'ICT and Technological Advances for Ayurveda Education and Practice: Status, Challenges and Scope'

Prasad Pandkar[1*], Sachin Kulkarni[2], Sarita Bhutada[3], Lakshmana Navale[4]

[1*]Associate Professor Bharati Vidyapeeth Deemed to be University, College of Ayurved, Pune, India. Email: prasad.pandkar@bharatividyapeeth.edu ORCID ID 0000-0002-4109-5662
[2]Associate Professor Bharati Vidyapeeth Deemed to be University, College of Ayurved, Pune, India ORCID ID 0009-0009-4543-1924
[3]Vice Principal, Head of Department & Professor, GJ Patel Institute of Ayurvedic Studies and Research (CVM University), New VV Nagar, Anand, Gujrat, India.
[4]Ex-Professor, Department of Mechanical engineering, Dr. DY Patil College of Engineering, Pimpri, Pune, India.

ABSTRACT

Ayurveda the 5000 year old health and medicine discipline of Indian sub-continent is now a recognized TRM (Traditional medicine) system by WHO at a global platform. Ayurveda Education has long history of 5000 years, whereas the formal education of Ayurveda in India (BAMS and MD Ayurveda) has recent History. The earlier Central Council of Indian Medicine (CCIM) and now National Commission for Indian System of Medicine (NCISM) are two key regulatory bodies in India responsible for overseeing education, practice, and standards in Ayurveda. Relevance of Ayurved has not faded over thousands of years simply because the time to time contemporization of Ayurveda that was done by its scholars with new scientific lights and with incorporation of modern tools. ICT has made revolution in Ayurveda Education process and technological advances for research have made same in machinery and devices in Pharmaceuticals and Panchakarma therapeutics. Today we are able to see the Microprocessor based modern Shirodhara (pouring medicated oil on forehead) unit with Digital Temperature Controllers replacing traditional Shirodhara unit. Majority of devices used in Pharmaceutical industry are outcomes of systems, control and product engineering. Use of ICT on other hand has come up with Ayurveda knowledge digitization, use of Informatics; emerge of many decision support systems & mobile phone applications in last few decades. Along with Education, Research is another field that has undergone change due to ICT. Unlike western biomedicine, decision making in Ayurveda diagnostics and therapeutics is non-linear and involves multiple variables and thus use of AI for same is a great scope. While world has now recognized and adopted 'Systems Biology' an integrative, nonlinear model of biology, 'Ayurveda and mechatronics' can have dialogue even at their epistemological level. This paper reviews examples of ICT applications in Ayurveda Education and technological advances for Ayurveda education and Research and evaluates challenges and scope of same.

Keywords: Ayurveda, Informatics, Education, Knowledge Digitization, Product engineering, Systems biology

I) INTRODUCTION

Ayurveda is a beautiful amalgamation of a health science, a medicine discipline, philosophy /logic (darshana shastra), psychology, nutrition science and even anthropology. Ayurveda carries a legacy of 5000 years of oriental scientific theories, over 7000 formulations, a rich symptomatology & disease diagnostics and therapeutics. The original oriental knowledge was later blended with contributions at principle & practical level experiences of the medieval & modern scholars. Ayurveda is not merely some ritualistic heritage but a continuously evolving health tradition. Ayurveda reveals an interesting journey from mythology to logical, rational and evidence based practices, observes prominent interdisciplinary scientists. Today in a global scenario we can interestingly see that alternative medicine continues to grow and even flourish in the mature scientific culture of late modern/ postmodern society. It was first time in 1990s The publication from New England Journal of Medicine surprisingly reported an interview data revealing 34% of U.S. population routinely using complimentary therapies for their health issues and36% of them visit complimentary systems practitioners for treatment[i]. Ayurveda is now recognized system as TRM I.e. Traditional Medicine by WHO (World Health organization).Reportedly the ayurveda sector in the country is poised to end 2018 with a

landmark achievement, touching a gross market size of $ 4.4 billion, or roughly Rs 30,000 crore and is expecting 16% growth by 2015. As the world is looking for natural, mind-body health care solutions, popularity of ayureda is on rise. Apart from this market scenario the scientific/ epistemological scenario is different. There is a vast difference in between western biomedicines and ayurvedic or other traditional medicines. The earlier is reductionists, mechanist, analytical and 'structure centric' approach basis on Newtonian Physics. On the other hand the approach of Ayurveda and other traditional healing sciences are holistic, 'Function centric' and with comprehensive observations. Scholarly writings for interpretations of Ayurveda epistemology for readers from modern biology and health sciences are seen encouraged.

