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Review article

Ayurnutrigenomics: Ayurveda-inspired personalized nutrition from inception to evidence

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ABSTRACT

Ayurveda proclaims food and drugs are intersecting concepts that are vital for human survival and for the prevention and mitigation of diseases. Food interferes with the molecular mechanisms of an organism's "physiome". It is consumed in large amounts compared to any drug. Hence, research on its effect and interaction with genome is highly relevant toward understanding diseases and their therapies. Ayurgenomics presents a personalized approach in the predictive, preventive, and curative aspects of stratified medicine with molecular variability, which embodies the study of interindividual variability due to genetic variability in humans for assessing susceptibility, and establishing diagnosis and prognosis, mainly on the basis of the constitution type of a person's *Prakriti*. Ayurnutrigenomics is an emerging field of interest pervading Ayurveda systems biology, where the selection of a suitable dietary, therapeutic, and lifestyle regime is made on the basis of clinical assessment of an individual maintaining one's *Prakriti*. This Ayurveda-inspired concept of personalized nutrition is a novel concept of nutrigenomic research for developing personalized functional foods and nutraceuticals suitable for one's genetic makeup with the help of Ayurveda. Here, we propose and present this novel concept of Ayurnutrigenomics and its emerging areas of research, which may unfold future possibilities toward smart yet safe therapeutics.

1. Introduction

The ability of food components to interfere with molecular mechanisms causal to an organism's "physiome" has incited a revolution in thinking about what we eat.[1] Pharmacogenomics and nutrigenomics are mostly intersecting concepts; surprisingly, we are more exposed to foods than to drugs.[2] Ayurveda is an ancient science of life, practiced for thousands of years, which evolved around the concept of preventive and personalized medicine by maintaining a balance of the three biological entities, called *Tridoshas*, namely, *Vata*, *Pitta*, and *Kapha*.[3] Ayurveda takes a holistic approach toward medicine that integrates mind, body, and soul, and toward several other stratifications. Interestingly, we find that Ayurveda merges foods (*Pathya* or *Ahara*) and drugs (*Ausadha*) inside the concept of therapeutics, to maintain harmonization of the *Doshas* or physiological factors according to individualistic variability or *Prakriti* and other environmental factors.[4] A herb that is consumed as a food or a spice, such as turmeric or haridra Curcuma longa; 薑黃 jiāng huáng), is also indicated in different ailments ranging from Gastro intestinal tract (GIT) disorder to cancer.[5] Thus, nutrition takes a central stage in Ayurvedic therapy, which is personalized according to individual constitution (*Prakriti*).

2. Ayurnutrigenomics from inception to evidence

Nutrition research began in 1785, when elementary metabolic and respiratory processes were discovered.[6,7] However, this personalized approach toward nutrition research evolved recently, to understand the mechanisms of individualized nutritional responses and nutrigenomics.[8] As a matter of fact, nutrition impacts predominantly on both health and human disease, together with the prevention and treatment of some widespread multifactorial

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chronic diseases. Nutrigenomics assures its relevance in public health and nutritional interference by human genomic variation. Moreover, the scope of analysis in nutrigenomic research is broad and genome wide, which may recognize new biological mechanisms governing host response to food.[9] Because heritability estimates vary across studies, there is evidence supporting an appreciable genetic contribution to host response to food, dietary habits, and food preferences.[10,11]

The inception of the term "Ayurnutrigenomics" ensued due to the integration of Ayurgenomics with the traditional concept of *Ahara* and *Pathya*. It is a systematic integration of nutritional practices according to Ayurveda in relation to the *Prakriti* of an individual, which amalgamates information from genomics, proteomics, and metabolomics projected to provide a solid evidence-based scientific foundation for the advancement of personalized nutrigenomic dietetics.[12] The use of metabolome-standardized foods or nutraceuticals with different biochemical components may leverage novel therapeutics where drugs are not effective on their own, or from a preventive aspect in a vulnerable population. It may prove to be very useful as personalized holistic food substances designed from traditional aspect inspire human health care and advance preventive applications. The following review details various salient features of Ayurveda-inspired approaches and cutting-edge nutrigenomic applications in an inclusive endeavor to explain the novel concept of Ayurnutrigenomics .

3. Ayurveda systems biology and disease etiopathogenesis

Ayurvedic principles are developed on the basis of innumerable clinical observations (time tested). The scientific rationality of these principles is based not merely on ancient texts, but also on the fact that they can demonstrate results that can be found in the Ayurvedic treatise *Astanga Hridaya* (AH.Ut.-40/81).[13] A primary reason for this demonstrable reproducibility is its development over a long period of what we call translational research today. An understanding of the systems biology of a disease or a disease complex at the genomic level gives us strategic advantage to identify targets and also related challenges to find out ways that may help us mitigate, treat, or manage the disease. The Ayurvedic internal medicine, known as *Kayachikitsa*, mainly consists of the etiopathogenesis, diagnosis, and treatment of diseases.[14] "Genome Wide Association Studies," where variations in its entirety for many diseased and healthy individuals, can be compared to identify regions in the genome that have sufficiently different frequency and can be associated with the disease.[15] We find that Ayurvedic drugs and diseases have been classified according to phenotypic classifications (symptomatic complex) correlated with the genomic concept of *Prakriti* (*Vata*, *Pitta*, and *Kapha*).[16] The diseases or phenotypes should be properly classified, and research should be initiated to discover the molecular pathways or network associated with these diseases. This will help us understand the pharmacology of the herbs that interfere with the disease complex that positively modulates the system (body and mind) against the disease.[17] This translation of disease and treatment philosophy in terms of recent findings of the "omics" level of research may discover novel targets or strategies to develop drugs and combinations of drugs, most importantly dietetic considerations, against diseases.

