FSTA®
sciences of food and health

Redesigning Resilience: What 5 Years of Food Security Research Reveals

EXECUTIVE SUMMARY

The past five years show a decisive reorientation in food security research beyond simple volume growth. Analysing thousands of records indexed from 2021–2025 in FSTA®, the Food Science & Technology Abstracts database, we quantify how attention has shifted across topics and translated into solutions along the food system. Rather than one grand narrative, five threads recur and interlock:

- **Digital systems move from analysis to control**. AI, sensing, and model-driven operations now aim to anticipate failure on farm, in plants, and in quality systems. *Where is this actually working, and what are the limits to generalisability and trust?*

- **Safety becomes a design constraint, not a checkpoint**. As chains lengthen and diversify, the literature pivots from detection to actionable control. *Which interventions travel from lab to line, and what new risk interactions are we missing?*

- **Climate pressure is now a design brief**. Studies translate CO_2–water–heat–nitrogen interactions, toxin dynamics, and circularity into decisions. *What guardrails prevent rebound effects, and where do adaptation portfolios beat silver bullets?*

- **Chemistry and processing innovation does heavy lifting**. Green unit ops, clean-label bioactives, and omics-guided standardisation stabilise quality and nutrition under volatility. *How do these approaches scale, and what evidence still needs to be built?*

- **Nutrition and equity redefine outcomes**. Attention shifts toward diet quality, malnutrition, affordability, and lived vulnerability—treating nutrition as a systems issue that intersects with climate risk, economics, and access. *Which measures best capture nutritional risk in real time, and what kinds of products and programs actually move diets?*

This report investigates the descriptor trajectories that signal these shifts to uncover how food scientists are re-engineering resilience.

METHODOLOGY NOTE

This analysis draws on metadata from food security–related literature indexed in FSTA between 2021 and 2025. A targeted search was first conducted to identify relevant publications, after which we extracted and analysed the top 250 descriptors (keywords/tags) applied to these records in each year. The final dataset was cross-analysed using FSTA's subject expertise and thesaurus taxonomy. Descriptor trends are indicative rather than definitive; they capture where attention is flowing, not outcomes.

WHAT IS GAINING GROUND – AND WHY?

From cyberattacks on food producers to geopolitical shocks disrupting global grain supply chains, food security is no longer an abstract policy goal; it is a front-page issue shaping political discourse and public anxiety worldwide.

Researchers have long studied food security; what's new is both a surge in research volume and a marked shift in emphasis. How is this shaping the trajectory of scientific literature? What themes are gaining ground? What does this reveal about where the science is heading? And why does it matter?

To answer these questions, we conducted a longitudinal analysis of the top 250 descriptors applied to food security literature indexed in FSTA each year from 2021 to 2025, resulting in a dataset of just over 700 unique terms. While this represents a relatively small subset of the 17,000+ descriptors in the FSTA Thesaurus, it captures the most prominent and recurrent themes within food security research. By tracking how these high-frequency descriptors changed over time, we were able to map where research attention is accelerating and how food science is evolving in response to global shocks and systemic stress.

The past five years show clear expansion in several thematic areas. Some are long-established but gaining sharper focus. Others reflect emergent scientific frontiers. Below, we explore five key trends, ranked by scale of change, growth trajectory, and strategic significance.

