

Ayurveda: scientific research and publications

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Ayurveda is one of the oldest extant health systems in the world with fundamental principles and theory-based practices. Literally, the Sanskrit meaning of *Ayu* is life and *Veda* is knowledge or science. Therefore, Ayurveda is also generally translated as the Science of Life. The theoretical foundations, rational and epistemology of Ayurveda are based on the six darsanas, mainly the logic of *Samkhya* and *Nyaya-Vaisesika* system of natural philosophy¹. The modern medicine on the other hand, is based more on Aristotelean logic of analytical and reductive life sciences. India has over 600,000 registered practitioners of Ayurveda and other traditional medicine who are close to the community, just not only in the geographical sense but also in terms of cultural and social ethos. Due to better accessibility and affordability, these systems enjoy wide acceptance among large segments of the population especially in India². Thus, Ayurveda remains a most comprehensive and practical medical science that receives acceptance and support of the public. However, due appreciation from the global scientific and medical community is still evolving³.

For several reasons scientific research on Ayurveda has been a much debated issue⁴. The Ayurveda fraternity is concerned about the transferability of the current scientific methods, models and approaches in totality to develop acceptable evidence. The Ayurvedic community is also concerned about the exploitation and intellectual property protection. Modern biomedical scientists, on the other hand, have been sceptic of traditional knowledge-techniques, materials and practice. These two polarized points of view do not represent the whole picture. The axioms of both are important yet distinctly different and logically coherent within each system. Therefore, use of identical research approaches may not be appropriate for inter-system validation. These approaches have been critically reviewed earlier, rightly emphasizing the need for new standards and methodologies for evaluating quality, safety and efficacy of traditional medicine⁵.

Whereas allopathy was being transmuted into modern medicine by adopting

emergent basic sciences, Ayurveda remained stagnated and even suppressed. Yet, it survived against the adversity of time especially during the Mughal and the British period^{6,7}. Regardless of this, Ayurveda has made significant contributions to medical science by providing many leads in natural product drug discovery^{8,9}. The epoch-making discovery of monoamines in *Rauwolfia serpentina* opened up the floodgates to new vision through Ayurvedic pharmacology¹⁰. Until then, value of Ayurveda in medicine and natural product research remained largely unrecognized, understudied and remained neglected. The discovery of reserpine through traditional knowledge-inspired approach, known as reverse pharmacology, is now being practised successfully¹¹. However, it is important to ensure that Ayurveda is not reduced to mere drug discovery engine. The modern research should benefit this ancient science to become more contemporary and affordable global health care system.

Generally, biomedical scientists have been sceptical on extent, rigour and quality of research on Ayurveda. Even the House of Lords Committee concluded that Ayurveda was a system lacking in evidence base¹², until a high level scientific delegation was sent by the Government of India¹³. However, ironically though, experimental research on Ayurveda had really been limited more to botany, chemistry and pharmacology of medicinal plants until 'a decadal vision document' on Ayurvedic biology¹⁴ was put forth. It is satisfying to note that the interest in research on basic principles of Ayurveda is increasing and of late few studies on genomics have been published in international peer reviewed journals¹⁵⁻¹⁷. More systematic and rigorous studies on Ayurveda at all the levels of biological organization are necessary to develop interest among global scientific community. Of course, in doing so, it will be vital to respect and understand basic concepts of Ayurveda, which should remain the key driver. Such an approach, in addition to increasing the number of research articles in peer reviewed reputed journals, would also motivate scientists from Ayurveda and the life

sciences to engage in more meaningful, collaborative and integrative manner¹⁸.

Pioneering efforts

Early stirrings of such an endeavour can be recognized in the medicinal plant research programmes from the Indian Council of Medical Research (ICMR), Council for Scientific and Industrial Research (CSIR), Department of Science and Technology (DST), Department of Ayurveda, Yoga, Unani, Siddha, Homoeopathy (AYUSH), Central Council for Research on Ayurveda and Siddha (CCRAS) and Department of Biotechnology (DBT). Few industrial based research centres such as of Ciba and Hoechst also had undertaken very active screening programmes on medicinal plants. The legacy of such work can be traced back to G. N. Sen¹⁹, Sir Ram Nath Chopra²⁰, Rustom Jal Vakil²¹, K. N. Udupa²², S. V. Bhide²³, Sukh Dev²⁴, C. K. Atal²⁵, C. Dwarkanath²⁶, G. V. Satyavati²⁷, B. N. Dhavan²⁸, Nitya Anand, Ranjit Roy Chaudhury²⁹, Sharadini Dahanukar³⁰, Vaidya Antarkar³¹, Singh³², Vaidya Triguna³³ and many other unsung heroes. There is a need to take a serious relook at some of these pioneering works.