4. *Ahara*: traditional concept of personalized foods

Ayurveda describes *Ahara* as specific food/dietary schedules for different times of the day and for different seasons according to one's age and, most importantly, to suit one's individual constitution or *Prakriti*.[18–23] In *Taiteriyopanishad*, *Ahara* has been considered as *Brahma* (mythologically, the creator of universe) because every animate object is dependent on energy for survival, which comes from any form of food (Tait.Up.Bh.V.-2/1).[24] *Bhagwad Gita* acknowledged diet as a source for the creation of life (Bhag.G.-3/14). In addition to achieving success in Yoga, appropriate diet along with other activities and regimens of life are, in fact, addressed (Bhag.G.-6/17).[25] *Ahara* as a causative factor, in the context of the origin of *Purusha* (man) and his diseases, carries the historical value of dietetics, according to *Charaka Samhita* (C.Su.-25/31).[26] On the other hand, *Susruta Samhita* comprehensively narrated dietetics concerning the applicability and significance of diet in human life, establishing the historical importance of diet.[27]

It has been said that whatever material taken by mouth into the alimentary canal, which after proper digestion is transformed into the tissue elements and performs functions such as the promotion of growth, recovery due to loss, and protection from diseases for survival, is termed *Ahara*.[23] Charaka proclaims that *Ahara* maintains the balance of *Doshas* (biological humors) and *Dhatus* (body components) by promoting healthiness and disease avoidance (C.Su.-25/33).[26] *Ahara* restores vigor, provides strength, sustains the body, and increases lifetime, bliss, memory, *Ojas* (immunome), and digestive capability (S.Ci.-24/68).[27]

Dietary consideration in terms of wholesome and unwholesome food is an important component of Ayurvedic therapeutics, which eventually leads to happiness or misery. Sometimes, dietary management in itself is a complete treatment. Ayurvedic dietetics is concerned primarily with the energetics of food as a means of balancing the biological humors (*Dosha*). As opposed to the present-day approach, Ayurvedic nutrition not only deals with the detailed nutritional aspects of food, but also takes into account our food intake and manner of eating, the nature of the foodstuff, *Agnibala* (enzymatic activity of digestive metabolism), the process of cooking, blending, time of year, and surroundings and settings, etc.

5. Concept of Ayurgenomics

Ayurgenomics presents a personalized approach in the predictive, preventive, and curative aspects of stratified medicine with molecular variability, which intersects mind and body.[16,28] It embodies the study of interindividual variability due to genetic variability in humans[15] for assessing susceptibility, and establishing diagnosis and prognosis, mainly on the basis of the constitution type of a person's *Prakriti*.[29,30] Selection of a suitable dietary, therapeutic, and lifestyle regime is made on the basis of clinical assessment of the individual, keeping one's *Prakriti* in mind.[31,32] *Prakriti* is a corollary of the comparative proportion of three entities, i.e., *Tridoshas*, namely, *Vata*, *Pitta*, and *Kapha*. This is not only genetically determined (*Shukra Shonita*), but also influenced by environment (*Mahabhuta Vikara*), chiefly by maternal diet and lifestyle (*Matura Ahara Vihara*), and the age of the parents (*Kala Garbhashaya*). Ethnicity (*Jati*), familial characteristics (*Satmya*), as well as place of origin of an individual (*Desha*) are also considered to influence the development of *Prakriti* besides the aforementioned individual specific factors. Metabolic variability has been correlated with CYP2C19 genetic variability and Human Leukocyte Antigen (HLA) gene polymorphism to elucidate the concept of pharmacogenomics with the *Prakriti* types.[31,33] However, the knowledge regarding population-wide unevenness athwart Indian populations endows one with a major thrust to promote the quest for understanding the variability in healthy individuals. Transcriptional profiles of pooled RNA from *Vata*, *Pitta*, and *Kapha* revealed differences in core biological processes between the *Prakriti* groups that overlapped with the biochemical pathways and biochemical profiles, signifying the existence of genetic variations and their cellular manifestation, as mentioned in Ayurveda.[34]

6. Ayurnutrigenomics: nutrigenomics in Ayurveda

Ayurveda emphasizes *Prakriti* or body constitution in the consideration of food intake. Three extreme human phenotypes—*Vata*, *Pitta*, and *Kapha*—form seven types of *Prakriti* among human beings with contrasting phenotypic differences. This *Tridosha* theory has been deciphered as Ayurgenomics at the genomic expression level.[29] They have found contrasting differences with respect to the biochemical and hematological level at the genome-wide expression level. The Ayurvedic concept essentially integrates personalized food and drugs together with this *Prakriti* concept. Every individual should take a diet suitable to one's predominant constitutional *Doshas*, to balance them in different seasons (Table 1).