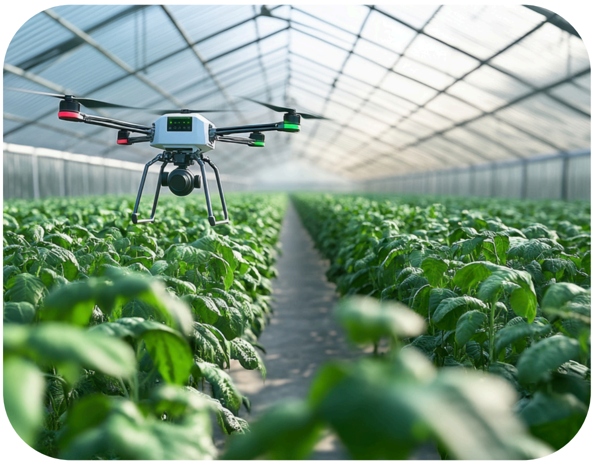
1. TECHNOLOGY, AI, AND ADVANCED ANALYTICS – DIGITAL TRANSFORMATION ACCELERATES

Descriptors linked to *artificial intelligence* (+600%), *machine learning* (+350%), and *information processing* (+81%) remain modest in absolute volume within the food security corpus, but their exponential growth between 2021 and 2025 signals a decisive shift toward computational approaches designed to handle the complexity, scale, and uncertainty of global food systems.

Recent literature presents advances in AI as an enabling framework for efficiency, precision, and resilience across the food security spectrum, from production and processing to safety and policy (Rugji et al., 2025). Applications now extend well beyond data analysis to include predictive modelling, automation, and real-time decision support. Machine learning, computer vision, and sensor networks are being used to forecast risks, detect pathogens, and optimise resource use, while robotic inspection systems and supply chain optimisation tools are reshaping how safety and sustainability are managed in practice.

The global push for sustainable, resilient food systems is accelerating this shift. Researchers are adopting AI not only to improve yields but also to mitigate losses, enhance traceability, and reduce environmental impact.

Recent studies demonstrate how this transformation is unfolding in practice:



CROP RESEARCH

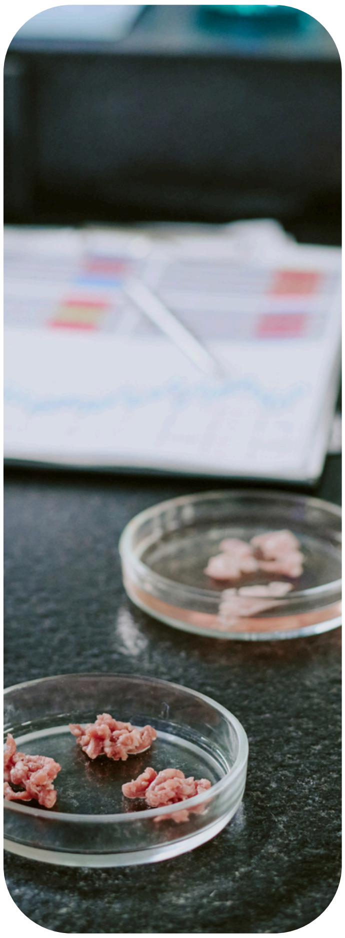
Digital image analysis and machine learning are being combined with genome-wide association studies (GWAS) and CRISPR editing to predict and enhance wheat yield traits such as thousand-kernel weight (Jamil et al., 2025), and to improve disease resistance through dual-GWAS of host and pathogen genomes, integrating pixel-based disease severity estimation for more accurate genomic selection (Hudson, 2025).

AQUACULTURE AND FISHERIES

Supervised ML models analyse nutrient–contaminant profiles in Arctic fish, balancing dietary benefit and toxin exposure to guide consumption recommendations (Ho et al., 2025), while AI-driven smart seafood systems monitor freshness, fraud, and traceability in real time (Jiao et al., 2025).

FOOD SAFETY AND PROCESSING

Food safety and processing are being revolutionised through AI-enhanced Raman spectroscopy for non-invasive contamination screening (Jayan et al., 2025) and anti-counterfeit packaging integrated with blockchain for end-to-end authenticity verification (Jain et al., 2025).



ALTERNATIVE PROTEIN DEVELOPMENT

AI technology is being leveraged in process optimisation, quality assurance, and safety evaluation of emerging sources of protein such as microalgae and edible insects (Rugji et al., 2025).

SMART AGRICULTURE

Smart agriculture is emerging in hydroponic systems that combine biosensors, AI-assisted computer vision, and plant stress diagnostics to automate harvest timing and improve nutrient density (Um et al., 2025).

