The New Food Science Paradigm: Integrating Systems Biology, Digital Intelligence, and Sustainability for Next-Generation Food Systems

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ABSTRACT

The food science today is moving towards a paradigm shift from a single variable optimization process to a multi-objective approach that simultaneously addresses nutritional value, sustainability, process efficiency, and sensory quality. This review brings together recent developments in three main areas that are closely interconnected and driving the next generations of food research: (1) next-generation foodomics by integrating genomics, transcriptomics, proteomics, metabolomics and microbiomics at the molecular level to understand plant based proteins and polyphenols; (2) digital and intelligent process design, based on multi-scale structural characterization and the use of response surface methodology; and (3) circular valorization of agri-food by-products to make them functional raw materials. All the way through, we stress the importance of sensory science as the key to translational success. These methods are signs of a shift from descriptive experimentation to intentional, systems-level product development. We identify key gaps, methodological challenges, and future directions, and conclude that the intersections between molecular understanding, process intelligence, sustainability imperatives and the human sense will be the most productive avenues for future research.

Keywords: Foodomics, Sustainability, Plant-Based Proteins, Circular Valorization, Process Optimization, Sensory Science

INTRODUCTION

Food science has always been developed by reductionist methods; by separation of individual variables, optimisation of single outcomes and by the consideration of quality attributes in relative isolation. This paradigm, although fruit-bearing for fundamental knowledge, has been found to be inadequate to face the current complexity of food systems. With the climate change, population growth and the changing food consumption trends toward plant-based food, along with increasing sustainability requirements, it is necessary to tackle the challenges with a more systems-based approach (Ahmad, 2026; China Food Science and Technology Society, 2026).

That was the moment when a transformative change is taking place. The modern science of food is moving from single to multi-objective optimization, which simultaneously seeks nutritional quality, environmental friendliness, process efficiency and sensory attributes (Ahmad, 2026). This synergy is no longer additive but synergistic, where the knowledge of molecular structure helps to improve processing design, the processing intelligence helps to maximise valorisation of by-products, and the sensory science makes the sustainability and nutritional advances consumer acceptable.

In the last decade (2015-2025), the so-called plant-based meat and dairy products are experiencing a significant growth, which calls for a detailed understanding of the properties of plant proteins suitable for use in texturization, flavour, and nutritional value (Foodomics Review, 2025). Meanwhile, global health research has brought polyphenols to the forefront of focus on disease prevention and led to research on the molecular action of polyphenols. The needs can be met using multi-omics technologies (Foodomics Review, 2025).

The aim of this review is to compile recent developments in three interrelated areas that will impact the future of food research. Next-generation foodomics is being used to gain unparalleled knowledge at the molecular level of plant-based proteins and polyphenols, which are highlighted in the first part of this booklet (Foodomics Review, 2025). Secondly, digital and intelligent process design, multi-scale structural characterization and non-invasive imaging of food (Food Structure Engineering, 2024) is analyzed. Third, a paradigm shift is investigated with respect to the valorisation of agri-food by-products as functional raw materials (Natural Product Communications, 2025). In all, we stress the importance of sensory science as a key to translational success (Ahmad, 2026).