However, this warrants a need for epidemiological research on the nutrition concepts of Ayurveda. Research on *Prakriti* together with nutrition is going to emerge as a major field, which may be termed as Ayurnutrigenomics. As we develop toward the "omics" age of science, we find notable parallelism with the thoughts of our ancient scientific lineage, including Ayurveda. At that time, they also felt the necessity of correlating nutrition with differences in biological phenotypes, which is the expression of individual genome or variome. We find the concept of Ayurgenomics and then Ayurnutrigenomics back at the time of Ayurveda quite novel and contemporary even today. The National Institute of Health defines genomics as the study of all the genes of a person and their functions, including the interactions of those genes with each other and with a person's environment.[35] Nutrigenomics extends from the study of the genome-wide influence of nutrition to the ensuing time-dependent response in transcriptomics, proteomics, and metabolomics to express the phenotype of a biological system.[36,37] The influence of genetic variation on pharmacokinetics and nutrikinetics (i.e., absorption, metabolism, elimination, or biological effects of nutrients on human body) have also traditionally been incorporated in the concept of nutrigenomics, to optimize nutrition according to the one's genotype. The Ayurvedic concept of nutrition can be explained or translated in the same direction. However, molecular nutrition research is broader than nutrigenomics, because it includes the effect of nutrients and food/food components on whole-body physiology and health status at the systems biological level. Nutrigenomics also includes precise determination of molecular mechanisms essential to human health and disease, advocating an enormous prospective for promoting health, and lowering mortality and morbidity. Sophisticated molecular techniques based on the different omics (genomics, epigenomics, transcriptomics, proteomics, and metabolomics)[38,39] may help us in this regard to develop a better understanding toward Ayurvedic principles on nutrition and genomics. A nutritional epidemiology approach, where we study the role of nutrition in the causes and prevention of disease to guarantee precision of health recommendations, is currently needed to develop evidence-based quantification. Ayurveda is an evidence-based science, but it has not been updated in thousands of years when genetic evolution and environmental changes have occurred. Hence, research should be

Table 1
Food prescribed for people of different *Prakriti*.

	Dietary guidelines according to *Prakriti*					
	Vata		*Pitta*		*Kapha*	
	Use	Avoid	Use	Avoid	Use	Avoid
Rasas (taste)	Sweet Sour Salty	Bitter Pungent Astringent	Sweet Bitter Astringent	Sour Salty Pungent	Bitter Pungent Astringent	Sweet Sour Salty
Cereals (grains)	Rice, wheat, oats, ragi	Corn, maize, white bread	Rice, wheat, oats, barley	Corn, millet, ragi	Rice, corn, oats (dry), barley	White rice, wheat, flour, white bread
Pulses (legumes)	Green gram, split red gram, split black gram, soybean	Bengal gram, peas, red kidney beans, horse gram	Green gram, split red gram, split black gram, soybean	Red kidney beans/ horse gram	Green gram, split red gram, split black gram, peas, red kidney beans, horse gram	Soy products
Vegetables	Carrot, beetroot, sweet potato, green beans, radish, onion, sweet corn, capsicum	Cabbage, cauliflower, broccoli, turnip, green beans, leafy greens, lady's finger	Cabbage, cauliflower, broccoli turnip, green beans, leafy greens, lady's finger, peas, potato, cucumber, sweet potato	Brinjal, radish, onion/garlic, carrot, capsicum, spinach, mushroom	Cabbage family, leafy greens, bitter gourd, beans, brinjal, radish, onion, capsicum, spinach, lady's finger, lettuce, mushroom	
Fruits	Banana, berries, grapes, citrus fruits, mango, sweet melons, papaya, pineapple, peaches, plums	Dry fruits, raw apple, pear, sour melons, pomegranate	Apple, avocado, orange, mosambi, guava, mango, papaya, sweet pineapple, pomegranate, melons	Berries, banana, grapes, lemon, orange (sour), peaches, pineapple (sour), plums, mango, raisins	Apple, pear, berries, cherries, dry fig, prunes, peaches, guava	Banana, avocado, grapes, lemons, melons, orange, papaya (ripe)
Spices	Coriander (芫荽 yán suī), curry leaves, fenugreek (葫蘆巴 hú lú bā), turmeric (薑黃 jiāng huáng), mustard (芥菜 jiè cài), cumin (茴香 huí xiāng), carom seed (藏茴香 zàng huí xiāng), ginger (生薑 shēng jiāng), garlic (大蒜 dà suàn), mint (薄荷 bò hé), asafetida (阿魏 ē wèi), cinnamon (肉桂 ròu guì), cardamom (豆蔻 dòu kòu)		Coriander, cardamom, cinnamon, fennel (小茴香 xiǎo huí xiāng), turmeric, fresh ginger	Dry ginger, chilly (辣椒 là jiāo), mustard	Black pepper (黑胡椒 hēi hú jiāo), chilly, ginger, turmeric, cumin, carom seed, fennel, mint, coriander, cinnamon, asafetida	Salt