MANUFACTURING

Industry 4.0 frameworks are embedding AI for real-time quality control and predictive maintenance, with interpretability becoming a regulatory priority (Semercioz-Oduncuoglu & Luning, 2025).

CELLULAR AGRICULTURE

In the production of animal-derived foods such as meat, milk, and eggs from cultured cells rather than livestock, AI is helping to overcome key scalability and cost barriers. Digital twin systems and reinforcement learning models are being used to optimise bioreactor conditions, predict tissue formation, and improve sensory quality, accelerating the shift from experimental to commercially viable cell-based production (Gao et al., 2025).

WHAT THIS MEANS FOR FOOD SCIENCE

AI's role is expanding rapidly from analytical support to a key enabler of innovation across the food system. Common themes across the research include:

INTEGRATION OVER ISOLATION

AI is being embedded across the entire research-to-market pipeline, from genomic prediction and environmental modelling to supply chain monitoring.

INTERPRETABILITY AND TRUST

A growing focus on explainable AI (Sarti et al., 2025) reflects recognition that adoption depends on transparent, regulator-ready models.

PREDICTIVE RESILIENCE

The next generation of food systems may rely on real-time sensing, predictive analytics, and digital twins to anticipate shocks rather than react to them.

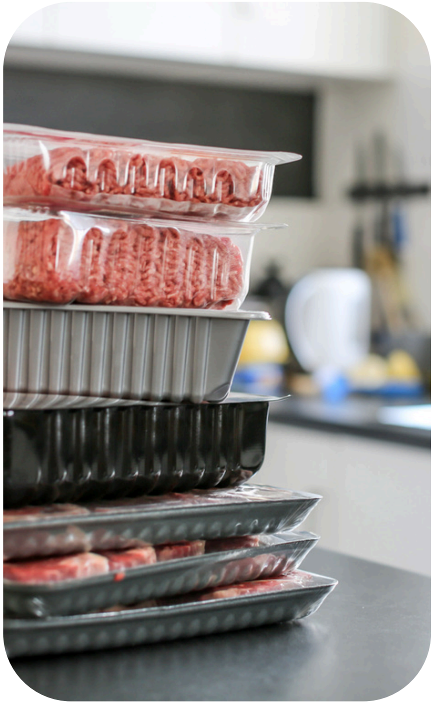
DATA ETHICS AND GOVERNANCE

As AI moves into policy and consumer research, issues of bias, data provenance, and responsible automation are coming to the forefront (Motoki et al., 2025).

2. SAFETY, CONTAMINANTS, AND RISK – A SURGE IN SCIENTIFIC SCRUTINY

Within our FSTA food-security subset (2021–2025), usage of descriptors such as *contamination* (+183.3%), *pesticide residues* (+142.9%), *residues* (+111.1%), and *trace metals* (+180%) more than doubled over the period.

The rise signals both intensifying real-world pressures and a broader definition of "security" from "is there enough food?" to "is the food safe, acceptable, and compliant at scale?" Several forces are converging:



MORE POINTS OF FAILURE IN LONGER, LEANER CHAINS

Globalised, just-in-time supply chains create more interfaces where contamination, fraud, and spoilage can arise driving work on freshness monitoring, adulteration detection, and end-to-end traceability (Jiao et al., 2025).

DEMONSTRATED CO-EXPOSURES AND SHELF-LIFE THREATS

Studies report co-occurrence of mycotoxins and veterinary drugs in retail products (Zheng et al., 2025) and psychrotrophic spoilage organisms shortening vacuum-packed meat shelf life (Angerer et al., 2025), making safety an operational priority.

BIOSECURITY AS A FIRST LINE OF DEFENCE

Farm-level evidence pinpoints contamination routes —e.g., carry-over via catching crews/equipment for *Campylobacter* in broilers—highlighting hygiene "choke points" where interventions have outsized impact (Kingsbury et al., 2025).

DIVERSIFICATION OF INPUTS TO BOOST SECURITY

As systems explore alternative proteins (insects, algae) and valorised side-streams, safety questions move with them—spanning welfare/residue governance for insects (Zanzot et al., 2025) and antimicrobial properties of citrus by-products (Figuccia et al., 2025).