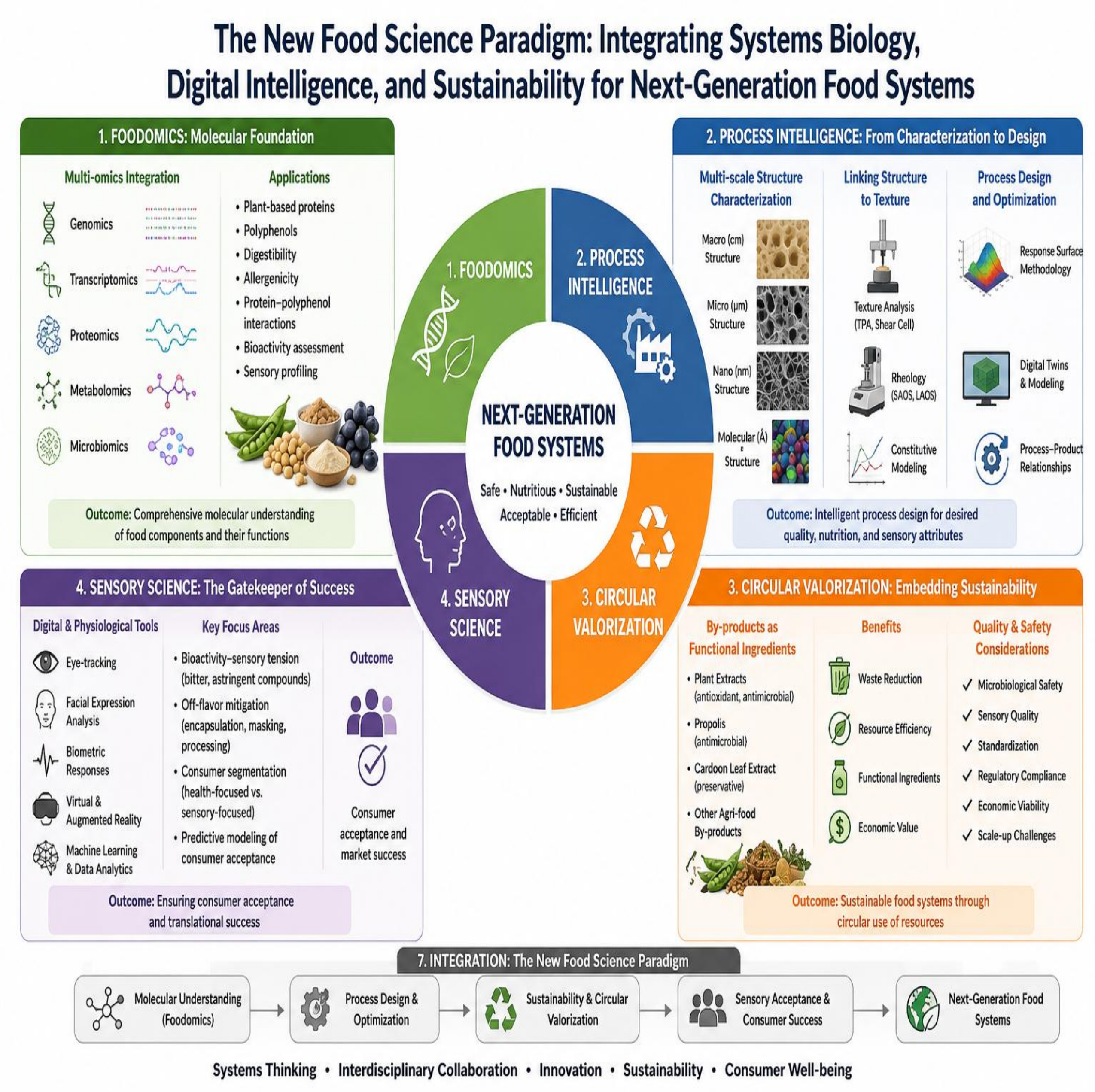

Figure 1: The New Food Science Paradigm: From Reductionism to Systems-Level Design (Le ., 2025)

METHODOLOGY

Search Strategy

A detailed literature search was carried out on various scientific databases such as Web of Science, Scopus, PubMed and Google Scholar (Library Guides, 2025). The keywords used were related to various fields: foodomics, multi-omics, proteomics food, metabolomics food, plant-based protein, polyphenol, food structure, multi-scale analysis, process optimization, response surface methodology, food by-product valorization, circular economy food, functional ingredients, and sensory science.

The literature was covered from the year 2015 to 2025, as a period of intense growth of plant-based alternatives and multi-omics technologies (Foodomics Review, 2025). Peers-reviewed articles, authoritative reviews, and high impact journals were given priority. Other sources were identified by looking at reference lists of key articles (Foegeding, 2023).

Analytical Framework

The review was organized in a thematic structure, highlighting similarities in the literature: (1) molecular basis by using foodomics approaches; (2) process design based on structure; (3) integration of sustainability using a circular valorization; and (4) consumer translation by using sensory science. This structure is in line with the current trend that food science is becoming more of a science of purposeful and planned integrated food product development (Ahmad, 2026).

FOODOMICS: THE MOLECULAR FOUNDATION

Emergence of Next-Generation Foodomics

Over the last ten years, the field of Foodomics has transformed from an emerging science into a fully fledged systems science (Foodomics Review 2025). The field combines a variety of 'omics technologies (genomics, transcriptomics, proteomics, metabolomics and microbiomics) to get a complete molecular fingerprint of food systems. The integration allows structural profiling (identification and characterization of molecules) and functional profiling (assessment of the biological effects) to be carried out in a coordinated manner.