guided to follow Ayurvedic understanding and develop evidence to find its justification in the present time. Ayurvedic principles have also given the concept of adaptability termed *Satmya*. According to this concept, even if a food habit is harmful considering a person's genetic constitution, due to climatic (*Ritu Satmya*), geographical (*Desha Satmya*), disease (*Roga Satmya*), regular habit (*Oka Satmya*), and sociocultural (*Jati Satmya*) factors, his or her nutriome may become adjusted to that food habit. Here, nutriome is referred to as the entire food habit of a person interacting with his/her genome or physiome. A simple example is a carbohydrate-rich rice diet consumed by Indians; yet they are prone to diabetes. Different clinical principles have been mentioned in Ayurveda to advise a human being about preventive and personalized treatment, such as *Prakriti* (individual constitution), *Dosha-Dushya* (disease state and localization), and *Satmya* (habituation factor), to determine food, medicine, or lifestyle. Thus, we find that Ayurnutrigenomics presents a huge scope of development toward the understanding of nutrigenomics and molecular nutrition research. The fundamental recommendations can be very useful in framing health recommendations and personalized food design. In the subsequent sections, we have described several recommendations and directions toward a rational approach in modern Ayurnutrigenomic research.

7. Ayurnutrigenomics-inspired foods and nutraceuticals

Ayurnutrigenomics is a commune where food and drugs intersect to project their effects according to the genetic constitution (*Prakriti*) of a person at the systems biology level. It is evident that the above-reviewed techniques can be of immense importance in the way forward for Ayurnutrigenomic research. From nutriepidemiology to food quality-control efforts, metabolomics will surely find inclusive applications in standard research methodology for obvious reasons. Traditionally inspired approaches will augment distinctive research and development efforts toward safe and personalized foods. The outcomes will favor not only better health and food habit recommendations, but also smart Ayurnutrigenomic-inspired foods. Prevention and development of Ayurceuticals to augment the healing processes is a crucial area of nutrition research to cure already fully developed diseases.[40] Correlating Ayurvedic terminologies, we find that genetic (*Prakriti*) and environmental factors (*Mahabhuta Vikara*) together with diet (*Ahara*) and lifestyle (*Dinacharya*), particularly overnutrition (*Satmya*) and sedentary behavior (*Eksthanasna*), are interrelated in promoting the progression and pathogenesis (*Nidana*) of these polygenic diet-related diseases.[41] Novel advanced methods for mass measurements of genes, transcripts, proteins, and metabolites are united with advanced imaging, epidemiology, clinical interventions with diverse threats, and ultimately bioinformatics, to amalgamate all information in systems biology.[35] The above sections have explained the Ayurvedic principles of diet correlating to various factors such as genomics (*Prakriti*) and other environmental factors. Research utilizing these advanced methods can only augment a better understanding of Ayurnutrigenomics. Although powerful analytical platforms are accessible to analyze genes, proteins, and metabolites, their inclusive and combined use to appreciate the interferences of nutritional factors on metabolism is quite limited.[1,42–44] Studies utilizing these analytical platforms (i.e., genomics, proteomics, and metabolomics) offer precise information about a given phenotype, and their integration provides the best possible resources to unfold the effects of a biological dispute on an organism at the integrated metabolism level.[45,46] Undoubtedly, it is crucial that these methods are incorporated in standard routine investigations, however, we face various challenges due to a lack of standardized statistical methods and public databases because their practice is still rare.[47–52]

