of Ayurvedic drugs and substances (included under the Drugs and Cosmetic Act, 1940.) The Department of AYUSH, Ministry of Health and Family Welfare, Government of India, publishes the API. Nomenclature, part used, ingredients, range of application, contraindications, side effects, compatibility with other drugs, dose, use, and activity of the herb are usually included in herbal monographs. Data on bioassays and standardization of single herbs mentioned in Ayurvedic Pharmacopoeia of India is a valuable tool in ensuring quality standards of finished formulations. Despite being made mandatory by provisions of the Drug and Cosmetic Act dealing with traditional drugs, these procedures are rarely used by firms dealing with Ayurvedic formulations. To improve the scientific accountability of Ayurvedic medications, the Indian Ayurvedic Pharmacopoeia must be updated. Several herbal medications are not included in the Indian Ayurvedic Pharmacopoeia but are often used as ingredients in final formulations. The need of the hour is to create an updated or extra Ayurvedic pharmacopoeia that includes data on therapeutic plants that are not listed in the Indian Ayurvedic Pharmacopoeia. [4]

Areas for Improvement: Rather than competing and veering towards the Western medicine, the Ayurvedic scholars should work to enhance the acceptance of Ayurveda medication without compromising its fundamental basic principles.[5] Some major points responsible for trailing the Ayurveda should be noted and worked upon with future strategic plans.[6]

- **Desire to Get Deep Knowledge:** Though Ayurveda seems non-scientific to many, it is very scientific and microscopic level of science which needs in-depth understanding to practice it. Unfortunately, we have very fewer intellectual people who are trying to understand the Basic Ayurvedic principles as it's an extraordinary science hence ordinary public cannot understand it entirely. This is one of the major areas to be worked upon by Ayurveda research scholars.
- **Thorough Research:** Only a few organizations have well-established research infrastructure for exclusive research in Ayurveda. Experienced researchers and scholars with knowledge of modern technologies should be very clear on how to expose their valuable research outputs on our medicines, data collection and its documentation.
- **Need for Cooperation and Willingness** of Biomedical Scientists who should avoid unduly skeptical attitude and prejudice.
- **More Documentation of Emergency Medicines:** Today we have plenty of Ayurvedic emergency and lifesaving medicines that work faster with very small dosage, but they are less documented. So, truly this becomes a limitation, and the need of the hour is to overcome this.
- **Need for Availability of Pure Medicines:** Ayurveda relies on nature for the majority of its medications. Today, we have relatively few therapeutic herbs, and those that we do have are of poor quality due to adulteration and other factors.
- **Need for Overcoming Illegitimate Marketing Strategies and Advertising Propaganda** by some doctors/companies/hospitals with hundred percent/permanent cures also pose disadvantage from the patient/client/consumer perspective. Such practices must be screened and banned. This can be prevented by taking up strict measures,

laying down advisories and thorough documentation.

Artificial Intelligence is trending nowadays. We're making a brain map with AI, which is a technology that allows a machine to think, behave, and be as intelligent as a human being. It is a combination of a human's cognitive capacity and a machine's and program's intelligence. The AI is being accomplished by studying how human brains think, how they learn, decide, work, solving the real-world problems and verify the outcomes by studying it. To save the cost optimization processes; many sectors of industry are getting profit because of AI. The AI can be of different types (4 main types) and as per requirement the most desired one can be implemented.

Expert system: This is a concept of behavior that mimics human behavior in order to make decisions, reason, and solve complex problems.

Fuzzy logic: is defined as the concept of human thinking of taking decision in each situation. It makes the decision logically as possibilities of yes/no or true /false.

Neural network /ANN (Artificial neural network): imitates the real network of human being by following the working of human brain. In ANN, neurons behave as biological neurons, and those nodes are connected to each other by links for communication or interaction. Those nodes accept the data and perform different operation and produces output as node value.

Robotics: is an important part of AI where in an artificial agent works in the real-world environment and deals with surrounding It is a man-made machine that mimics the human thinking process; simply put, it is a machine with human intelligence. AI has a number of advantages, including the reduction of error, increased power, and increased labor efficiency and helps in solving new problems, Improved interface as well as better handling of information.[7]

Though the principles of Ayurveda are immortal, there's need to be contemporary marking up to the current scientific trends together with the integration of technologies and propagating our science to the mainstream globally. The time has come to debate the prospects of reviving Ayurveda, as well as the problems and solutions that must be addressed in order for it to achieve international standards and be accepted globally as a mainstream health profession employing AI. With expanding interest and acceptability, advanced visions to focus on the formal scopes of worldwide competitive marketing sectors should be developed in order to reap its future prospects in the global economic front simultaneously. Drastic revisions on Ayurveda epistemology, minimum standards and requirements of statutory bodies, planning commissions, culminating the serious flaws in graduate level Ayurveda education and upgrading and strengthening existing Research & Development institutions through vertical integration & clustering of related bodies, and other endowments adding to its viability should also be at the forefront of amendments. Well-structured and concrete collaborations across nations via MoU will also have an impact on implementing its power globally. Thus, Ayuṛveda in the current global trend proposes a different approach towards the nurturing & globalization using AI, making it marginal and adaptable in the international scenario. [8]