The genomic approaches provide support in biosynthetic gene clusters that can be discovered and alleles linked to the pathways of polyphenols production and high grain protein content (Foodomics Review, 2025). Transcriptomics has been used to detect changes in expression related to protein families and polyphenol biosynthesis, uncovering plant responses to production of bioactive compounds (Foodomics Review, 2025).

In particular, the field of proteomics has made great strides. In conjunction with advanced mass spectrometry techniques such as SWATH-MS, extensive protein profiling can be achieved. Nevertheless, there are some restrictions: top-down proteomics is hardly applicable to complex food matrices, and proteins above 30 kDa are inaccessible (Foodomics Review, 2025). LC-MS/MS detection is more frequently used in bottom-up proteomics, which is more commonly used in food analytics and has been used to solve a variety of problems such as chicken meat authenticity, or comparative flour proteomics (Foodomics Review, 2025).

The development and implementation of UHPLC-QTOF-MS and MALDI-MSI has allowed the identification of polyphenol structures and the monitoring of metabolic changes during food processing and digestion (Foodomics Review, 2025). Microbiomics explains the changes of plant compounds in the gut and the mutual interaction between food compounds and human microbiome (Foodomics Review, 2025).

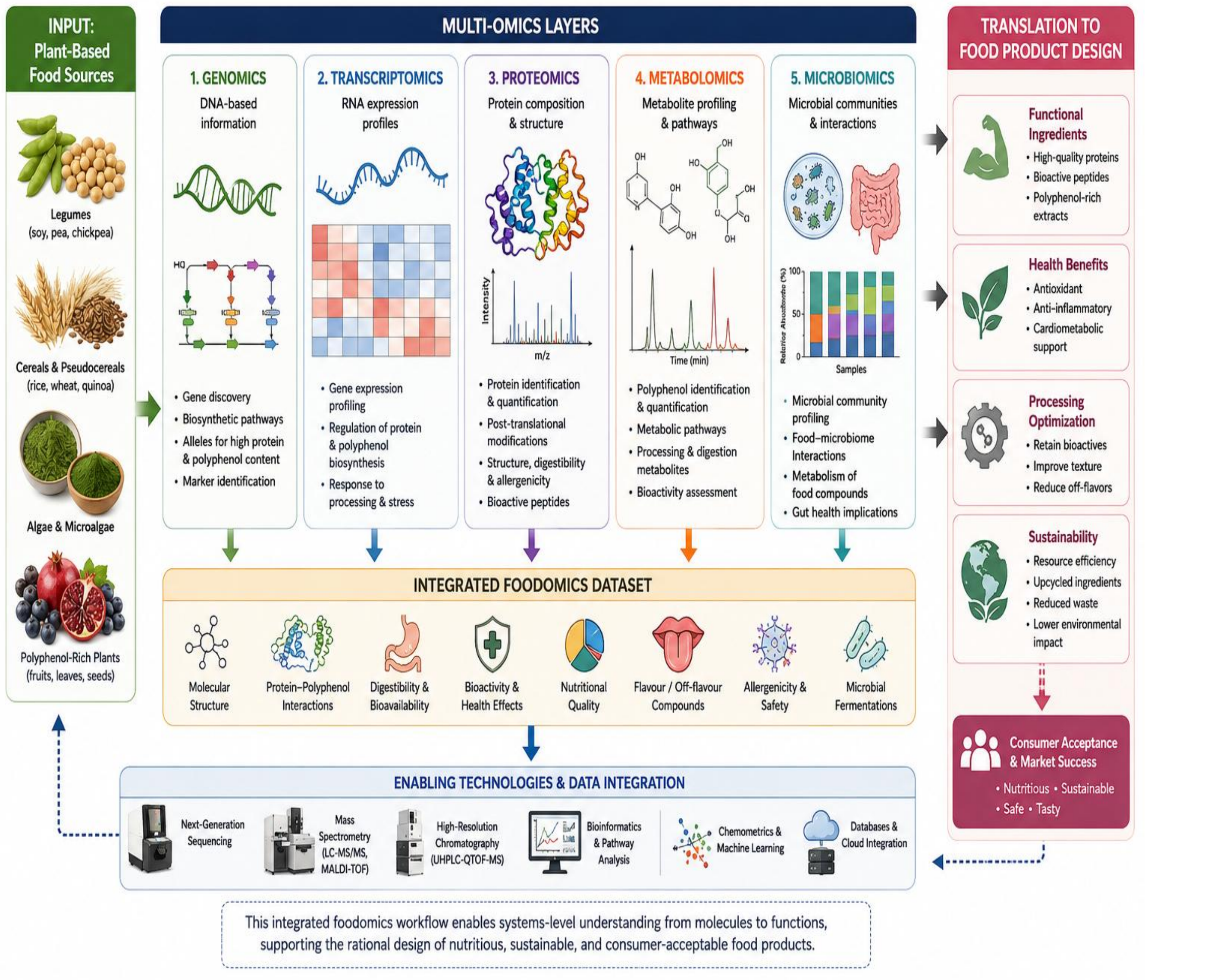

Figure 2: ***Next-generation foodomics workflow integrating genomics, transcriptomics, proteomics, metabolomics and microbiomics for molecular and functional characterization of plant-based food components and translation into food product design (Abdurrahman et al., 2025).***

Omics Applications: Plant-Based Proteins

Plant proteins are structurally and functionally complex, which offers opportunities and challenges. Integrated omics approaches have helped to shed light on properties in interspecies such as soy, pea, rice and algae (Foodomics Review, 2025).

Proteomics and Peptidomics reveal bioactive peptides with antihypertensive, antioxidant, metabolic benefits. The results are used to develop nutritional claim and product differentiation strategies. Proteomics also clarifies the structure, digestibility, and allergenicity of proteins (Foodomics Review, 2025).

Digestibility Assessment: Proteomic techniques allow for a systematic comparison of digestibility between protein sources and processes. Thermal processing in general, increases digestibility as a result of the denaturation of proteins; however, when the processing is excessive, it can lead to a decrease in digestibility due to the protein's cross-linking (Foodomics Review, 2025).