Nutrigenomics maps the influence of dietary molecules on the genome, to correlate consequential phenotypical divergence in the cellular response such as metabolic pathways and homeostatis of the biological systems, which may be further controlled by genetic interactions also.[7,36] Traditionally, plants that are used as both food and a source of medicine embody great public and medical significance worldwide because the foundation of nutraceutical development in personalized food design is utilized in novel lead compounds for drug development.[53] Metabolomics is a promising and rapidly evolving science and technology system of broad experimental analysis of metabolite profiles, either as a targeted subset of related chemicals or, more globally, for diverse applications in diagnosis, toxicology, disease development and animal disease models, genetic modification of specific organisms, drug discovery and development, and phytomedicines.[54–56] Metabolomics is also a crucial module of the systems biology approach. In nutrigenomics, it can be used for the measurement of metabolite profiles, behavior, and responses toward the body milieu, disease, and counteractive changes of a given tissue or biological fluid due to food or medication.[57,58] Metabolite analysis or metabolite profiling is performed using a meticulous set of systematic technique(s) such as gas chromatography–mass spectrometry and liquid chromatography–mass spectrometry, together with an estimate of quantity. Analytical techniques from thin-layer chromatography to high-end technologies such as Fourier transform infrared spectroscopy, Raman spectroscopy, and nuclear magnetic resonance are also included in the metabolite analysis arsenal. Gas chromatography–mass spectrometry has been considerably used in metabolite profiling of human body fluids or plant extracts[59–61] and also for efficient quality control.[62] The Human Metabolome Database is presently the largest and most inclusive database offering spectral, physicochemical, clinical, biochemical, genomic, and metabolism information for a library of >2500 known human metabolites.[63] The diversity of plant metabolites evolved through unremitting interaction with intimidating environments, together with distinctive species and agronomic differences, and these metabolites generally present a definite phenotypic expression correlated to their biochemical structures.[64] A spectrum of pharmacological or nutraceutical efficacy experienced traditionally arises only as a synergistic action of multiple ingredients in a single plant or from a multiple-component herbal supplement recently reported in traditional Chinese medicine.[65] The connection of metabolomics to this effort can provide the required associations between the complex chemical mixtures used in traditional Chinese medicine and molecular pharmacology.[66] Herbal metabolite signatures in gene and/or protein expression profiles can also be of eminent significance in nutraceutical standardization, such as their use in "biological fingerprinting" of medicinal plant extracts (i.e., bioactivity spectra of phyto-extracts or phyto-compounds vs. their medicinal efficacy in test animal or human systems).[67,68] Metabolomic approaches using gas chromatography–mass spectrometry, liquid chromatography–mass spectrometry, or 2D nuclear magnetic resonance are effective tools for quality control of clinically active food products that are used in medicinal plants or herbs and medicinal products.[69,70] Moreover, current metabolomic research can be used for the comparison of small-metabolite signatures to discern health and disease states.[69] Focused or targeted metabolomic platforms, for example, lipid profiling or lipidomics, may be applied in the corrective nutraceuticals and therapeutic personalized food development process in lipid-related metabolic disorders and inflammatory diseased states, as used in modern drug development.[71,72] The use of genetically modified mouse models, together with liquid chromatography–mass spectrometry-based metabolomics, can be a useful tool for mechanistic studies of genotype-dependent food or drug metabolism.[73]

8. Conclusion

This Ayurveda-inspired concept of personalized nutrition is a novel concept in the realm of nutrigenomic research for developing personalized functional foods and nutraceuticals suitable to one's genetic makeup. The concept is that food and drugs intersect, considering their effects according to the genetic constitution (*Prakriti*) of a person at the systems biology level. It is evident that the reviewed techniques can be of immense importance in the way forward for Ayurnutrigenomic research. Technological platforms based on the different omics (genomics, epigenomics, transcriptomics, proteomics, and metabolomics) may help in this regard to develop a better understanding toward Ayurvedic principles on nutrition and Ayurgenomics. This review introduces and presents this novel concept of Ayurnutrigenomics as an emerging area of research, which may unfold future possibilities toward smart yet safe therapeutics.

Conflicts of interest

The authors do not have any conflicts of interest regarding competing financial and/or personal relationships.