There are 495 Ayurveda colleges in India those typically offer comprehensive curricula covering both traditional Ayurvedic principles and modern medical sciences. The curriculum often spans five and a half years, including a one-year internship. Students usually start with a foundation in basic medical sciences such as anatomy, physiology, and biochemistry. They then delve into specialized Ayurvedic subjects like Ayurvedic anatomy, physiology, pharmacology, and toxicology. Clinical training is a significant component, where students learn diagnostic skills, patient management, and treatment methods including herbal medicine, diet, yoga, and Panchakarma therapies[ii].

II) AYURVEDA ENCOUNTERS WITH REVOLUTIONS IN EDUCATION and AYURVEDA PHARMACY:

Industrial Revolution changed the world extensively, followed by revolution in printing technology and later by revolution of computing science. Ayurvedic fraternity and practitioners were not untouched from these major revolutions.

The Bachelor of Ayurvedic Medicine and Surgery (BAMS) education in India has a rich history dating back centuries. In 1920, the first Ayurvedic college, Government Ayurveda College, was established in India in Kolkata (then Calcutta). This marked the beginning of formal education in Ayurveda. Over time, more Ayurvedic colleges were established across the country, and BAMS emerged as the primary degree for Ayurvedic practitioners. The earlier Central Council of Indian Medicine (CCIM) and now National Commission for Indian System of Medicine (NCISM) are two key regulatory bodies in India responsible for overseeing education, practice, and standards in traditional Indian systems of medicine, including Ayurveda, Yoga and Naturopathy, Unani, Siddha, and Sowa-Rigpa (Tibetan medicine).

Pharmaceuticalization of ayureda was the most important impact of industrialization on Ayurveda fraternity. Use of Mechatronics, intelligent systems applications, many machines / electronics, electrical devices became routine as standardization (standardization at every stage - the raw materials (mainly medicinal plants), the process of manufacture and quality control of the product) was the need of hour. Professor Madhulika Banerjee reports that Dabur is a classic example. Founded by Dr. P. C. Burman, this giant Ayurveda manufacturer actually initiated and executed this processes for all steps for standardization for the company. Until the late 1940s, Dabur's medicines were being manufactured by hand, following the processes prescribed by the accepted texts. It took him about fifteen years to complete the mechanization processes to cover the entire range of medicines that Dabur had undertaken to produce[iii]. The Printing technology revolution also helped Ayurveda fraternity. Editions of Classics and emerge and spread of curricular and non-curricular Ayurveda literature after institutalization of ayurvedic education.

The inventions of computers, which are having the capacity to remember and analyse millions of data in a nanosecond was the second major revolution to make paradigm shift change in all scientific discipline. However unfortunately even 50 per cent of the available ayurvedic literature/data is not properly utilized by the present day Ayurveda clinicians. Scholars put an urgent necessity to link computer technology and Ayurveda so that it could be utilized for present practical applications of diagnosis and treatment and Research[iv]. It was later followed by emerge of many decision support systems and mobile phone applications. Addressing this need of digitization in Ayurveda healthcare, Dr. Leena Chhatre, OSD-AYUSH Grid, Ministry of AYUSH, reported that AYUSH Grid has been formed by the Ministry of AYUSH to concentrate on this aspect, especially digitization in Ayurvedic healthcare system. Digitization of AYUSH systems is in process, for bringing transparency, standardization, drug control, quality control, decision support and continuity of care[v].