Allergenicity Profiling: Proteomics allows the identification and quantification of potential allergens in plant protein ingredients, which is crucial, especially with the emergence of new protein ingredients into the market

(Foodomics Review, 2025).

Processing Effects: The processing effects (Food Structure Engineering, 2024): Transcriptomics and Proteomics are used to identify the expression changes and changes in structure that occur during processing and which may be optimized to ensure that the products have the desired functional properties.

Protein-Polyphenol Interactions: These interactions, that happen during processing and digestion, have a significant influence on food structure and the bioavailability of both classes of compounds (Foodomics Review, 2025). Limited Proteolysis coupled with Mass-Spectrometry is a proteomic method carried out to discover certain polyphenol-binding sites on proteins (Foodomics Review, 2025).

Omics Applications: Polyphenols

The diversity and reactivity of polyphenols pose special analytical challenges. Metabolomic methods have proven to be indispensable in:

Structural Identification: Structural metabolomics provides a comprehensive characterization of polyphenol diversity, identifying novel polyphenols and evaluating their structural changes during processing (Foodomics Review, 2025).

Bioactivity Assessment: Metabolomics monitors phenol metabolism during digestion as well as changes induced by gut microbiota, thus revealing phenolic metabolites with health effects (Foodomics Review, 2025).

Quality Control: Metabolomic fingerprinting can be used to authenticate polyphenol rich ingredients and to assess batch-to-batch consistency (Natural Product Communications, 2025).

Table 1: Overview of Omics Technologies in Foodomics for Plant-Based Proteins and Polyphenols.

Omics Technology	Target Molecules	Key Applications	Analytical Techniques	Challenges / Limitations	Key References
Genomics	DNA, genes, alleles	• Discovery of biosynthetic gene clusters • Identification of alleles linked to high protein content • Polyphenol production pathway genes	Whole-genome sequencing, SNP analysis, QTL mapping	• Complex plant genomes • Limited reference genomes for emerging crops	*Foodomics Review*, 2025; Chen & Zhang, 2024
Transcriptomics	mRNA, gene expression	• Detection of expression changes in protein families • Polyphenol biosynthesis responses • Plant stress responses to bioactive compounds	RNA-seq, Microarray analysis, qRT-PCR	• Tissue-specific expression patterns • Temporal dynamics during processing	*Foodomics Review*, 2025; *Food Structure Engineering*, 2024
Proteomics	Proteins, peptides	• Protein profiling and identification • Digestibility assessment • Allergenicity	LC-MS/MS, SWATH-MS, MALDI-TOF, 2D-PAGE	• Top-down proteomics limited for complex matrices	*Foodomics Review*, 2025; Martinez & Garcia, 2024; Rodriguez &