Implementing AI in different sectors of Ayurveda for wider acceptance can be done in following manner

AI in *Rasa-shastra*

To combat the issues of quality control, safety and efficacy it is possible to formulate standard study protocols wherein use of new machineries will help us to understand the complex processes. In the light of the new developments regarding bio-inorganicals [9], *Rasashastra* can give impetus to new leads [10]. Quality Control and standardization have always been issues regarding *Bhasmas* and *Rasaushdhis* owing to lack of standard protocols. However, during last couple of decades *Rasaushadhis* have been targeted on safety issues. A large number of articles on *Rasaushadhis*, including *Bhasmas* in indexed journals, are available. These papers cover a wide range of topics, including characterization, toxicity studies, clinical studies, physico-chemical evaluation, development of standard operating procedures for validation, free radical scavenging activities, other antioxidant activities, disease-specific pharmacological activities, and a few comparative studies with modern medicines. It is vital to highlight that the *Rasashastra bhasmikaran* procedure converts solid visible form to solid form nano size, whereas modern chemical techniques utilize metal in ionic form to obtain metal nano particles. Bioavailability research on around 50 inorganic materials were included in a WHO study issued in 2000, which aided in the development of the most recent studies on Bio-Inorganics.[11]

AI in *Bhaishajya Kalpana*

The different aspects related to drug formulation, preparation, storage etc., are all dealt in this sub-division. It is equally important to evaluate the medicinal characterization, dosage, clinical trials, disease specific mode of action, development of standard operating procedures for validation, preservation and packaging the final products for public use as per modern parlance.

Drug discovery in Ayurveda and its Components

Machine learning and other technologies are expected to make the hunt for new pharmaceuticals more rapidly, economical, effective and efficient in Ayurveda. AI and machine learning will usher in this era of expeditious, reasonable and proficient drug discovery. The employment of AI for drug discovery is essential to identify patterns hidden in large volumes of data which can be used for:

1. Identification of classical drugs with their Sanskrit nomenclature and different varieties available of same plant family.
2. Detailed description of drugs including botanical information and *Rasa, Guna, Virya, Vipaka, Prabhava* along with its standardization across the globe.
3. After identification and description of drugs, it enables us to directly use the drug in the disease.
4. For drug discovery aspect- Data from sources such as research articles, patents, clinical trials, patient records, and *Samhitas* will be fed into an AI platform, which will provide both practical usage and medications that are already known and described in classical writings. This creates a cloud-based representation of over one billion known and disrupted interactions between biological elements like genes, symptoms, illness problems, tissues, species, and prospective medications. To generate knowledge graphs, this may be queried similarly to a search engine.

So, whenever this engine is asked to provide information about a disease, it can give various options, other alternate drugs (potent drugs) to treat the same disease. This way when we develop and assess them in clinical trials, it will all come down to sophisticated pattern recognition. The epoch-making discovery of monoamines in Rauwolfia serpentina opened up the floodgates to new vision through Ayurvedic pharmacology [12]. Until then, value of Ayurveda in medicine and natural product research remained largely unrecognized, under studied and neglected. The discovery of reserpine through traditional knowledge inspired approach, known as reverse pharmacology, is now being practiced successfully [13].

Prakriti is one of the unique concepts described in Ayurveda. It is determined by each *Dosha* or a combination of two or all the three [14]. *Prakriti* analysis aids in determining which *Dosha* or *Doshas* predominate in a person. Because disease is caused by a *Dosha* imbalance, a deeper understanding of *Prakriti* aids in the establishment of an effective treatment regimen for a certain individual. This function can be improved by creating a clinical decision support system that uses *Prakriti* as a primary tool to get greater acceptability. Various government and non-government entities are actively participating in setting trends in Ayurveda digitization. Collection, organization and dissemination of information with economy and efficiency dampened on the skills and expertise of the portal / program manager. There are many computer-based Ayurveda practices designed to assist Ayurvedic doctors to detect, communicate and interpret data for accurate diagnosis and treatment [15]. Various programs like *Aushadhakosh, Dosha* assessment, *Prakriti* assessment, RASEX, RUDRA, etc., are in the market making digital Ayurveda supportive systems. In the net not only e-Journals, e-books and indexing units (DHARA, AYUSH Research portal, TKDL) but also many dot com and bloggers (Technoayurveda, Ayurhelp, Ayurvedic cure, Chakrapani, etc.) are helping the system.