Recent initiatives

Certain significant developments have boosted systematic research on various aspects of Ayurveda and traditional medicine in India. They include the Golden Triangle project jointly managed by CSIR, ICMR and AYUSH; the New Millennium Indian Technology Leadership Initiative (NMILLI) of CSIR and various schemes of DST and DBT. Under the Science Initiative in Ayurvedic Research, DST has supported several collaborative projects on science and Ayurveda on involving network of institutions, focusing on subjects such as the genomic basis of Ayurvedic phenotypes, metabolic and immunologic correlates of the traditional procedure of Panchakarma, and the microstructure of metal-based Ayurvedic drugs in powder form. The

ICMR has established an Advanced Centre of Reverse Pharmacology at Kasturba Health Society with an initial focus on malaria, sarcopenia and cognitive decline. More recently, the Department of AYUSH, Government of India, has proposed a Council of International Collaboration for Indian Systems of Medicine as a new initiative.

All these efforts are expected to encourage interdisciplinary collaborative research leading to quality publications in high impact journals. The government is rightly supporting traditional knowledge systems and also recognizes the importance of encouraging young researchers to attempt innovative and ambitious research projects to carry out rigorous science³⁴. It is considered that the resulting visibility and global acceptance of Ayurveda will enhance once rightful thought leadership position is attained. This can be achieved by more systematic scientific research leading to quality publications in high impact journals.

Ayurveda and TCM in science database

Anthropologically, both Ayurveda and Traditional Chinese Medicine (TCM) are great medical traditions³⁵. The vast knowledge, scientific and experiential wisdom of these systems could play an important role in the new drug discovery and development process³⁶, which can be useful even to modern medicine. Ayurveda remains to be an independent medical system, which is successfully practised in India, Sri Lanka and few other parts of the world. On the other hand, the practice of TCM has become more globalized and integrative³⁷ by involving modern medicine, diagnostics and therapeutics. TCM is well integrated with modern medicine at research and practice levels at many of the health and modern science institutions. Scientists from China and other parts of the world continue to exhibit active research interest in TCM. In the West, the Chinese community continues to use TCM and acupuncture as an integral part of health care and has been adopted by major medical centres. TCM has many international collaborative research projects besides its strong presence at the important bodies such as WHO³⁸. As a result, in comparison to Ayurveda, TCM based scientific publications clearly

exceed and excel. Desolately, the number of scientific publications on Ayurveda in international peer reviewed journals continues to be dismal in contrast with TCM.

As rightly pointed out by Balaram, several confounding factors may be involved in science metrics and analytics³⁹. Yet, we can certainly learn some lessons without being obsessed by the race to higher citation. Here, we have used popular science databases for a comparative study with limited objective to stress the need for more Ayurveda based research, which may result in better publications in high impact journals. We searched and compared citations on Ayurveda (including terms Ayurvedic and Ayurved), Yoga, TCM and acupuncture using the science databases including *Scopus*, *Pubmed*, *Scirus* and *Google Scholar* (Table 1).

Interesting trends

We noticed that high quality scientific research articles on acupuncture have appeared in the journals including *New England Journal of Medicine* (NEJM), *Proceedings of National Academy of Sciences* (PNAS), *British Medical Journal*

(BMJ), *Journal of American Medical Association* (JAMA), *Nature*, *Science*, etc. This has contributed to significantly high citations on TCM. While the scientific journal articles in *Scopus* and *Pubmed* are significantly higher on TCM and acupuncture, the total number of citations in *Scirus* and *Google Scholar* are highest for Yoga. This is mainly due to hits contributing from web sources other than journals and is an indication of the greater popularity of Yoga among the general public than the scientific community. Although Yoga enjoys much larger global visibility and adoption, its connections with Ayurveda have not been optimally explored as effectively done in case of acupuncture with TCM.