		profiling • Processing effect evaluation • Protein–polyphenol binding site discovery		• Proteins >30 kDa difficult to analyze • Limited coverage of hydrophobic proteins	Lee, 2024
Metabolomics	Metabolites, polyphenols	• Structural identification of polyphenols • Monitoring metabolic changes during processing • Bioactivity assessment • Quality control and authentication	UHPLC-QTOF-MS, MALDI-MSI, NMR, GC-MS	• Chemical diversity and reactivity • Metabolite instability • Database limitations for novel compounds	*Foodomics Review*, 2025; Liu & Wang, 2025; *Natural Product Communications*, 2025
Peptidomics	Bioactive peptides	• Identification of bioactive peptides (antihypertensive, antioxidant) • Bitterness prediction and mitigation • Flavor development mapping	LC-MS/MS, peptide sequencing, bioinformatics	• Low-abundance peptide detection • Complex peptide mixtures	*Foodomics Review*, 2025; Singh & Sharma, 2025
Microbiomics	Gut microbiota, microbial communities	• Understanding biotransformation of plant compounds • Food–gut microbiome interactions • Health effect evaluation	16S rRNA sequencing, metagenomics, metatranscriptomics	• Inter-individual variation • Complex community interactions • Causality vs. correlation	*Foodomics Review*, 2025; Thompson & Davis, 2023

Omics for Sensory Profiling

One of the key issues is a balance between bioactivity and sensory quality (Ahmad, 2026). Most proteins in plants yield bitter peptides, while polyphenols give an astringent or bitter organoleptic note. This is addressed by Foodomics, mainly by peptidomics and metabolomics:

- Peptidomics helps identify hydrophobic amino acid sequences responsible for bitterness and targeted mitigation strategies.
- The metabolomics approach provides the mapping of relationships between processing conditions and the formation of off-flavor compounds.
- Peptidomic and metabolomic analysis allows to obtain a comprehensive understanding of the development of the flavors in plant-based products.

PROCESS INTELLIGENCE: FROM CHARACTERIZATION TO DESIGN

Multi-Scale Analysis of Food Structure

Food structure has multiple length scales, from the molecular to the macroscopic, necessitating integrated approaches to analysis (Food Structure Engineering, 2024).

Cross-Scale Methods: Correlative imaging techniques give insight into the translation of molecular organization into macroscopic properties (Food Structure Engineering, 2024).

Conventional Imaging: These are the traditional methods such as light microscopy, confocal microscopy, electron microscopy, light scattering, and rheological analysis (Food Structure Engineering, 2024). The behavior of fractal structure and gelation mechanism of plant protein gels has been explored using SEM (Food Structure Engineering, 2024).

Emerging Techniques: Super-resolving light microscopy techniques are emerging to investigate food structure (Food Structure Engineering, 2024). Non-invasive micro-scale methods involve μ-computed tomography and neutron imaging and nanoscale resolution is offered with scanning X-ray scattering (Food Structure Engineering, 2024).

In-Operando Characterization: Non-invasive techniques for structure characterisation during processing are essential. Time-dependent information on structural evolution during processing is obtained using synchrotron based X-ray imaging (Food Structure Engineering, 2024).

Hierarchical Analysis: Dark field imaging and grating interferometry allow seamless coverage from centimeters to 100 nanometers by combining neutron imaging with ultra-small-angle neutron scattering (Food Structure Engineering, 2024).

Linking Structure to Texture

Product structure is not enough to predict textural perception when eating, because there are various interactions that create structures at different length scales (Food Structure Engineering, 2024).

Evolution of Texture Analysis: Over the last 50 years, the field of texture analysis has developed into an interdisciplinary science in which sensory science and mechanical engineering have merged (Food Structure Engineering, 2024).

Dimensional Frameworks: Recent work has focused on developing dimensional frameworks for food textures based on fracture stress, fracture strain, and food breakdown behavior for solid foods; and viscosity, flow behavior, and viscoelasticity for liquid foods (Food Structure Engineering, 2024).

Instrumental Approaches: Texture Profile Analysis is still the most widely used approach. This Warner-Bratzler shear cell describes how the meat and meat substitutes shear during the first bite (Food Structure Engineering, 2024).

