# Transforming Tradition to Technology through Integration of Indian Knowledge System Food Wisdom and Artificial Intelligence

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***Abstract***

*This chapter explores the convergence of Indian Knowledge Systems (IKS) and Artificial Intelligence (AI) in the food and nutrition sector, with a particular emphasis on natural pigments such as betalains. IKS traditions, especially Ayurveda, have long recognized food as medicine, linking attributes such as color, taste, and seasonal adaptation to health and vitality. Pigmented foods are traditionally associated with blood purification, resilience, and holistic wellness. Modern science validates these insights, identifying betalains as potent antioxidants with anti-inflammatory and detoxifying properties, while also noting challenges of stability and bioavailability. AI offers powerful tools to extend and contextualize this wisdom. Applications include digitization of classical texts, computational modeling of pigment stability, machine learning for food processing optimization, and personalized nutrition systems that integrate prakriti profiling with modern health data. Agricultural AI further supports sustainable cultivation of crops by combining traditional seasonal practices with predictive climate models. By weaving empirical validation with the ethical and philosophical depth of IKS, this chapter argues for a pluralist and collaborative approach. The synthesis of tradition and technology can yield food systems that are nutritionally robust, culturally authentic, and ecologically sustainable, positioning natural pigments as a model for responsible innovation.*

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## Introduction

Food is not merely sustenance but also culture, medicine, and knowledge. Indian Knowledge Systems (IKS) have long recognized food as a central pillar of health and well-being, embedding dietary practices within philosophical, ecological, and medical frameworks. Ayurveda, for instance, treats food (*ahara*) as medicine, emphasizing balance, personalization, and context. Traditional practices highlight the importance of color, taste, and seasonal adaptation in diet, linking food to vitality and resilience (Timane & Wandhe, 2024).

In parallel, Artificial Intelligence (AI) has emerged as a transformative force in food science and nutrition. AI enables large-scale data analysis, predictive modeling, and personalized dietary recommendations. It can digitize ancient texts, simulate biochemical interactions, and optimize agricultural practices. When combined with IKS, AI offers a pathway to technologies that are meaningful, ethically grounded, and scientifically robust (Mahendran et al., 2024).

This chapter explores the convergence of IKS and AI in the food and nutrition sector, focusing on natural pigments, especially betalains which are found in beetroot, amaranth, and other plants. These are bioactive compounds with antioxidant, anti-inflammatory, and detoxifying properties. They serve as natural colorants and nutraceuticals, embodying the intersection of tradition and modern science. By correlating IKS insights with AI applications, we can unlock new possibilities for sustainable diets, personalized nutrition, and culturally authentic food systems.

## Perspectives of Indian Knowledge System on natural plant pigments

### Food as medicine

Ayurveda emphasizes that food is the first line of defense against disease. The concept of *rasa* (taste) and *guna* (qualities) links sensory attributes to physiological effects. The six rasas (sweet, sour, salty, bitter, pungent, and astringent) are believed to influence the body's doshas (Vata, Pitta, and Kapha), thereby guiding dietary choices

for maintaining harmony. Complementing this, the gunas such as heaviness, lightness, warmth, and coolness further refine how foods interact with the body systems. Pigmented foods are often associated with vitality, blood purification, and balance. Rather than treating food merely as nourishment, Ayurveda views it as a powerful agent of balance, capable of shaping both physical and mental well-being. Thus, Ayurveda's claim that "food is medicine" anticipates contemporary ideas of functional foods and personalized nutrition, demonstrating how ancient wisdom continues to inform and enrich modern approaches to health (Ibrahim et al., 2025).

**Symbolism of color**

Colors in food carry symbolic and therapeutic meaning. Red and violet foods, such as beetroot and amaranth, are linked to energy, circulation, and detoxification. Yellow and orange pigments, like turmeric and saffron, are associated with immunity and warmth. Brightly colored fruits and vegetables are seen as carriers of *prana* (life force), with red and purple pigments linked to circulation and rejuvenation, and yellow or orange pigments tied to digestive fire, immunity, and clarity of mind. These traditional insights resonate with modern nutritional science, which recognizes that natural pigments such as betalains, carotenoids, and flavonoids possess antioxidant, anti-inflammatory, and detoxifying properties. Thus, the symbolism of color in food bridges cultural wisdom and scientific insight, underscoring how the vibrancy of natural pigments reflects their capacity to nourish, protect, and harmonize human health (Mahajan & Meena, 2025).