III) AYURVEDA ADAPTING ICT AND OTHER TECHNOLOGICAL ADVANCES

Ayurveda has been practiced since the second century BC. The ancient Hindu philosophical traditions Vaisheshika and Nyaya, known for their reasoning, established the groundwork for Ayurveda. It was founded during the same time as the schools of Nyaya and Vaisheshika developed, and it is also connected to the manifestation framework, also referred to as Samkhya.

Inferences and perceptions on a patient's pathological condition should be collected for therapy purposes, according to the Vaisheshika School's teachings. On the other hand, the Nyaya school spread its beliefs based on the idea that before beginning treatment, one should have a thorough understanding of the patient's condition as well as the state of the disease. The Vaisheshika school divides an object's qualities into six categories: substance, particularity, activity, generality, inherence, and quality. These categories are known in Sanskrit as Dravya, Vishesha, Karma, Samanya, Samavaya, and Guna, respectively. Subsequently, the

Vaisheshika and Nyaya schools collaborated to establish the Nyaya– Vaisheshika school. In later years, the nyaya– Vaisheshika school promoted ancient wisdom and aided in the spread of Ayurvedic knowledge[vi].

The Bachelor of Ayurvedic Medicine (BAMS), the only program offering an Ayurvedic degree, was kept in place in 1977 by Ayurvedacharya[vii]. The eligibility requirements stated that students who have passed the second year pre-university test—that is, 10 years plus two years of board examination, or any other examination that is comparable—and in certain states, pre-university examination are eligible to enroll in the BAMS degree program.

ICT and technological advances for Ayurveda can be mainly classified in to four as Advances for manufacturing of medicines, Advances for laboratorial research and quality control, Advances used in Panchakarma processes and Computing Advances for decision making.

1) Advances for manufacturing of medicines:

History of ayurvedic medicine making processes dates back to vedic era. Emerge of Rasashastra i.e. Indian Chemistry was during Buddhist period of Indian History. Earlier (and even today) Ayurveda practitioner used to manufacture medicines for their patients. Mechanics came in picture after industrialization of ayurvedic pharmacy. Today every ayurvedic pharmacy is using all such advanced machines/ devices for same. They are summarized in table no.1

Table (1)

Instrument Name	Remarks
Inductive coupled Plasma – optical emission spectrometer ICP-OES	Used to detect element at ppm level to percent level From Organic and Inorganic samples (Bhasmas) e.g. Ca, Mg, Na, K, Pt, Au, Hg, As etc)
Gas Chromatography with headspace – GC	To check purity of Herbs, assay of Herbal/Herbal exracts, volatile organic compounds, fatty acid profile of Oils and Fats
CHNS-O analyzer	To determine percentage of Carbon, Oxygen, Nitrogen & Hydrogen Use for determination of empirical formula for organic compounds
Thermal Analyzer TGA	To study the thermal properties of compounds Determine Thermal stability of compounds temperature up to 90000 C deg Both TGA and Differential Scanning Calorimeter curves for stability of Bhasmas
Fourier Transform infrared spectrometer FTIR	Identification of main functional groups of organic compounds on the basis of IR frequency
UV/Vis spectrometer	Determination of Lambda max of colour bearing compounds Determine absorption and its concentration of colour bearing compounds Identification of compounds at particular wavelength
High performance Liquid Chromatography (HPLC)	To check purity of Herbs, assay of Herbal/Plant extracts, impurity profile of Plant extracts, stability study of organic compounds

Microwave digester	Use for Digestion of solid organic and inorganic samples using different type of acids Nitric acid , Hydrochloric acid etc. for extraction of metals In aqueous form For ICP-OES analysis
pH meter	Measures the hydrogen ion activity in water based solutions, indicating its acidity or alkalinity expressed as pH.
Conductivity meter	Measures the conductivity in a solution.