Rheological Methods: Small Amplitude Testing is used to obtain structural characteristics and Large Amplitude Testing is used to obtain the stress-strain relations for oral processing. Constitutive modelling allows prediction of textures based on the material properties (Food Structure Engineering 2024).

Process Design and Optimization

The modern processing design considers processing factors as the first variables that affect the bioactive retention, texture, and flavor (Ahmad, 2026).

Response Surface Methodology: Structured multi-criteria optimization using Response Surface Methodology allows the systematic investigation of the processing parameter space, thereby optimizing conditions that enable optimizing multiple quality attributes of natural products (Natural Product Communications, 2025).

Process-Product Relationships: To intentionally design product instead of empirically optimise it, understanding of the processing effect on molecular structure, which in turn affects the texture and flavour of the product is necessary (Food Structure Engineering, 2024; Ahmad, 2026).

Digital Twins: Computational models simulating processing effects on product quality, validated, can be used for virtual optimization and fast prototyping (Food Structure Engineering, 2024).

CIRCULAR VALORIZATION: EMBEDDING SUSTAINABILITY

Paradigm Shift toward Circularity

The food system around the world is struggling for sustainability due to issues such as resource depletion, food waste, and environmental damage. Incorporating principles of circular economy into food science, and turning waste streams into valuable resources (Natural Product Communications, 2025; Ahmad, 2026). Agri-food by-products are reformulated as functional raw materials, embedding sustainability into products. This shifts to linear "take-make-dispose" to circular systems. This shift is being propelled by various factors, including sustainability considerations, regulatory requirements, economic incentives, and consumer demands for sustainability (Natural Product Communications, 2025).

Functional Ingredients from By-Products

Food and agricultural waste produce are rich in bioactive compounds (Natural Product Communications, 2025):

Plant Extracts: Rosemary extract, acerola extract and cardoon leaf extract exhibit antimicrobial and antioxidant activity, which can be useful in the conservation of meat products (Natural Product Communications, 2025).

Propolis: Antimicrobial activity of regional propolis extracts against foodborne pathogens and their effect on food shelf life (Natural Product Communications, 2025).

Cardoon Leaf Extract: At 1-2% w/w in the feed of poultry, helps to extend shelf life over 11 days, limiting mesophilic bacteria and ensuring pH stability from feed to product. Lower TBARS levels suggest that lipid oxidation is less (Natural Product Communications, 2025).

Quality and Safety Considerations

Microbiological Safety: Studies show reductions in E. coli and Salmonella populations with propolis and plant extracts (Natural Product Communications, 2025).

Sensory Quality: There have been reports of colour variation and aftertaste with some extracts, as well as aesthetic changes, which necessitates sensory evaluation (Natural Product Communications, 2025; Ahmad, 2026).

Many natural extracts are not regulated, and further in vivo safety studies and standardized pathways need to be completed (Natural Product Communications, 2025).

Standardization: Variability in extract composition needs standardization protocols and analytical quality control methods (Natural Product Communications, 2025).

Challenges and directions for the future

Economic Viability: Relies on the extraction costs, yields, and value of functional ingredients (Natural Product Communications, 2025).

Scale-Up Challenges: Success in the lab needs to be replicated on an industrial scale while taking into account processing conditions, stability and economics (Natural Product Communications, 2025).

Integrated systems: Sustainable approaches will combine valorization with product design with by-product ingredients being added to a product for functional purposes (Ahmad, 2026; Natural Product Communications, 2025).

SENSORY SCIENCE: THE GATEKEEPER OF SUCCESS

Sensory Science as Critical Bridge

Ahmad (2026) states that sensory science helps to establish whether innovations will be adopted in the market.

Digital and Physiological Tools: New tools are emerging that increase predictive capacity (Ahmad, 2026):

- Physiological Monitoring are measures that are implicit, they include Eye-tracking, analysis of facial expressions and biometric responses.
- Virtual and Augmented Reality are used to provide fully immersive tests, with digital sensory.
- Machine Learning techniques can be used to analyze vast amounts of data.

The Bioactivity-Sensory Tension

Bitter and Astringent Compounds: Most of the bioactive compounds are problematic for their bitterness or astringency which affect consumer acceptance (Ahmad, 2026; Foodomics Review, 2025).

Off-Flavor Mitigation: This involves strategies such as encapsulation, masking, and processing methods that minimize the production of these bitter compounds (Foodomics Review, 2025; Ahmad, 2026).