**Seasonal and traditional wisdom**

IKS emphasizes seasonal diets and local adaptation. Pigmented foods are consumed at specific times to align with ecological cycles. For example, beetroot is often recommended in winter for its warming and blood-enriching properties. Similarly, other seasonal pigments such as the golden hues of turmeric or saffron are favored in cooler periods for their immune-boosting and protective properties. This approach acknowledges that the body's needs shift with the seasons, and that locally available foods are naturally suited to meet those changing requirements. This seasonal wisdom resonates with modern nutritional science, which highlights the importance of

fresh, local produce and bioactive compounds in supporting immunity, detoxification, and overall well-being (Bhatt & Tripathi, 2020).

**Natural plant pigments: betalains**

In the Indian Knowledge System, betalain pigments are valued not only for their vibrant hues but also for their holistic role in health and well-being. Traditional texts highlight their cooling, detoxifying, and rejuvenating properties, linking them to the balance of *pitta* and *rakta dhatu* (blood tissue) in Ayurveda. These pigments are recognized for their antioxidant and anti-inflammatory potential, symbolizing the deep integration of food, medicine, and color in Indian wisdom, where natural dyes and plant-based nutrition are seen as vital for sustaining harmony between body and environment (Gupta, 2025; Bhalekar et al., 2022).

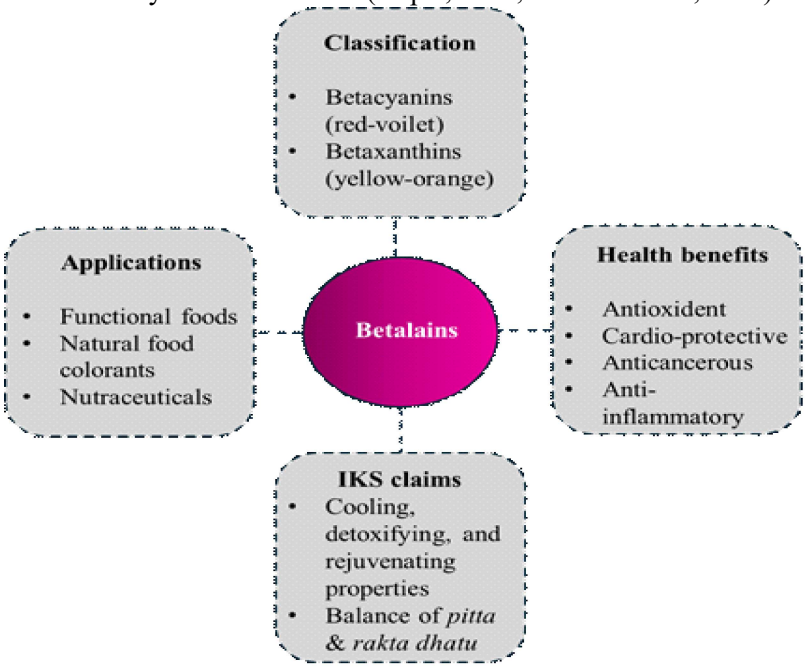


**Figure 1: Comprehensive overview of natural plant pigment betalains**

Scientifically, betalains are water-soluble nitrogen-containing pigments divided into two groups i.e. Betacyanins: Red-violet pigments, and Betaxanthins: Yellow-orange pigments. According to Martinez et al., (2024) they are sensitive to pH, temperature, and light.

They degrade during cooking or storage, posing challenges for food processing. Scientific studies also highlight their antioxidant, anti-inflammatory, and detoxifying properties. They may reduce oxidative stress, support cardiovascular health, and offer anti-cancer potential. They have wide nutritional applications in functional foods, nutraceuticals, pharmaceuticals, and as eco-friendly alternatives to synthetic food and cosmetic colorants as depicted in Figure. 1 above.

**AI applications in pigment research and food innovation**

- Digitization of traditional knowledge: AI-driven digitization projects can create searchable hub of Ayurvedic texts and ethnobotanical manuscripts. Natural Language Processing (NLP) can extract references to pigmented foods and their therapeutic uses, linking them to modern nutritional databases (World Health Organization, 2025).
- Computational chemistry and predictive modeling: Machine learning can predict pigment stability under different conditions, simulate bioavailability, and model molecular interactions. This helps design foods and supplements that retain pigment activity (Singh et al., 2025).
- Food processing optimization: AI can optimize cooking, drying, and storage methods to minimize pigment loss. For example, predictive models can suggest ideal temperatures and pH levels for preserving natural plant pigments in different foods (Jayan et al., 2025).
- Personalized nutrition: AI can integrate Ayurvedic *prak[ti* profiling with betalain-rich dietary recommendations. Wearable sensors and health apps can track physiology, lifestyle, and environment, tailoring diets that align with both traditional wisdom and modern science (Agrawal et al., 2025).
- Agricultural AI: Smart farming systems can combine seasonal wisdom with climate models to optimize cultivation of betalain-rich crops. AI can predict soil conditions, water needs, and pest risks, supporting resilient agriculture (World Economic Forum & BCG X, 2025).