ANALYTICS THAT MAKE RISK VISIBLE AND ACTIONABLE

Rapid sensing, machine learning, and quantitative risk assessment reveal problems earlier and help prioritise controls (e.g., phage-based *Campylobacter* biosensing; Lwin et al., 2025), reinforcing a feedback loop where better measurement begets more safety research (Rugji et al., 2025).

Notably, the literature reflects both heightened documentation of real-world hazards (e.g., co-exposures, supply-chain spoilage) and proactive assessment of emerging inputs (insects, side-streams) to ensure that diversification strategies for food security do not introduce new risks.

WHAT THIS MEANS FOR FOOD SCIENCE

A CLEAR SHIFT FROM DETECTION TO CONTROL

Biocontrol enzymes, practical decontamination, and behaviour-targeted risk levers complement surveillance (Li et al., 2025; Xiao et al., 2025).

FIT-FOR-OPERATIONS METHODS

Faster assay, simplified residue workflows and node-specific hygiene protocols close the lab-to-plant gap (Lwin et al., 2025; Liu et al., 2025; Angerer et al., 2025).

INTEGRATED RISK THINKING

Co-exposures and cross-contamination models emphasise system levers (source control, equipment/people flow, household practices) over single-hazard fixes (Zheng et al., 2025; Xiao et al., 2025).

SAFETY QUESTIONS EXTEND WITH INNOVATION

As novel inputs and circular uses expand, further work on safety assessment is required (Zanzot et al., 2025; Figuccia et al., 2025; Rugji et al., 2025).

3. CLIMATE AND ENVIRONMENTAL IMPACT – EMBEDDED AND EXPANDING

Climate has shifted from backdrop to design brief. Within the corpus of FSTA data related to food security, descriptor use is up for *global warming* (+84%), *environmental impact* (+80%), *greenhouse gas emissions* (+71%), and *climate change* (+70%) from an already comparatively high base, indicating a substantial rise in underlying articles.

Broadly, three categories dominate the research: (i) primary production & agronomy (CO_2 responses, rotation, mushrooms as low-footprint foods); (ii) safety & loss prevention (toxins under climate stress; sensing/packaging to stabilise quality); (iii) systems & policy (circularity rebounds; rights-based mapping; farmer adoption). On a more granular level, several critical themes can be noted:

FROM AWARENESS TO OPERATIONALISATION

Climate pressure is now translated into actionable levers for decisions across the chain—e.g., response functions that show how CO_2 interacts with water/heat/nitrogen for major cereals (guiding planting windows and crop mix), rotation “legacy effects” that raise yield and soil quality with lower inputs, and packaging/sensing that reduces loss and extends shelf life (Bai et al., 2025; Wang et al., 2025; Sukhavattanakul et al., 2025; Ndwandwe et al., 2025).

CLIMATE-SAFETY COUPLING

Warmer, more variable conditions elevate toxin risk (aflatoxins and broader mycotoxin portfolios), so safety work is pivoting to integrated pipelines: early detection (biosensors), prevention/biocontrol, and intelligent packaging to manage risk from field to retail (Alemu & Berihun, 2025; Kępką-Borkowska et al., 2025; Nji et al., 2025).

CIRCULARITY WITH CONSEQUENCES

Valorising side streams and upcycling can lower waste and emissions, but systems modelling shows rebound (cheaper feed can expand herds and offset GHG gains) unless accompanied by policy guardrails (Long et al., 2025).

DIET, DEMOGRAPHY, AND DEMAND

Macro forces reshape footprints and feasibility: population ageing shifts dietary carbon and labour supply; meanwhile, plant-based foods (including egg alternatives) are being tested for sensory performance and sustainability to support lower-impact diets (Liu et al., 2025; Zahir & Akhter, 2025; Lira et al., 2025).