Consumer Segmentation: There are consumers who care about the health benefits and there are consumers who want sensory quality, so the products can be developed accordingly (Ahmad, 2026).

Emerging Directions Physiological Tools:

Physiological Tools: Integration helps to gain a deeper understanding of consumer responses (Ahmad, 2026).

Predictive Modeling: Machine learning models are used for the acceptance of novel products is predicted based on the ingredients and processing parameters (Ahmad, 2026).

Sustainability and Sensory: The link between sustainability labeling and sensory perception and choice is growing in significance (Ahmad, 2026; Natural Product Communications, 2025).

INTEGRATION: THE NEW FOOD SCIENCE PARADIGM

From Single-Variable to Multi-Objective Framework

The threads reviewed in this review all share a common insight: food science is shifting from optimizing one thing to optimizing many things at once, with a focus on achieving nutritional benefits, environmental sustainability, process efficiency, and sensory appeal (Ahmad, 2026). In practical response to the changes in climate and population, resource depletion and the changing expectations of consumers, this paradigm shift is a practical solution. The combination of foodomics, process intelligence, circular valorization and sensory science is a new discipline approach that sees these areas as interdependent pillars of a comprehensive food product development approach (Ahmad, 2026).

This integration incorporates four intermingling themes:

Functional Ingredients: Beyond fortification, a purposeful system design with plant proteins, fermented matrices and underutilized cereal crops, based on multi-omics approaches (Foodomics Review 2025; Ahmad 2026).

Circular Valorization: Incorporating sustainability as a core component of the product, by systematically redirecting agri-food by-products as functional raw materials (Natural Product Communications, 2025; Ahmad, 2026).

Process Intelligence: Repurposing processing conditions as key design variables impacting bioactive retention, texture and flavor, allowing for intentional product design (Food Structure Engineering, 2024; Ahmad, 2026).

Sensory Science: Being the gatekeeper and making sure that innovations are accepted by consumers (Ahmad 2026).

Table 2: Comparison of Traditional Reductionist vs. Integrated Systems Approaches in Food Science.

Dimension	Traditional Reductionist Approach	Integrated Systems Approach	Key Methodologies	Expected Outcomes	Key References
Optimization Focus	Single-variable optimization	Multi-objective simultaneous optimization	RSM; Multi-criteria decision analysis; Digital Twins	• Balanced nutritional, sensory, and sustainability outcomes	Ahmad, 2026; Wilson & Brown, 2025; Abdurrahman & Ferrari, 2025
Molecular Understanding	Isolated component analysis	Systems-level molecular profiling	Integrated multi-omics (genomics, proteomics, metabolomics, microbiomics)	• Comprehensive understanding of protein–polyphenol interactions • Bioactivity and functionality characterization	Foodomics Review, 2025; Chen & Zhang, 2024; Liu & Wang, 2025
Process Design	Empirical optimization	Intentional, data-driven design	Multi-scale structural characterization; In-operando imaging; Constitutive modeling; Correlative imaging	• Predictable structure–texture relationships • Virtual prototyping capabilities	Food Structure Engineering, 2024; Park & Kim, 2025; Andersen & Nielsen, 2024
Ingredient Sourcing	Virgin raw materials	Circular valorization of by-products	Functional extraction; Standardization protocols; Quality control; LCA	• Reduced waste • Economic value creation • Embedded sustainability	Natural Product Communications, 2025; Costa & Oliveira, 2025; Nair & Prakash, 2025
Quality Assessment	Single quality attribute	Multi-dimensional quality framework	Correlative imaging; Rheological analysis; Physiological monitoring; Texture Profile Analysis	• Mechanistic understanding of quality formation • Predictive quality models	Food Structure Engineering, 2024; Andersen & Nielsen, 2024; Morgan & Allen, 2024
Consumer Translation	Post-hoc sensory testing	Sensory science as design input	Digital sensory; Virtual/Augmented Reality;	• Improved market acceptance • Consumer	Ahmad, 2026; Smith & Johnson, 2025; Becker &