**Case Studies**

Insights from Indian Knowledge Systems (IKS) with modern AI applications, showing how traditional wisdom about pigmented

foods like betalains can be validated and enhanced through technology as presented in Table 1 below. Each case study highlights a specific convergence point- Ayurvedic perspectives, cultivation practices, fermentation methods, and food safety.

**Table1: Examples on convergence of IKS and AI in food sector**

| Case Study | IKS Perspective | Contribution of AI | Source |
|---|---|---|---|
| Beetroot in Ayurveda and AI nutrigenomics | Ayurveda describes beetroot as blood-purifying, energizing, and supportive of vitality. | AI-driven nutrigenomics links beetroot consumption to biomarkers of cardiovascular health, validating traditional claims. | Rajput et al., 2024 |
| Amaranth cultivation | Traditional crop rotation emphasizes amaranth's resilience and ecological adaptability. | AI-based soil and climate analytics optimize cultivation, enhancing betalain yield while respecting ecological wisdom. | Mukuwapasi et al., 2024 |
| Fermentation practices | Traditional fermentation enhances pigment stability and probiotic value. | AI simulations of microbial interactions validate and optimize fermentation, ensuring stable betalain content in functional foods. | Yee at al., 2025 |
| Food safety and authenticity | IKS emphasizes purity and integrity in diet, discouraging adulteration. | AI detects adulteration in pigment-rich foods using spectroscopy and deep learning, ensuring authenticity and consumer protection. | Magdas et al., 2025 |

The convergence of Indian Knowledge Systems (IKS) and artificial intelligence (AI) in the domain of food and nutrition demonstrates significant potential for advancing both scholarship and application. The case studies presented illustrate how tradition and technology can reinforce one another. These examples highlight the importance of empirical validation, ecological sustainability, and cultural authenticity as guiding principles in the design of future food systems. Ultimately, the integration of IKS and AI calls for humility in engaging diverse epistemologies, care in preserving authenticity, and commitment to creating food systems that are resilient, inclusive, and sustainable.

**Ethical, Cultural, and Contextual Considerations**

The integration of Indian Knowledge Systems (IKS) with artificial intelligence in the food and nutrition sector brings with it important ethical, cultural, and contextual considerations that must

be carefully addressed. One central issue is **authenticity and ownership**. As traditional pigment knowledge is digitized and commercialized, it raises questions about who holds the rights to this wisdom and how benefits are shared. Communities that have preserved and practiced this knowledge for generations must be acknowledged as custodians, and mechanisms should be established to ensure they receive recognition and tangible benefits from its wider use. Equally important is the need for **empirical validation**. While IKS provides valuable insights into the therapeutic and nutritional roles of natural pigments, rigorous scientific testing is essential to substantiate these claims. AI can play a pivotal role here by supporting large-scale data analysis, predictive modeling, and experimental design, thereby ensuring that health claims are credible, safe, and aligned with modern standards of evidence (Sain & Behera, 2025).

At the same time, caution must be exercised to **avoid overclaiming**. AI-driven tools, with their capacity to generate persuasive narratives, must not exaggerate the benefits of compounds such as betalains. Responsible synthesis requires humility, transparency, and a commitment to presenting balanced information that respects both traditional wisdom and scientific rigor. There is also the challenge of **balancing global and local contexts**. While global AI models can identify broad nutritional trends and applications, they must be adapted to local dietary practices, cultural traditions, and ecological realities. Betalain-rich foods, for example, should be promoted in ways that honor indigenous culinary heritage and biodiversity rather than imposing homogenized global standards. By addressing these ethical, cultural, and contextual dimensions, the convergence of IKS and AI can foster innovation that is not only scientifically robust but also socially just and culturally respectful (Abrahams & Raimundo, 2025).