GOVERNANCE AND SOCIAL LICENCE

Rights-based mapping makes multi-hazard hotspots and inequality visible for targeting adaptation; farmer surveys show cautious optimism about "more with less," tempered by concerns over power asymmetries in digital transitions, key for adoption and legitimacy (Ruder et al., 2025).

ONE HEALTH LINKAGES

Antimicrobial resistance is framed as a cross-domain climate–environment–husbandry issue: reducing on-farm antibiotics matters, but environmental contamination and climate variability also drive ARGs—implying coordinated interventions across sectors (Rahman et al., 2026).

Within the scientific literature, climate framing is applied on a widespread basis: emissions metrics, safety risks, materials science, and behaviour/policy design are being combined to produce adaptation portfolios rather than silver bullets. For food-security outcomes, the centre of gravity is moving toward interventions that are measurable, modular, and locally configurable.

WHAT THIS MEANS FOR FOOD SCIENCE

PLAN WITH INTERACTIONS, NOT AVERAGES

Breeding and agronomy should incorporate CO_2 × water × heat × nitrogen interactions and regional heterogeneity into trials and recommendations (Bai et al., 2025).

STACK CO-BENEFITS

Rotation and soil strategies that deliver yield, quality, and SOM gains are prime adaptation assets—and reduce input intensity (Wang et al., 2025).

DESIGN CIRCULARITY WITH GUARDRAILS

Pair valorisation/upcycling with policy instruments to prevent emissions rebounds and leakage (Long et al., 2025).

MEASURE TO MANAGE LOSS

Advance waste-derived antimicrobial packaging and nanocomposite sensors—while investing in toxicology and end-of-life data to ensure genuine footprint reductions (Ndwandwe et al., 2025; Sukhavattanakul et al., 2025).

CENTRE EQUITY AND ADOPTION

Use rights-based mapping and farmer-reported constraints to target interventions where risk is concentrated and uptake is plausible (Ruder et al., 2025).

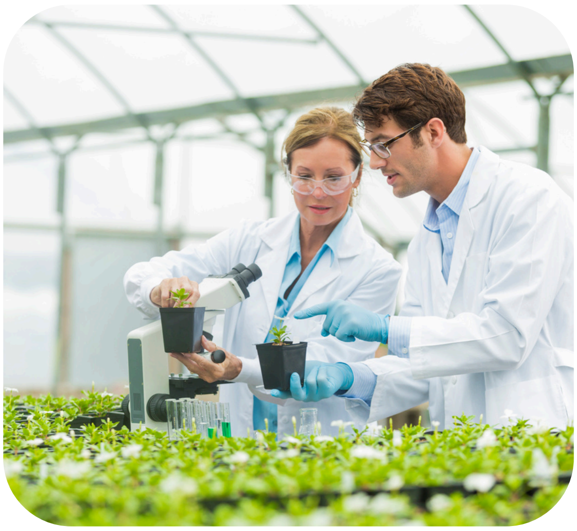
BROADEN "SECURITY" TO SAFETY

Expect continued integration of climate risk with toxin monitoring and mitigation pipelines (Alemu & Berihun, 2025; Kępką-Borkowska et al., 2025; Nji et al., 2025).

4. CHEMISTRY AND PROCESSING – ESTABLISHED BUT STRATEGIC

Terms such as *thermal processing* (+43.8%), *additives* (35%), and *organic compounds* (+38.1%) recorded steady but significant growth between 2021 and 2025. While their percentage increases may appear moderate compared to the rapid rise of AI- or contaminant-related descriptors, these gains are built on a much larger initial research base, making the absolute volume increase more substantial. Crucially, these trends track directly with key resilience levers: shelf-life extension, nutrient retention, functional reformulation, and clean-label preservation.

In the context of supply chain volatility and shifting consumer demands, this signals growing scientific investment in strengthening food quality and stability through processing innovation, especially in settings where resources are constrained or disruption is likely.