2) Advances for laboratorial research and quality control in Ayurveda research:

Different technological advances are used for laboratorial research, quality control and raw material standardization and Research. Bhasma the metal preparations are important part of ayurvedic medicines. Bhasma preparation is similar to the present-day nanotechnology having nano-size (25–50 nm) particles[viii]. Although Bhasmas are complex materials, physicochemical analysis using modern techniques can be most attractive for the standardization of Bhasma medicines. This can be certainly helpful in building confidence in the use of such products for medication by ensuring safety, efficacy, and batch to batch uniformity. Standardization of Bhasma with modern research tools is proposed and utilized.[ix]

They are summarized in table no.2

Table (2)

EDX (Energy Dispersive X ray analysis) –SEM	Chemical nature, size & morphology of particles
TEM (Transverse Electron Microscopy),AFM (Atomic Force Microscopy)	For Particle size, size distribution
EPMA (Electron Probe Micro Analyzer)	For Distribution of individual elements
XRD	For Phase Analysis
XRF,PIXE	For Bulk chemical analysis after making pellets, Detecting metal as element
ESCAr	For Electronic nature & oxidation state of metal
Extraction& Chromatography	To extract out organic matter if any
HPLC,NMR,IR(Infrared Spectroscopy),MALDI (Matrix Assisted Laser Desorption/ionization)	Characterization of organic matter

To add the contemporary methods of morphological, pharmacognostical and chemical examination for identification of plants, the advanced molecular marker analysis is now used because of its added advantages over the contemporary methods. Molecular markers, DNA based technology, biostatistics and bioinformatics are now becoming indispensable part of herbal drug research and standardization.[x] High-throughput screening (the high-speed data processing and sensitive detectors conducting millions of biochemical, genetic or pharmacological tests in a few minutes) is a useful advancement for identifying active compounds in a herb.

3) Advances used in Panchakarma processes:

Panchakarma are unique therapy procedures in Ayurveda. The include Vamana (planned emesis), Virechana (planned purgation), Basti (enemas of oils and different other medicines), blood letting and nasya
Automatic Shirodhara Unit" (ASU) is electronic and digitally controlled fully integrated device for Microprocessor based 'Digital Temperature Controller' to maintain the temperature of 'Shirodhara' fluid precisely, Semi-automatic steam cabinet generator, Automatic steam generator, Nadi sweda steam generator. There are attempts attempts for using automation for preparation of kadha i.e. Decoction of ayurvedic herbs.[xi] Also scholars have attempted automation techniques for or seka the unique ayurvedic ophthalmic therapy method.[xii]

4) Computing Advances for theuraptic decision making:

Computing advances have made an enormous impact on ayurvedic fraternity. Many softwares, decision support systems and many mobile applications are seen in use by students, researchers, practitioners and faculty members.

a) Computing advances for Ayurveda Academics:

There were several attempts of Digitization of Ayurvedic knowledge. Four important Ayurveda classics namely Charaka Samhita, Sushruta Samhita, Ashtanga hrudaya and Ashtanga Sangraha along with

commentaries were digitized and are available with search facility by Institute of Ayurved and Integrative Medicine (Foundation for Revitalization of Local Health Traditions, Bangalore). More than ten Nighantu (classics with pharmacognostic and pharmacological description of ayurvedic herbs) are again digitized and are available with search facility by same Institute. The AYUSH Ministry maintains a research portal having more than 13,000 entries which is an easily knowledge base repository[xiii]. Traditional Knowledge Digital Library (TKDL) was again an enormous initiative by Government to make repository of Indian traditional medicinal knowledge and prevent its misappropriations at International Patent Offices. DHARA (Digital Helpline for Ayurveda Research Articles) was a pioneering effort of making comprehensive online indexing of Ayurveda articles. As on today it contains more than 9,000 published papers.

b) Computing advances for Prakriti Assessment in Academia and Practise:

Assessment of 'Prakriti' the very own constitution of an individual remains pivotal in ayurvedic assessment of a healthy as well as unhealthy person. 'Prakes' the system for the assessment of Prakrti was developed by CIRA (Centre for Informatics Research Advancement, Kerala) in 1987. 'PRAKRTI The determination and Health Guidance by Computer' was the expert system designed and developed by Chaitanya Consultancy, Pune in 1989. It gives users Prakrti, health advice regarding diet, instructions about life style, probable diseases and their preventive measures. Centre for Development of Advanced Computing, Pune has developed software for assessment of prakriti which is seen used by many researchers. CCRAS the Central Council for Research in Ayurvedic Sciences, GoI has developed standardized software for prakriti assessment. In 2020 training of Ayurveda college teachers is started by Ministry of AYUSH, so that the CCRAS tool can be mainstreamed.

c) Computing advances for Disease Diagnostics in Learning Hospitals:

PILEX This software was developed to diagnose the piles, its prognosis, complications and treatments by Gujarat Ayurveda University, IPGTRA Jamnagar, Gujarat in 1990. MADHAVA the Ayurvedic Diagnostics decision support System was developed by Centre for Development of Advanced Computing, Pune has developed this diagnostics expert system based the medieval ayurvedic classic 'Madhava Nidana' for diagnosing purposes under the abled leadership of eminent practitioner Vaidya Vilas Nanal in1991. This system is developed to aid physicians in cases when the necessary information for a precise diagnosis is unavailable.

d) Computing advances for Education and Research of Ayurveda Pharmacology:

RASEX This package was developed by Government Ayurveda College, Trivandrum, CIRA, and ER & DC, Trivandrum in 1992. In this package an attempt has been made to correlate the pharmacological properties with that of therapeutic properties with the help of computer. VAIDYARAJ a software developed by Pune based eminent Practitioner Vaidya Rasik Pawaskar provides multimodal classification of over 7000 poly herbal-mineral ayurvedic preparations.

e) Computing advances for planning treatments:

'Triskandha Kosha' was an enormous project carried out at Tilak Maharashtra Deemed University, Pune. It was a brain child of Visionary stalwart late vaidya Madhava Kolhatkar and the decade long digitization process was carried out under coordinator ship of Vaidya Dilip Gadgil. Ayurvedic thought process is based on tripod of Hetu (causative factors of disease), Linga (symptoms and signs) and Aushadha (Treatment Principle/ Drug). The software is able to search Hetu, Linga and Aushadha cross-references.

IV) CHALLENGES & OPPORTUNITIES

The modernization and globalization of Ayurveda necessitate the integration of Information and Communication Technology (ICT) into its Education, research and practise. Nair (2003) underscores the need for a thorough study to establish theoretical and methodological foundations for this integration. The synergy between Ayurvedic and Allopathic medicine is crucial in meeting global healthcare demands, and ICT facilitates seamless interaction between the two. With the exponential growth of the global Ayurveda industry, leveraging ICT becomes economically imperative. The statistics provided underline the significant market potential, emphasizing the need for standardization and quality assurance. Overall, ICT revolutionizes Ayurveda by enhancing treatment efficacy, production processes, and global market reach.

Although the picture of incorporating ICT and technological advances in Ayurveda looks promising there are still many challenges. These advances are seen used in today's Ayurveda fraternity however certainly they are not mainstreamed. The important challenges include Ayurveda conceptualizations of health & Challenges in quantification of those subjective experiences of patients and challenge of reaching with Ayurveda practitioners. Ayurveda conceptualizations of health are essentially integrative of body, mind and soul. Ayurveda is again a essentially personalized medicine. The rich symptomatology of Ayurveda includes variety of symptoms experienced by patients. Thus quantification of these subjective experiences can be hardly done with some scales like Likert scale. Many a times many Ayurveda practitioners perform Nadi Pareeksha (Ayurvedic pulse diagnostics), or some of minimal sets of examinations to conclude to diagnosis and to plan

for treatment. An academician and researcher can have ample time to use different databases. But for a practitioner in a country like India where doctor-patient ratio is far less different from developed countries there is scarcity of time. Thus taking computing innovations and reaching with practitioners remains a difficult task.

Communication & Collaboration amongst different scientific disciplines and traditional medicine are really need of hour. The potential for Information technology to help medical practitioners to perform the complex information management tasks of patient care has long been recognized. Many promising systems that incorporate advanced information technology have been developed for clinical use, with regular improvements in availability, speed, and ease to use.