References

1. Mutch DM, Wahli W, Williamson G. Nutrigenomics and nutrigenetics: the emerging faces of nutrition. *FASEB J*. 2005;19:1602–1616. http://dx.doi.org/10.1096/fj.05-3911rev.
2. Ghosh D, Skinner MA, Laing WA. Pharmacogenomics and nutrigenomics: synergies and differences. *Eur J Clin Nutr*. 2007;61:567–574. http://dx.doi.org/10.1038/sj.ejcn.1602590.
3. Mukherjee PK, Nema NK, Venkatesh P, Debnath PK. Changing scenario for promotion and development of Ayurveda—way forward. *J Ethnopharmacol*. 2012;143:424–434. http://dx.doi.org/10.1016/j.jep.2012.07.036.
4. Debnath PK, Mitra A, Hazra J, Pandit S, Biswas TK, Jana U, et al. Evidence based medicine – A clinical experience on Ayurveda Medicine in Recent Advances in Herbal Drug Research and Therapy. In: Roy A, Gulati K, editors. New Delhi: I K International Publishing House Pvt. Ltd; 2010. p. 49–73.
5. Datta GK, Debnath PK. Ancient use of spices. In: De AK, ed. *Recent Trends in Spices and Medicinal Plants Research*. New Delhi: Associate Publishing Co; 2000: 27–30.
6. Carpenter KJ. A short history of nutritional science: part 1 (1785–1885). *J Nutr*. 2003;133:638–645 [Internet]. Available from http://jn.nutrition.org/content/133/3/638.long August 2014.
7. Ordovas JM. Genetic interactions with diet influence the risk of cardiovascular disease. *Am J Clin Nutr*. 2006;83(2 Suppl):443S–446S [Internet]. Available from http://ajcn.nutrition.org/content/83/2/443S.long August 2014.
8. Godard B, Ozdemir V. Nutrigenomics and personalized diet: from molecule to intervention and nutri-ethics. *OMICS*. 2008;12:227–228.
9. Ozdemir V, Motulsky AG, Kolker E, Godard B. Genome–environment interactions and prospective technology assessment: evolution from pharmacogenomics to nutrigenomics and ecogenomics. *OMICS*. 2009;13:1–6.
10. Breen FM, Plomin R, Wardle J. Heritability of food preferences in young children. *Physiol Behav*. 2006;88:443–447.
11. Teucher B, Skinner J, Skidmore P. Dietary patterns and heritability of food choice in a UK female twin cohort. *Twin Res Hum Genet*. 2007;10:734–748.
12. Debnath P, Banerjee S, Debnath PK. Ayurnutrigenomics: traditional knowledge inspired approach towards personalized nutrition. In: Ghosh D, Bagchi D, Konishi T, eds. *Clinical Aspects of Functional Foods and Neutraceuticals*. Florida: CRC Press; 2014:423–444.
13. Valiathan MS. *Towards Ayurvedic Biology: A Decadal Vision Document—2006*. Bangalore: Indian Academy of Sciences; 2006.
14. Roy A, Debnath PK, eds. *Rogavinischaya. Bengali version*. Kolkata: Jamini Bhushan Roy State Ayurvedic Medical College & Hospital; 1998.
15. Frazer KA, Murray SS, Schork NJ, Topol EJ. Human genetic variation and its contribution to complex traits. *Nat Rev Genet*. 2009;10:241–251.
16. Sethi TP, Prasher B, Mukerji M. Ayurgenomics: a new way of threading molecular variability for stratified medicine. *ACS Chem Biol*. 2011;6:875–880 [Internet]. Available from http://www.ncbi.nlm.nih.gov/pubmed/21923095 August 2014.
17. Debnath PK, Datta GK, Jana U, Pandit S, Sur T, Mitra A, et al. Ayurvediya ManoDaihikaVikara (Psychosomatic Diseases) on Modern Concept Strategies. In: *Proceedings of the National Academy of Ayurveda, New Delhi, India*. New Delhi: Government of India; 2006:110–117; **2006.**
18. Datar VK, ed. *The Charaka Samhita by Agnivesha with Ayurveda Dipika Commentary of Chakrapani Datta*. Bombay: Nirnaya-Sagar Press; 1922.
19. Debnath PK. *Ayurveda—The Ancient Science of Indian Medicine. Presented at the Faculty of Medicine*. Varese: Varese University; 1993.
20. Debnath PK. Ayurveda: La Scienza Della Vita L'antica risposta per man mantenere in salute l'uomo. *Boll Osp Varese*. 1993;22:838–843 [In Italian].
21. Debnath PK. *Ayurveda the Science of Life—The Ancient Answer for the Maintenance of Mental Health*. Pavia: Presented at the Pavia University; 1995.
22. Debnath PK. *Emerging Global change of Occidental outlook in Ayurveda for improvement in Quality of life: Prospects and Perspectives. Presented at the 89th Session of The Indian Science Congress Association (Medical & Veterinary)*. 2002. Lucknow.
23. Shastri RD, ed. *Swasthavritta Samucchaya*. 11th ed. Varanasi: Kamlavasa; 1985. Assi.
24. Nathani N. An appraisal of the concept of diet and dietetics in Ayurveda. *Asian J Modern Ayurvedic Med Sci*. 2013;2:1–9 [Internet]. Available from http://www.ajmams.com/viewpaper.aspx?pcode=ef5cc006-6583-4806-b293-7d170f36d956 August 2014.