A review of recently published literature demonstrates which topics are gaining attention within this established area of research:

CLEAN-LABEL BIOACTIVES, FROM PLANTS TO PACKAGING

Unconventional food plants and herbs are being chemically characterised for phenolics, flavonoids, and antimicrobial/antioxidant activity to replace or complement synthetic preservatives and fortifiers (de Oliveira et al., 2025; Fantasma et al., 2025).

GENTLER, GREENER UNIT OPERATIONS

Process optimisation emphasises efficiency and “green solvents” (e.g., microwave-assisted extraction with water) to concentrate phenolics/flavonoids while lowering solvent load and time, helpful for low-resource or decentralised contexts (Thanarukwuttikorn et al., 2025).

BIOFORTIFICATION AND TARGETED ENRICHMENT

Processing and agronomy converge to deliver micronutrients and quality at the ingredient level (e.g., selenium-enriched garlic via foliar strategies optimised for yield, quality, and Se uptake) (Liu et al., 2025).

PROCESS-STABILISED QUALITY AND REPRODUCIBILITY

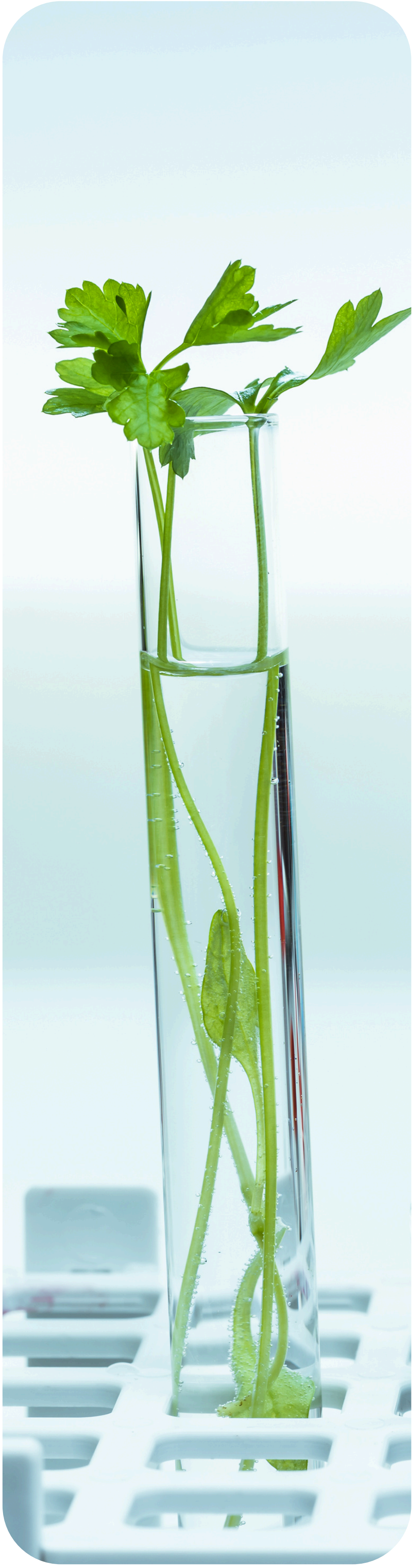
Tissue culture, micro-rhizomes, polyploidy, and hairy-root platforms are being used to produce stable, disease-free planting material and consistent metabolite profiles, reducing variability in functional ingredients and aromas (Aravind et al., 2024; Hiremath et al., 2024; Laffon et al., 2024).

CHEMISTRY FOR SPECIFIC HEALTH ENDPOINTS

Isolation, profiling, and in vitro/in vivo validation link processable extracts/oils to defined functions: α-glucosidase inhibition (antidiabetic), antihyperlipidemic flavonoid mechanisms, anti-liver-cancer essential oils, and dermal photoaging protection, driving "purpose-built" functional foods and cosmeceuticals (Chen et al., 2025; de Castro et al., 2025).

OMICS-GUIDED STANDARDISATION

UHPLC/HRMS-based phenolic maps, transcriptional control of pigment/antioxidant pathways, and enzyme families for active-compound transformation are turning botanicals into spec-able, repeatable ingredients (Bassolino et al., 2024; Ma et al., 2024; Vuko et al., 2024).