**Future Directions**

The future of integrating Indian Knowledge Systems (IKS) with artificial intelligence in the food and nutrition sector lies in creating open-access databases that combine traditional food wisdom with modern pigment science, thereby democratizing knowledge and making it widely available for research and application. At the same

time, AI can contribute to sustainability by designing eco-friendly methods for extracting natural pigments reducing dependence on synthetic colorants and supporting environmentally conscious innovation. Progress in this field also requires collaborative research, where food scientists, AI experts, and IKS scholars work together to bridge cultural insights with technological advances, ensuring that both empirical rigor and traditional authenticity are preserved. Equally important are pedagogical innovations, as AI-driven interactive platforms can be used to teach pigment science in engaging ways while safeguarding and transmitting the pedagogical traditions of IKS into digital form, thus ensuring continuity, accessibility, and relevance for future generations.

**Conclusion**

IKS and AI are not opposing forces but complementary streams of knowledge that, when synthesized with respect and rigor, can generate technologies that are both locally meaningful and globally relevant. This convergence ensures that innovations remain ethically grounded and scientifically robust, while honoring cultural traditions. A powerful example of this integration is Betalain pigments deeply rooted in traditional diets and rituals, now validated by modern biochemical research, and further enhanced through AI-driven modeling and applications. By weaving empirical validation with the ethical wisdom of IKS, food systems can be designed to be nutritionally rich, culturally authentic, and ecologically sustainable. The path forward must remain collaborative and pluralist, requiring dialogue across disciplines, humility in integrating diverse epistemologies, and care in preserving authenticity while enabling new applications that benefit both communities and science.

**Glossary**

1. Agricultural AI: Computational tools that use data on soil, climate, and crops to optimize farming practices, aligning with traditional seasonal wisdom.
2. Ahara: Sanskrit term in Ayurveda meaning “diet” or “food”.
3. Artificial Intelligence (AI): Computational systems that simulate human intelligence through learning, reasoning, and decision-making.

4. Ayurveda: Ancient Indian medical system emphasizing holistic health through balance of diet, lifestyle, and environment.
5. Betalains: Natural water-soluble pigments found in plants like beetroot and amaranth, divided into betacyanins (red-violet) and betaxanthins (yellow-orange).
6. Digitization: Conversion of manuscripts, texts, and traditional knowledge into digital formats.
7. Doca: Fundamental energies in Ayurveda (*vâta, pitta, kapha*) that govern physiological and psychological processes.
8. Explainable AI: AI systems designed to make their reasoning transparent, resonating with Nyâya's emphasis on justification and inference.
9. Functional Foods: Foods that provide health benefits beyond basic nutrition, often enriched with bioactive compounds like betalains.
10. Guna: Qualities in Ayurveda (e.g., heavy/light, hot/cold) that influence the effects of food on the body.
11. Natural Language Processing (NLP): AI subfield enabling computers to understand and process human language and useful for interpreting Sanskrit and Indian texts.
12. Nyâya: Classical Indian school of logic emphasizing structured reasoning, inference, and validation of knowledge.
13. Personalized Nutrition: Dietary recommendations tailored to individual physiology, lifestyle, and environment.
14. Prak[ti: An individual's constitution in Ayurveda, determining dietary and lifestyle recommendations.
15. Rasa: Taste linked to physiological and therapeutic effects in Ayurveda (sweet, sour, salty, bitter, pungent, astringent).
16. Sustainability: Designing food systems that balance ecological resilience, cultural authenticity, and long-term health.
17. Symbolic AI: Rule-based computational systems that mirror structured reasoning traditions like Paninian grammar and Nyâya logic.

**Suggested Readings**


1. Abrahams, M., & Raimundo, M. (2025). Perspective on the ethics of AI at the intersection of nutrition and behaviour change. *Frontiers, 6,* 1- 15. https://doi.org/10.3389/fragi.2025.1423759
2. Agrawal, K., Goktas, P., Kumar, N., & Leung, M. F. (2025). Artificial intelligence in personalized nutrition and food manufacturing: A comprehensive review of methods, applications, and future directions. *Frontiers in Nutrition, 12*, 1- 16. https://doi.org/10.3389/fnut.2025.1636980
3. ANI. (2025, July 12). India first country to launch a Traditional Knowledge Digital Library: WHO. The Economic Times. India first country to launch a Traditional Knowledge Digital Library: WHO
4. Bhalekar, O.S., Waghmare, S.A., Kamble, H.V., & Dhamal, K.S. (2022). Natural colourants and dyes from plants origin. *International Journal of Scientific Research and Engineering Development, 5*(3), 537- 549.
5. Bhatt, G.Y., & Tripathi, J.S. (2020). A critical review on Ayurvedic principles of Diet & Nutrition with special reference to prevention & management of lifestyle diseases. [Unpublished]. IMS, BHU, Varanasi-221005
6. Gupta, V. (2025). Integrating Indian Knowledge System into Plant Science Education: Bridging Traditional and Modern Perspectives. *Journal of Emerging Technologies and Innovative Research (JETIR), 12*(2), 551- 556.
7. Gupta, V. (2025). Integrating indigenous knowledge systems into biological sciences: A transformative approach. *International Journal of Advance Research in Multidisciplinary, 3*(2), 72-74. DOI: https://doi.org/10.5281/zenodo.15272196
8. Ibrahim, A.Y., Sankaran, R., Markandan, K., Peter, A.P, Menon, P., & Adhikari B. (2025). Betalains as Natural Pigments: Structure, Function, and Advances in Extraction, Encapsulation, and Application. *Food and Bioprocess*