25. Prabhupada ACBS, ed. *Bhagavad-gita as it is*. 2nd ed. Mumbai: The Bhaktivedanta Book Trust; 2010.
26. Sharma RK, Dash B, eds. *Agnivesa's CharakaSamhita. Text with English Translation & Critical Exposition Based on Cakrapani Datta's Ayurveda Dipika*. 2nd ed. Varanasi: Chowkhamba Sanaskrit Series Office; 2001.
27. Shastri A, ed. *Sushruta: Sushruta Samhita with Ayurveda Tattva Sandipika Hindi Commentary*. 14th ed. Varanasi: Chaukhambha Sanskrit Sansthan; 2003.
28. Patwardhan B, Bodeker G. Ayurvedic genomics: establishing a genetic basis for mind-body typologies. *J Altern Complement Med*. 2008;14:571–576. http://dx.doi.org/10.1089/acm.2007.0515.
29. Prasher B, Negi S, Aggarwal S, et al. Whole genome expression and biochemical correlates of extreme constitutional types defined in Ayurveda. *J Transl Med*. 2008;6:48. http://dx.doi.org/10.1186/1479-5876-6-48.
30. Mukherjee M, Prasher B. Ayurgenomics: a new approach in personalized and preventive medicine. *Sci Culture*. 2011;77:10–17 [Internet]. Available from http://www.scienceandculture-isna.org/jan2011/02%20Mitali%20Mukerji.pdf August 2014.
31. Patwardhan B, Joshi K, Arvind C. Classification of human population based on HLA gene polymorphism and the concept of Prakriti in Ayurveda. *J Altern Complement Med*. 2005;11:349–353.
32. Patwardhan B, Mashelkar RA. Traditional medicine-inspired approaches to drug discovery: can Ayurveda show the way forward? *Drug Discov Today*. 2009;14:804–811. http://dx.doi.org/10.1016/j.drudis.2009.05.009.
33. Ghodke Y, Joshi K, Patwardhan B. Traditional medicine to modern pharmacogenomics: Ayurveda Prakriti type and *CYP2C19* gene polymorphism associated with the metabolic variability. *Evid Based Complement Alternat Med*. 2011;2011:249528. http://dx.doi.org/10.1093/ecam/nep206.
34. Indian Genome Variation Consortium. Genetic landscape of the people of India: a canvas for disease gene exploration. *J Genet*. 2008;87:3–20 [Internet]. Available from http://www.ias.ac.in/jgenet/Vol87No1/3.pdf August 2014.
35. Norheim F, Gjelstad IM, Hjorth M, et al. Molecular nutrition research: the modern way of performing nutritional science. *Nutrients*. 2012;4:1898–1944. http://dx.doi.org/10.3390/nu4121898.
36. Muller M, Kersten S. Nutrigenomics: goals and strategies. *Nat Rev Genet*. 2003;4:315–322.
37. Afman L, Muller M. Nutrigenomics: from molecular nutrition to prevention of disease. *J Am Diet Assoc*. 2006;106:569–576. http://dx.doi.org/10.1016/j.jada.2006.01.001.
38. Margetts B, Nelson M. *Design Concepts in Nutritional Epidemiology*. New York: Oxford University Press; 1997.
39. Sempos CT, Liu K, Ernst ND. Food and nutrient exposures: what to consider when evaluating epidemiologic evidence. *Am J Clin Nutr*. 1999;69(6 Suppl): 1330S–1338S.
40. van Ommen B, Bouwman J, Dragsted LO, et al. Challenges of molecular nutrition research: the nutritional phenotype database to store, share and evaluate nutritional systems biology studies. *Genes Nutr*. 2010;5:189–203. http://dx.doi.org/10.1007/s12263-010-0167-9.
41. Phillips CM. Nutrigenetics and metabolic disease: current status and implications for personalised nutrition. *Nutrients*. 2013;5:32–57. http://dx.doi.org/10.3390/nu5010032.
42. van der Meer-van Kraaij C, Kramer E, Jonker-Termont D, Katan MB, van der Meer R, Keijer J. Differential gene expression in rat colon by dietary heme and calcium. *Carcinogenesis*. 2005;26:73–79. http://dx.doi.org/10.1093/carcin/bgh288.
43. Griffin JL, Bonney SA, Mann C, et al. An integrated reverse functional genomic and metabolic approach to understanding orotic acid-induced fatty liver. *Physiol Genomics*. 2004;17:140–149.
44. Hirai MY, Yano M, Goodenowe DB, et al. Integration of transcriptomics and metabolomics for understanding of global responses to nutritional stresses in Arabidopsis thaliana. *Proc Natl Acad Sci U S A*. 2004;101:10205–10210 [Internet]. Available from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC454188/ August 2014.
45. Zeisel SH, Allen LH, Coburn SP, et al. Nutrition: a reservoir for integrative science. *J Nutr*. 2001;131:1319–1321 [Internet]. Available from http://jn.nutrition.org/content/131/4/1319.long August 2014.
46. Nicholson JK, Holmes E, Lindon JC, Wilson ID. The challenges of modeling mammalian biocomplexity. *Nat Biotechnol*. 2004;22:1268–1274. http://dx.doi.org/10.1038/nbt1015.