It would therefore be prudent to develop a system that can present Ayurveda and Yoga to the world in an inclusive manner. Such a system could be used with advantage to build newer paths and scientific programmes pertaining to collective strengths of Indian traditional knowledge as a whole.

Ayurveda in high-impact journals

We searched selected high-impact journals in *Scopus* for the terms such as

Table 1. Comparative citation* for Ayurveda and TCM in science database

Category	Scopus	Pubmed	Scirus	Google Scholar
Ayurveda	1216	451	80,045	23,900
Traditional Chinese Medicine	16,096	16,191	137,414	218,000
Yoga	2101	1250	1,014,471	228,000
Acupuncture	22,420	14,081	720,748	190,000

*Citation figures as on 21 June 2009, 12.30 pm.

Table 2. Comparative citations* of Ayurveda and TCM in high impact journals

Journal	Impact factor	Ayurveda	TCM
NEJM	52.589	0	23
Nature Group	29 to 26	66	257
Science	26.372	6	45
Lancet	28.638	29	629
JAMA	25.547	16	466
BMJ	9.723	62	80
PNAS	9.598	0	15
DDT	7.7	0	4
JBC	5.581	0	1
eCAM	2.535	25	23
JEP	2.047	58	126
IJMR	1.67	7	0
AJCM	1.122	2	129

*Citations limited for presence in 'title, abstract or keywords' as on 21 June 2009.

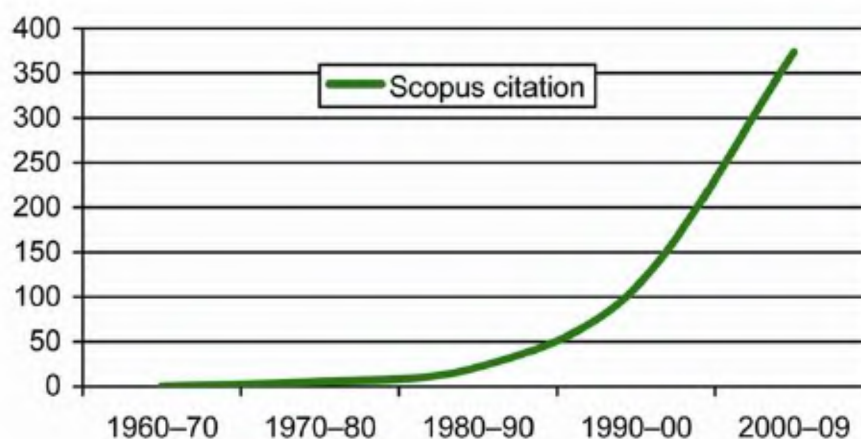


Figure 1. Scopus citations as on 21 June 2009 for Ayurveda in 'title, abstract and keywords'.

Ayurveda and 'traditional Chinese medicine' limited to be appearing only in title, keywords or abstract. This was mainly to avoid count of general articles on subjects like Complementary and Alternative Medicine (CAM), herbal medicine and traditional medicines. TCM remained way ahead of Ayurveda in majority of the journals selected for this study (Table 2). Currently, except a few letters, news and commentaries, hardly any critical reviews, perspectives and original research articles on Ayurveda are seen in journals like *BMJ*, *Lancet*, *Nature* or *Science*⁴⁰. Moreover, top journals like *NEJM* and *PNAS* showed zero hits for Ayurveda. Ironically, some articles concerning presence of heavy metals in Ayurvedic preparations and reports on the poor efficacy of popular Ayurvedic medicine Guggulu (*Commiphora wightii*) published in *JAMA* have generated a negative image of Ayurveda among consumers, scientific and medical communities^{41,42}. It is beyond dispute that the number and the quality of research articles on Ayurveda in high-impact journals must be enhanced.

Past bias and future hopes

It may be important to note that journals like *JAMA* were little curious and supportive in the past to Ayurveda. Despondently, few publications (maybe touching boundaries of pseudoscience) with apparent motives other than science seem to have caused significant damage and great embarrassment especially as in the case of *JAMA*⁴³. While detailed analysis of this case is beyond the scope of the

present article, such incidences may have aggravated the perceived bias of the West against Ayurveda⁴⁴. Providentially, few main-stream journals of science, medicine and CAM are now focusing on Ayurveda⁴⁵. Also, of late, high-impact journals like *Cell*⁴⁶ and *Journal of Biological Chemistry (JBC)*⁴⁷ have published features and articles about the popular Ayurvedic plant turmeric.