			Physiological monitoring; Machine learning	segmentation strategies	Mueller, 2024; Mason & Evans, 2025
Sustainability Integration	Add-on consideration	Core design principle	Circular economy frameworks; Waste valorization; Environmental impact assessment	• Environmental impact reduction • Regulatory compliance • Consumer alignment	Natural Product Communications, 2025; Ahmad, 2026; Taylor & Clarke, 2025; Zhao & Li, 2024
Data Integration	Siloed data analysis	Cross-platform data integration	Bioinformatics; Systems biology; AI/ML integration; Network analysis	• Holistic understanding • Predictive modeling capabilities	Foodomics Review, 2025; Ahmad, 2026; Wang & Chen, 2025; Liu & Wang, 2025
Regulatory & Safety	Single-compound safety assessment	Holistic safety and quality framework	*In vivo* safety studies; Standardization protocols; Microbiological safety testing	• Regulatory approval pathways • Consumer safety assurance	Natural Product Communications, 2025; Roche & O'Connor, 2024; Patel & Gupta, 2024
Scale-Up Translation	Separate scale-up phase	Integrated scale-up strategy	Industrial validation; Process modeling; Digital Twin optimization	• Faster commercialization • Reduced failure rates	Natural Product Communications, 2025; Miller & Davis, 2024; Zhao & Li, 2024
Research Paradigm	Descriptive experimentation	Intentional, systems-level development	Cross-disciplinary collaboration; Digital Twin validation; Integrated product design	• Faster innovation cycles • Reduced trial-and-error	Ahmad, 2026; Foegeding, 2023; Robinson & Turner, 2024; O'Brien & Walsh, 2025

Knowledge Gaps and Research Needs

Though much progress has been made, there are still important knowledge gaps:

Quantitative Integration: There is a need for the development of robust methods for quantitative integration of diverse data types such as omics, structural, processing, and sensory data, which are being treated separately so far (Foodomics Review 2025, Ahmad 2026).

Further development of reliable predictive models between molecular characteristics and processing properties and sensory properties (Food Structure Engineering, 2024; Foodomics Review, 2025).

Scale-Up Translation: Laboratory results to industrial production is another priority, understanding of the influence of processing conditions at scale on molecular structure and product properties (Natural Product Communications, 2025).

Consumer Behavior: Better understanding of consumer behavior to new sustainable foods that have different sensory qualities is required (Ahmad, 2026).

Methodological Challenges

Technical challenges of data integration: Data I ntegration from various omics platforms is still challenging because of data type, scale, and quality differences (Foodomics Review, 2025).

Model validation: Models need to be tested extensively on a variety of products and conditions to ensure generalizability (Food Structure Engineering, 2024).

Cross-Disciplinary Collaboration: The need for effective cross-disciplinary collaboration is perhaps most widespread, as researchers need to span terminological and methodological differences (Ahmad 2026; Foegeding 2023).

FUTURE DIRECTIONS

Moving forward, there are several potential avenues:

Systems-Level Understanding: The ultimate target is still to achieve systems-level understanding of food from molecules to the consumer experience (Foodomics Review, 2025; Food Structure Engineering, 2024; Ahmad, 2026).

Digital Twins: Food product and process digital twins help optimize it virtually and quickly (Food Structure Engineering, 2024).

Personalized Nutrition: Foodomics in combination with the data from the microbiome and metabolome can facilitate the creation of food products personalized for each individual's health (Foodomics Review 2025).

Sustainability Integration: Sustainability integration throughout the product design life cycle will become increasingly central, driven by consumer demand, regulatory pressure, and environmental imperatives (Natural Product Communications, 2025; Ahmad, 2026).

Research at the Intersection: The most impactful research will occur at the intersection of molecular understanding, process intelligence, sustainability imperatives, and human perception.

CONCLUSION

Food science is moving from descriptive experiments to intended, planned and integrated product development.Three interrelated elements are transforming the landscape: Next-Generation Foodomics: New molecular knowledge of plant-based proteins and polyphenols. Systems-level insight is obtained by combining the genomic, transcriptomic, proteomic, metabolomic and microbiomic approaches. Process Intelligence, which involves multi-scale structural analysis and response surface methodology, puts processing conditions in the center of processing as design variables influencing product quality. Advanced imaging and rheological techniques allow correlation between molecular structure, texture and consumer perception. Circular Valorization aims at using agri-food by-products as functional raw materials thus embedding sustainability in product design. These approaches not only represent a new paradigm but also pinpoint the importance of molecular understanding in the design of processing, the sustainability criteria for the choice of ingredients, and the role of sensory science in assessing translational success. What will have the greatest impact on the future will be research that combines molecular understanding, process intelligence, sustainability considerations, and human perception.

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