As the world is looking for more natural, safer and holistic medicine there is a lot of scope and opportunities for adaption of more and more technological advances in Ayurveda. AI is all set to make paradigm shift changes in western biomedicine. Recently an antibiotic was invented using artificial intelligence.[xiv]

As the perception of 'being healthy' is becoming broader and broader not only product engineering but many more automations and AI have the potential to be used for Ayurveda practices.

V) EPISTEMOLOGY IN SYSTEMS BIOLOGY, TRADITIONAL MEDICINE AND INTELLIGENT SYSTEMS:

Attempts of paraphrasing engineering and biological systems together were exercised after emerge of the term systems biology. Systems biology is a holistic approach to understand the way different chemicals and metabolic processes and their interactions within the body[xv]. It is proposed that the ayurvedic medicines mostly have numerous active ingredients; it could be used to understand the whole body's response to the complex mixture of herbs with many active molecules.

Our increasing understanding of life's multi-scale architecture suggests that living systems share similar characteristics with much to be learned about biological complexity from engineered systems as health reflects a dynamically stable integration of molecules, cell, tissues, and organs; disease indicates displacement compensated for and corrected by activation and combination of feedback mechanisms through interconnected networks. Engineered systems are afterall coupled networks of interacting sub-systems, whose dynamics are constrained to requirements of robustness and flexibility. They have evolved by design to optimize function in a changing environment and maintain responses within ranges.[xvi]

The Pathophysiological framework on which Ayurveda medicine depends is unique and different from western biomedicine. Instead of 'Systems-Organs-Tissues' model with a reductive approach, Ayurveda is based upon 'dosha-Dhatu-Mala, Agni and Srotas' model which itself is a holistic model of biology. It is distinctly different from conventional biology which is based on its organ-system structure-function relationship. Professor Josephson from University of Cambridge, UK in his lecture on 'Eastern Philosophy and Western Science,' had emphasized that reality is too complex to be reduced to a formula in general. In his opinion the problems with "objective reality" are central to quantum theory. It was Neils Bhor in western world to voice that complementary descriptions are needed to understand nonlinear Bio-systems.[xvii] 'Systems biology' a biology based essentially integrative field was later emerged where complex interactions and interrelations between biological systems themselves are studied with holism as approach.[xviii]

Thus Ayurveda itself can be seen as a systems biological model. A intelligent systems engineer unites the principles of mechanics, electronics, and computing to generate a simpler, more economical and reliable system. In that perspective, intelligent systems philosophy is again nonlinear and a kind of systems model. Thus there is need to understand the similitude at level of philosophy of science of both of them. Email inventor Ayyadurai Shiva has reported and discussed that Grand challenges of modern healthcare are motivating a paradigm shift towards systems of systems (SoS) approaches. The recent emergence of modern systems biology and the concomitant growth of evidence-based research in ancient systems of holistic medicine such as Siddha and Ayurveda, practiced in India for over 5,000 years, exemplify this shift.[xix]

VI) DISCUSSION AND CONCLUSION:

If IT professionals and Ayurvedic practitioners have a mutual grasp of both systems, there is great potential for applying IT to Ayurveda. But other Ayurvedic specialists worry that changing customs could spell the end for the system. It is imperative that they acknowledge the opportunities and the worldwide potential of Ayurveda in this century in order to overcome this hesitation. By incorporating ICT, Ayurveda can improve its education and research and thereby can meet new healthcare issues in a culture that is increasingly reliant on technology. This is a new area of endeavour where ICT is heavily involved, especially with regard to contemporary allopathic medicine. Ayurveda is the most suitable system of medicine in which Information Technology can be applied, provided both the IT experts and Ayurveda experts have got very clear idea about the potentiality of both systems. The adoption of ICT in Ayurveda Education and Research will certainly enhance the interactions between Ayurveda and modern medicine for the broader understandings of health and newer diseases. The need for modernization of Ayurveda with the application of ICT is again needed to meet the challenges of future healthcare needs of a cyber-society. Pharmaceutics and Research laboratories

are always been upgraded as the automation processes get upgraded. There is great scope for fundamental level integrations as there are similitudes in philosophy of systems biology, traditional medicine and intelligent systems.