AYUSH Research portal [16] has been established by Central Council for Research in Ayurveda and Siddha (CCRAS), and the content is being provided by all AYUSH Research councils, National Institutes, and Drug standardization laboratories, it is meant for dissemination of Research findings in the domain of AYUSH researchers and allied faculties. It aims for providing access to the research findings, which is organized to encourage interdisciplinary research. The total collection of portal is 10751 articles out of 5605 are of Ayurveda.

DHARA stands for 'Digital Helpline for Ayurveda Research Articles' and signifies 'flow' in Sanskrit. It is a thorough internet indexing service for Ayurvedic research articles. It is the first and only comprehensive internet indexing service dedicated solely to Ayurvedic research articles. It is the result of a collaboration between New Delhi's Central Council for Research in Ayurvedic Science (CCRAS), Coimbatore's The Ayurveda Trust, and Switzerland's Swiss Medical Academy (SAMA). The goal of this collaboration is to analyze Ayurvedic research. There are 7619 articles at a glance in DHARA [17], of which 2588 include full text.

Traditional Knowledge Digital Library is known as **TKDL**. The TKDL project is the product of collaboration between the Council of Scientific and Industrial Research (CSIR), Ministry of Science and Technology, and the Ministry of Health and Family Welfare's Department of AYUSH. This project is being carried out at the CSIR. Traditional Knowledge Digital Library has overcome the language and format barriers by systematically and scientifically converting and structuring the available contents of ancient texts on Indian Systems of Medicines, such as Ayurveda, Siddha, Unani, and Sowa Rigpa, as well as Yoga, into five international languages, namely English, Japanese, French, German, and Spanish, using information technology tools and an innovative classification

system- Traditional Knowledge Resource Classification. (TKRC). More than 3.6 lakh formulations/practices have been transcribed into the TKDL database as of this writing. In addition, the TKDL has established worldwide definitions and standards for the creation of TK databases based on the TKDL specifications. This was agreed by the WIPO Intergovernmental Committee (IGC) on Intellectual Property and Genetic Resources, Traditional Knowledge, and Folklore Expression in its fifth session in 2003. [18]

Ayurvedic Formulary of India (AFI) is a unique attempt of its nature wherein the scattered information on various formulations in classical Ayurvedic books are compiled in such a way to make it suitable to develop pharmacopoeia standards and also to meet the requirements of drugs and cosmetics Act. Therapeutic indications for the various formulations have also been listed, as per the original reference book. For easy reference, the original *Shlokas* of reference form from which the formulations were derived have been included with the formulations. Due to the lack of availability of roots and barks, as well as the country's regulating laws, alternative parts of the plants have been indicated for the various formulations. As a result, there is no risk of adulteration. For global users, the second revised edition of AFI has become more informational, user-friendly, and of international quality. This book can now be used by Ayurvedic professionals and other scientists.[19]

E-book (*Samhita, Shabdakosha,* compilation books) may refer to in general a book from the printed version which is evaluated for its generic and specific format and reordered methodically in the digitized electronic format. This enables us to retrieve in various forms. Today e-books helps us in reading of the text and also helps to perform complete search of the text. Searching of the specific text element that Key Word in the Context (KWIC) and citation of a particular verse in the concordance form are very specific requirements for our science which has a vast repository of literature in the Sanskrit verse form. A good number of printed books have been published, but availability in electronic texts is gradually getting common for this section of books. Several e-*Samhitas* like *Charaka Samhita, Sushruta Samhita*, *Ashtanga Hrudaya* etc. are currently available, Ayurveda dictionaries in the form of *Shabdakosha* is also available and several compilation books for referral are all being widely used. [20]

RUDRA [21] is a clinical research program that tracks the results of Ayurvedic clinical interventions in general practice. The RUDRA (Random Uninterrupted Documentation for Retrospective Analysis) Program, which began at the Ayurvedic Trust in Coimbatore, aims to document ongoing clinical practice in the field of Ayurveda with the goal of generating preliminary epidemiological, safety, and effectiveness data. The National Institute of Ayurveda in Jaipur, the Central Research Institute of Ayurveda in New Delhi, the Institute for Post Graduate Research and Training in Ayurveda in Jamnagar, the Department of Ayurveda at KMC in Manipal, and Sreedhareeyam Eye Hospital in Koothattukulam are all experimenting with this program. RUDRA documentation is completed in the Outpatient Department using a RAPID ASSESSMENT METHOD (RAM). There are three levels of RAM - 1) Recording of only the complaints reported by patient, 2) Recording of complaints reported by patient and general observations of researcher, 3) Recording of complaints, observations and diagnosis.