Another silver lining is the fact that as compared to last four decades, there has been an encouragingly sharp increase in the number of good articles on Ayurveda in international journals during this decade (Figure 1). Clearly, this indicates that systematic efforts of Indian Ayurvedic and scientific community and strategic encouragement from government especially from AYUSH and national collaborative network projects like CSIR NMITLI have certainly given the required boost in the right direction. We feel that the innovation and research contributions from Indian pharmaceutical and Ayurveda industry also need to be encouraged and augmented. There is a caveat to our findings. Many Indian journals may not appear in science databases or international abstract services and so may not have been captured here. This may have contributed to lesser numbers observed by us. Still, our study clearly indicates that number and impact of scientific publications based on Ayurveda is far less as compared to TCM. We do hope that the scientific community and the government would further intensify systematic efforts and encourage collaborative research to bridge this gap and strengthen the presence of Indian Ayurveda in high-impact journals.

Ayurveda in Drug Discovery Today

With the aforesaid background, the recent article on Ayurveda in *Drug Discovery Today (DDT)* is a positive development⁴⁸. *DDT* is one of the most cited peer review journals in the field of drug discovery with the impressive current ISI Impact Factor of 7.7. Earlier in the year 2005, *DDT* published an article on botanical immunodrugs where Ayurveda was mentioned for the first time⁴⁹. Since then, it was hoped that a full article on Ayurveda could be commissioned. After several rounds of consultations with the editor of *DDT* to ensure that the article would conform to the journal's tone, structure, size, number of figures, etc., the authors also sought top level comments before formal submission. The first response included comments from six peer reviewers, of which five recommended strongly, of course making a lot of critical suggestions. The main concern was that the article should be cautious in claims and tone so that the industry and academia are intrigued but not offended. The authors consulted several Indian scientists in an informal peer review to seek their views and suggestions. To ensure that the article would not become counterproductive, they also consulted few top drug discovery scientists from the pharmaceutical multinationals. As a result, the revised article was entirely different from the submitted one. The entire exercise was vital to optimize the review. The authors feel that such an approach would provide a much higher success

rate and help to achieve the desired increase in Ayurveda publications in high-impact journals. Of course, for 'high-impact' publications, we need 'high-impact' projects and motivated scientists.

Capacity building

In this process, it is vital to ensure the required rigour of the science as well as respect to traditional knowledge. To achieve these dual goals, we may have to strengthen existing centres of excellence and create new ones. We need a new high quality peer reviewed journal as a platform for Indian and international researchers to publish research articles interfacing Ayurveda and integrative medicine. We also need an exemplary institution as an epitome of quality and rigour balancing science with shastra. In the past, institutions of excellence such as Indian Institute of Science and Indian Institutes of Technology did offer new leadership and needed renaissance to Indian science and also brought Nobels and other laurels. We need to create similar world class institutions of excellence to provide capacity building, human resource development and thought leadership to the Ayurveda sector. We hope that interesting science will emerge through such efforts giving India and Ayurveda due visibility, acceptance and much desired fillip in the global scientific and industrial fraternity.

In India and abroad, a vast range of scientists are now trying to investigate huge potential of Ayurveda. The depth of its wisdom is now beginning to be appreciated through the lens of modern science. Here, we have raised several issues: epistemological differences; balance of shastra and science; putative bias; need for newer research approaches for intersystem validation; need for increased scientific rigour, and particularly, capacity building and the resulting increased numbers of scientific publications in the field of Ayurveda. However, we agree that critical analysis pointing to directions or prescriptions for actions is also needed. This should call for a series of focused articles on these crucial issues of future relevance. We no longer consider approaches like Ayurvedic biology or reverse pharmacology as new. What is new is our emerging ability to recognize and understand them from contemporary

perspectives. Emerging commonalities between biomedicine and Ayurvedic science remain exciting. We hope that better insights to interrelations between the basic principles of Ayurveda and modern science will happen in a complementary and integrative way rather than conflicting or competitive manner. We opine that such an exercise may offer newer perspective to human life and also expand our vision of its true potential.