*Technology, 18,* 9142–9169. https://doi.org/10.1007/s11947-025-04028-9

9. Jayan, H., Min, W., & Guo, Z. (2025). Applications of Artificial Intelligence in Food Industry. *Foods, 14*(7), 1- 6. https://doi.org/10.3390/foods14071241
10. Magdas, D. A., Hategan, A. R., David, M., & Berghian-Grosan, C. (2025). The Journey of Artificial Intelligence in Food Authentication: From Label Attribute to Fraud Detection. *Foods*, *14*(10), 2- 31. https://doi.org/10.3390/foods14101808
11. Mahajan, S., & Meena, R.R. (2025). Integrating Artificial Intelligence in Ayurveda: Pioneering Personalized Health and Innovation. *International Journal of Health Sciences and Research, 15*(3), 60- 64. DOI: https://doi.org/10.52403/ijhsr.20250311
12. Mahendran, M., Karthika, B., Verma, M. K., & Krishnaja, U. (2024). AI innovations in nutrition: A critical analysis. *Biological Forum – An International Journal, 16*(9), 124-132.
13. Martinez, R.M., de Paula Barros de Melo, C., Pinto, I.C., Mendes-Pierotti, S. & Vignoli, J.A., Verri, W.A., & Casagrande, R. (2024). Betalains: A Narrative Review on Pharmacological Mechanisms Supporting the Nutraceutical Potential Towards Health Benefits. *Foods, 13,* 1- 27. https://doi.org/10.3390/foods13233909.
14. Mukuwapasi, B., Mavengahama, S., & Gerrano, A.S. (2024). Grain amaranth: A versatile untapped climate-smart crop for enhancing food and nutritional security. *Discover Agriculture, 2,* 1- 17. https://doi.org/10.1007/s44279-024-00057-8
15. Rajput, I., Sharma, N., Sharma, K., Mehra, R., Thakur, S., Kumar, S., Sharma, P., Parmar, R., Chaudhary, Y., Thakur, S., Singh, B., Thakur, R., Parmar, R.S., & Thakur, Y.S. (2024). Beetroot as a Therapeutic Aid in Cardiovascular Health: An in- Depth Analysis. *International Journal of Innovative Science and Research Technology (IJISRT), 9* (10), 2782-2787. https://doi.org/10.38124/ijisrt/IJISRT24OCT1833

16. Sain, S.K., & Behera, P.K. (2025). The Role of Artificial Intelligence in Preserving and Promoting Indian Knowledge Systems. *Shodh Samagam, 8*(2), 660- 665.
17. Singh, D.P., Singh, S., Raheja, T., Agarwal, N., Bairwa, P., Kaur, S., & Krishania, M. (2025). Production of microbial pigments: mathematical modelling and applications in functional foods. *International Journal of Advances in Engineering Sciences and Applied Mathematics, 17,* 311- 323. https://doi.org/10.1007/s12572-025-00402-0
18. Timane, R., & Wandhe, P. (2024) Indian Knowledge System. *Journal of Emerging Technologies and Innovative Research (JETIR), 11*(2), 512-529.
19. World Economic Forum, and BCG X. (2015, February). *Future Farming in India: A playbook for scaling artificial intelligence in agriculture* [Insight report]. Ministry of Electronics and Information Technology, Government of India. WEF_Future_Farming_in_India_2025.pdf
20. Yee, C. S., Zahia-Azizan, N. A., Abd Rahim, M. H., Mohd Zaini, N. A., Raja-Razali, R. B., Ushidee-Radzi, M. A., Ilham, Z., & Wan-Mohtar, W. A. A. Q. I. (2025). Smart Fermentation Technologies: Microbial Process Control in Traditional Fermented Foods. *Fermentation*, *11*(6), 1- 38. https://doi.org/10.3390/fermentation11060323