47. Cahill DJ, Nordhoff E. Protein arrays and their role in proteomics. *Adv Biochem Eng Biotechnol*. 2003;83:177–187.
48. Corthals GL, Wasinger VC, Hochstrasser DF, Sanchez JC. The dynamic range of protein expression: a challenge for proteomic research. *Electrophoresis*. 2000;21:1104–1115.
49. Arab L. Individualized nutritional recommendations: do we have the measurements needed to assess risk and make dietary recommendations? *Proc Nutr Soc*. 2004;63:167–172. http://dx.doi.org/10.1079/pns2003325.
50. Mendes P. Emerging bioinformatics for the metabolome. *Brief Bioinform*. 2002;3:134–145. http://dx.doi.org/10.1093/bib/3.2.134.
51. Rabilloud T. Two-dimensional gel electrophoresis in proteomics: old, old fashioned, but it still climbs up the mountains. *Proteomics*. 2002;2:3–10.
52. Rose K, Bougueleret L, Baussant T, et al. Industrial-scale proteomics: from liters of plasma to chemically synthesized proteins. *Proteomics*. 2004;4:2125–2150.
53. Shyur LF, Yang NS. Metabolomics for phytomedicine research and drug development. *Curr Opin Chem Biol*. 2008;12:66–71. http://dx.doi.org/10.1016/j.cbpa.2008.01.032.
54. Lindon JC, Holmes E, Nicholson JK. Metabolomics in pharmaceutical R&D. *FEBS J*. 2007;274:1140–1151. http://dx.doi.org/10.1111/j.1742-4658.2007.05673.x.
55. Ulrich-Merzenich G, Zeitler H, Jobst D, Panek D, Vetter H, Wagner H. Application of the "-Omic-" technologies in phytomedicine. *Phytomedicine*. 2007;14:70–82. http://dx.doi.org/10.1016/j.phymed.2006.11.011.
56. Kell DB. Systems biology, metabolic modelling and metabolomics in drug discovery and development. *Drug Discov Today*. 2006;11:1085–1092. http://dx.doi.org/10.1016/j.drudis.2006.10.004.
57. Sumner LW, Mendes P, Dixon RA. Plant metabolomics: large-scale phytochemistry in the functional genomics era. *Phytochemistry*. 2003;62:817–836. http://dx.doi.org/10.1016/S0031-9422(02)00708-2.
58. Dunn WB, Ellis DI. Metabolomics: current analytical platforms and methodologies. *Trends Analyt Chem*. 2005;24:285–294. http://dx.doi.org/10.1016/j.trac.2004.11.021.
59. Horning EC, Horning MG. Metabolic profiles: gas-phase methods for analysis of metabolites. *Clin Chem*. 1971;17:802–809 [Internet]. Available from http://www.clinchem.org/content/17/8/802.long August 2014.
60. Sandberg DH, Sjoevall J, Sjoevall K, Turner DA. Measurement of human serum and bile acids by gas–liquid chromatography. *J Lipid Res*. 1965;6:182–192 [Internet]. Available from http://www.jlr.org/content/6/2/182.long August 2014.
61. Sauter H, Lauer M, Fritsch H. Metabolic profiling of plant: a new diagnostic technique. In: Baker DR, Moberg WK, Fenyes JG, eds. *Synthesis and Chemistry of Agrochemicals*. 2nd ed. Washington, DC: American Chemical Society Press; 1991:288–299.
62. Zeng ZD, Liang YZ, Chau FT, Chen S, Daniel MK, Chan CO. Mass spectral profiling: an effective tool for quality control of herbal medicines. *Anal Chim Acta*. 2007;604:89–98. http://dx.doi.org/10.1016/j.aca.2007.09.057.
63. Wishart DS, Tzur D, Knox C, et al. HMDB: the human metabolome database. *Nucleic Acids Res*. 2007;35(Database issue):D521–D526. http://dx.doi.org/10.1093/nar/gkl923.
64. Schauer N, Fernie AR. Plant metabolomics: towards biological function and mechanism. *Trends Plant Sci*. 2006;11:508–516. http://dx.doi.org/10.1016/j.tplants.2006.08.007.
65. Williamson EM. Synergy and other interactions in phytomedicines. *Phytomedicine*. 2001;8:401–409. http://dx.doi.org/10.1078/0944-7113-00060.
66. Wang M, Lamers RJ, Korthout HA, et al. Metabolomics in the context of systems biology: bridging traditional Chinese medicine and molecular pharmacology. *Phytother Res*. 2005;19:173–182. http://dx.doi.org/10.1002/ptr.1624.
67. Wang CY, Chiao MT, Yen PJ, et al. Modulatory effects of *Echinacea purpurea* extracts on human dendritic cells: a cell and gene-based study. *Genomics*. 2006;88:801–808. http://dx.doi.org/10.1016/j.ygeno.2006.08.011.
68. Yang NS, Shyur LF, Chen CH, Wang SY, Tzeng CM. Medicinal herb extract and a single-compound drug confer similar complex pharmacogenomic activities in mcf-7 cells. *J Biomed Sci*. 2004;11:418–422.
69. Yang SY, Kim HK, Lefeber AW, et al. Application of two-dimensional nuclear magnetic resonance spectroscopy to quality control of Ginseng commercial products. *Planta Med*. 2006;72:364–369. http://dx.doi.org/10.1055/s-2005-916240.
70. Ye M, Liu SH, Jiang Z, Lee Y, Tilton R, Cheng YC. Liquid chromatography/mass spectrometry analysis of PHY906, a Chinese medicine formulation for cancer therapy. *Rapid Commun Mass Spectrom*. 2007;21:3593–3607. http://dx.doi.org/10.1002/rcm.2832.
71. Morris M, Watkins SM. Focused metabolomic profiling in the drug development process: advance from lipid profiling. *Curr Opin Chem Biol*. 2005;9:407–412.
72. van Meer G, Leeflang BR, Liebisch G, Schmitz G, Goñi FM. The European lipidomics initiative: enabling technologies. *Methods Enzymol*. 2007;432:213–232. http://dx.doi.org/10.1016/S0076-6879(07)32009-0.
73. Chen C, Gonzalez FJ, Idle JR. LC–MS-based metabolomics in drug metabolism. *Drug Metab Rev*. 2007;39:581–597. http://dx.doi.org/10.1080/03602530701497804.