References:

1. John GM, Hershman DL, Falci L, Shi Z, Tsai WY, Greenlee H. Complementary and alternative medicine use among US cancer survivors. J Cancer Surviv. 2016 Oct;10(5):850-64. doi: 10.1007/s11764-016-0530-y. Epub 2016 Feb 26. PMID: 26920872; PMCID: PMC5001939.
2. https://ncismindia.org/A.%20List%20of%20Total%20Ayurveda%20Colleges%20across%20Country%20till%2014.03.2023.pdf
3. Ayurveda in Modern India Standardization and Pharmaceuticalization, Madhulika Banerjee, Modern and Global Ayurveda, State University of New York Press, Albany, 2008 State University of New York
4. Shajahan, M.A. (1998). Computer and Ayurveda. Apta. 5 (1): 5-17.
5. https://www.financialexpress.com/lifestyle/health/how-to-reinvent-ayurveda-for-the-modern-age-with-integrated-technology-and-digitization/1673436/
6. Jaiswal YS, Williams LL. A glimpse of Ayurveda - The forgotten history and principles of Indian traditional medicine. J Tradit Complement Med. 2016 Feb 28;7(1):50-53. doi: 10.1016/j.jtcme.2016.02.002. PMID: 28053888; PMCID: PMC5198827.
7. Narayan J. Teaching reforms required for Ayurveda. J Ayurveda Integr Med. 2010 Apr;1(2):150-7. doi: 10.4103/0975-9476.65075. PMID: 21836806; PMCID: PMC3151386.
8. Pal D, Sahu CK, Haldar A. Bhasma: The ancient Indian nanomedicine. J Adv Pharm Technol Res. 2014;5:4–12.
9. Jain Rahi, Padma Venkatasubramania: Proposed correlation of modern processing principles for Ayurvedic herbal drug manufacturing:A systematic review, http:// www. ncbi.nlm.nih.gov/pmc/articles/PMC4342652
10. Bijoya Chatterjee et. al. Significance of Molecular Markers and DNA Based Technology in Research and Standardization of Medicinal Plants: A Review Int J Res Med. 2015; 4(2);5-16
11. Amol Makade et.al. Automation of kadha (medicine) preparation process in ayurveda using plc International Journal of Advanced Research (2016), Volume 4, Issue 6, 347-353
12. Sivabalaji et al., Automation of Netra Seka Procedure in Ayurvedic Drug Delivery System Journal of Clinical and Diagnostic Research. 2019 Feb, Vol-13(2): KE01-KE03
13. YUSH Research Portal. [Online]. Available: http://ayushportal.nic.in/
14. Marchant J. Powerful antibiotics discovered using AI. Nature. 2020 Feb 20. doi: 10.1038/d41586-020-00018-3. Epub ahead of print. PMID: 33603175.
15. Claudio Angione Human Systems Biology and Metabolic Modelling: A Review—From Disease Metabolism to Precision Medicine BioMed Research International Volume 2019, Article ID 8304260,
16. Yoram Yodovotz et.al. A systems engineering perspective on homeostasis and disease, Frontiers in Bioengineering and Biotechnology | Systems Biology, September 2013 | Volume 1 | Article 6
17. N. Bohr, "Medical research and natural philosophy," Acta Medica Scandinavica. Supplementum, vol. 266, pp. 967–972, 1952
18. Tavassoly, Iman; Goldfarb, Joseph; Iyengar, Ravi (2018-10-04). "Systems biology primer: the basic methods and approaches". Essays in Biochemistry. 62 (4): 487–500
19. V.A. Shiva Ayyadurai, The control systems engineering foundation of traditional Indian medicine: the Rosetta Stone for Siddha and Ayurveda, Int. J. System of Systems Engineering, Vol. 5, No. 2, 2014