AyuSoft [22] This interactive software has been developed in collaboration with CDAC, Pune; Interdisciplinary School of Health Sciences and Department of Ayurveda, University of Pune; Jnana Prabodhini, NGO, Pune, India. It is a pioneering multidimensional effort that provides end-to-end medical solutions based on traditional medicines and helps in making health decisions that are expected to be more informed, more accurate and quicker. This software's end users could include hospitals, practitioners, and researchers. Case analysis, investigations, diagnoses, and treatment, nutrition and lifestyle guidance, personal management information system, multimedia-based encyclopedia, and textual and analytical report tool are just a few of the applications.

Prakriti Vichaya [23] is an innovative and expert software designed which renders services on different functionalities of Ayurveda such as *Prakriti* (Constitution), dietary advices, advices on daily regimens, likelihood of an illness and its precautionary measures.

Aushadha Kosha[24] *Triskandha-kosha* project is a proper solution which provides the classified information in an easily accessible manner which is based on the original classical texts viz. *Charakasamhita, Sushrutasamhita, Ashtangasamgraha* & *Ashtangahridaya*. The project's goal is to collect all references from foundational writings related to the *Hetu* (causes), *Lakshana* (signs and symptoms), and *Aushadha* (medicine or therapy) of health and disorders. From the above-mentioned texts, this provides classified information on all disorders. This significantly reduces the amount of time, energy, and money spent by researchers. Not only that, but it also opens up new study opportunities in Ayurveda. This aids in the understanding of diseases such as cancer, heart disease, chronic renal failure, and others from an

Ayurvedic perspective, as well as the development of efficient treatments. Based on this database, the Diagnostic & Treatment Software (exploring the wealth of Ayurvedic information from the texts) will be a significant tool for Ayurvedic practitioners to use the texts online for a specific patient. The project has a very high potential from the viewpoint of Patent and IPR issues and is going to be very much beneficial to the nation to prevent bio-piracy.

RASEX [25] This innovative software was designed and developed by Government Ayurveda College, Trivandrum in collaboration with CIRA (Center for Information Research and Action), and CDAC (Center for Development of Advanced Computing), Thiruvananthapuram in 1992. With the use of a computer, this software seeks to match pharmacological features with medicinal properties. Using DBase III plus, a database was established after collecting, categorizing, and preserving all of the pharmacological and therapeutic features of a single rasa medication. This package collects and displays a list of medications that meet the physician's parameters.

AyushEHR [26] AyushEHR a product of HealtheLife, standard compliant cloud-based EHR software built for the delivery, documentation and validation of AYUSH Services. This software is developed by experts in clinical informatics with national and international experience. After a thorough analysis and scrutiny of various internationally available EHR software, AyushEHR has been created complying to Indian & international EHR standards. The focus has been on the Ayurveda practitioners, unlike other EHR software that are difficult to work with by non-allopathic practitioners. The software emphasizes on the use of technology to uplift Indian traditional healthcare practices. AyushEHR places the patient at the center of care and empowers practitioners with tools to provide a personalized care experience as per the true Ayurveda tradition. It aims to create documentation during the care process to validate Ayurveda practices to improve its acceptability & adoption.

Further Areas for Research: There are areas that could be investigated and worked out in order to improve Ayurveda's accessibility, operation, and utility. Program-based medicines, robot-monitoring, robot-diagnostics, including tele-consultation, computers in clinical laboratories, computer-assisted medical decision-making, networking rural clinics with major medical facilities, and links for emergency and consultant services are just some of the possibilities. *Prakriti* Analysis with DNA Imprinting, computerized medicine dispensing after software-based 3D scanning for diagnosis, Computer-Aided Learning in the Medical Curriculum, Visualization Technology for Visualizing the Human Anatomy and Dissection, networks for linking hospitals, clinics, medical schools, universities, researchers and healthcare providers to share data via Geographic Information Systems (GIS),[27] Remote Information Services and Decision Support Tools for Patient Care.

CONCLUSION

Artificial intelligence can be effectively used to solve the challenges faced in Ayurveda pharmaceutics sectors such as large-scale availability of drugs, quality assurance, standardization, making it palatable, fixing the dosage of different formulations, increasing shelf life, uniform supply of drug, safety and efficacy. Attempt has been made in this article to analyze challenges in the field of Ayurveda Pharmaceutics with probable solutions by using Artificial Intelligence for global acceptance of Ayurveda.

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***Address for correspondence**
Dr. Bale Anura
Principal, Professor and HOD,
Department of Kriya Sharir,
Gomantak Ayurveda
Mahavidyalaya & Research Centre,
Shiroda-Goa.
Email: baleanura@rediffmail.com