Finally, we wish to end this article with a quote from the *Legacy of Charaka*⁵⁰ that captures the true spirit of Ayurveda and its vision of rigour: 'Ayurveda owes its call not to selfish goals or to worldly pleasure, but to compassion for fellow beings. In seeking to know my legacy, you have but seen the leaves of a universal tree, too vast for your eyes. May your sight grow and your quest never ends'.

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ACKNOWLEDGEMENTS. We thank Drs Rama Vaidya, Kasturba Health Society, Mumbai; Girish Tillu, CDAC, Pune and Darshan Shankar, FRLHT, Bangalore for valuable

advice. Special thanks to Dr Alex Hankey, I-AIM, Bangalore for valuable editing.

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Otoliths – the biological CD-ROMs of fish

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‘Otoliths are like biological CD ROMs. They constantly record information about the environment and about how fish lives. The information on them is never lost and you can retrieve potentially any temporal sequence that you like.’

—Suzanne Kingsmill¹

Otoliths are dense calcareous stones found in the inner ear of bony fishes. These fishes have three types of otoliths – sagitta, lapillus and asteriscus; considered to be involved in hearing and balancing functions. They are the first hard part formed in the fish and grow continuously by successive deposition of mineral-rich calcium carbonate (aragonite) and protein-rich layers. Otoliths are metabolically inert, not subject to reabsorption and remodeling by growth and their characteristic shape will not be affected by the mode of fish preservation (excluding acid preservatives). Having these inherent but outstanding qualities, otoliths proved themselves as good recorders of life history of the fish and its surrounding environment. While the otolith morphology is species-specific, the pattern of growth rings in an otolith microstructure reveals the age and temporal growth of the fish in relation to the environmental conditions whereas the elemental composition can answer questions on its preoccupied and current habitat features.

A vast array of research has been conducted on a wide variety of fishes based on otolith analyses, e.g. morphology, microstructure and microchemistry. Gen-

erally the otolith applications can be classified under the following aspects: (1) Age and growth estimation, (2) Early life history recruitment, (3) Habitat shifts and migration, (4) Stock determination and (5) others.

Age and growth estimation

Counting the daily, seasonal and annual increments to estimate age of a fish seems to be the most primary and widest application of otoliths. Otoliths also proved capable of estimating the age of fishes having extreme longevity, those living for more than 80 years, the technology of which has now been used for age estimation in fossil fishes. Radiometric ageing, where the relative abundance of radioisotopes (e.g.: ²²⁶Ra and ²¹⁰Pb, and ²²⁸Th and ²²⁸Ra) at the core of otoliths are measured, promises more accurate age determinations². As bodily (somatic) growth and otolith growth are more often closely correlated, the width of otolith increment will reflect the rate of somatic growth³. Accurate size-at-age and age-at-first maturity estimations assume high significance in management and conservation of exploitable fishery resources, artificial breeding and aquaculture practices.

Early life history and recruitment

Otolith microstructures record life history events and stage transitions of fish

during the early life stages. The deposition of the first otolith increment occurs at the time of hatching, at yolk absorption or at first feeding in most of the fishes. Secondary growth centres are another developmental mark. The onset of metamorphosis is marked in many species by the appearance of transitional zone/bands or settlement mark and/or the formation of secondary growth centre in the otoliths. Otolith growth rates also change at transitions between life history stages². By comparing the hatch date frequency distribution of surviving larvae to the seasonal production of eggs, it is possible to identify larval survival and recruitment success within the season of reproduction⁴. An otolith record of life history events combined with the age and size information contained within them can answer the role of age versus size in the timing of life history transitions.

Habitat shifts and migration

Otolith microchemistry is a developing technique, which finds application in routine migration studies of diadromous fishes. Shifts between marine, freshwater and estuarine habitats can be tracked from predictable variations in strontium–calcium ratio or isotopic concentration within otoliths⁵. Otolith elemental analysis is also applied to understand the influence of physical hindrance on their migration, and to detect short habitat shifts, from the nursery ground to the adult habitat in non-diadromous fishes⁶.