Chemical and processing sciences are quietly underpinning resilience efforts, from heat treatments to clean-label preservation. This will only grow in importance as supply chains face more disruption.

WHAT THIS MEANS FOR FOOD SCIENCE

RESILIENCE VIA CHEMISTRY

Expect continued pivot from “detect & label” to “process & prevent” through mild heat, green extraction, and bioactives that suppress oxidation, microbes, and quality drift.

SPECIFICATION & SCALE

Omics fingerprints + controlled propagation will make botanical ingredients *auditable* (batch-to-batch), easing regulatory and supplier qualification.

CLEAN-LABEL PERFORMANCE

Natural antioxidants/antimicrobials are maturing into drop-in tools; the competitive edge is in process design (matrix compatibility, release, stability).

LOW-RESOURCE VIABILITY

Techniques that reduce solvent/energy/time (e.g., MAE with water) and field-level biofortification will matter for decentralised, cost-sensitive supply chains.

HEALTH-TARGETED REFORMULATION

Pipeline from isolation → mechanism → formulation accelerates nutraceutical and functional-food claims, provided standardisation and safety dossiers keep pace.

5. NUTRITION & WELLNESS IN FOOD SECURITY – A HUMANISED LENS

Food security is being subtly recast through a nutritional lens. In the 2021–2025 FSTA corpus, human-centred descriptors such as *nutrition assistance* (+85.7%), *poverty* (+84.6%), *malnutrition* (+76.9%), and *diet quality* (+66.7%) grow ahead of the curve, signalling a shift from predominantly system- or production-focused frames toward nutrition equity, social vulnerability, and the lived experience of hunger. In other words, adequacy is no longer judged only by aggregate supply or yield stability; it is increasingly assessed by what people can afford, prepare, and metabolically benefit from under real constraints.

Several forces appear to be driving this reframing, and they cut across disciplines. Post-COVID recovery exposed persistent scarring in access and diet quality; inflation and widening inequality re-elevated affordability as a scientific variable, not just a policy talking point; and nutrition-sensitive interventions (from school meals to fortification) have matured into testable, designable levers. Crucially, this is not a return to siloed public health. The new work overlaps with climate resilience, economics, and digital modelling, treating nutrition as a systems property that is co-determined by shocks, markets, behaviours, and mid-chain reliability.

Digging into recently published literature that views food security through a nutritional lens reveals how this theme is being operationalised inside the corpus. Several strands stand out:

LIVED ACCESS, NOT JUST AVAILABILITY

Work on beverage choice maps how infrastructure, taste, and trust shape sugary beverage consumption (Estrade et al., 2025). Studies on program use emphasise *use* and *experience* (benefit redemption; barriers) rather than eligibility per se, highlighting where nutrition intent fails at the point of purchase or meal uptake (Anderson & Whaley, 2025).

CONDITION-AWARE NUTRITION

Clinical vulnerability reframes measurement and product needs. Adults with nondialysis chronic kidney disease describe affordability, health constraints, and support as binding dimensions of “nutrition security,” arguing that current instruments miss condition-specific realities (Andrade et al., 2025).

BEHAVIOURAL AND CULTURAL TAILORING

Generational analyses in fast-changing diet contexts (Saudi Arabia) show distinct motivations and readiness for sustainable eating; plant-protein intake predicts healthier patterns, but most remain early-stage in behaviour change, implying segmented interventions and culturally coherent product design (Al-Otaibi et al., 2025).

ONE-HEALTH PATHWAYS TO DIET QUALITY

In pastoral settings, buffering asset shocks improves nutrition: livestock-feed support sustained milk and improved women’s and children’s dietary diversity, with further gains when paired with light counselling, evidence that modest, context-fit inputs can move core diversity indicators (Mutono et al., 2025).

SHOCKS, RESILIENCE, AND NUTRITION RISK

Extreme temperature events suppress staple yields with region-specific dynamics; some adaptations (e.g., protected agriculture, insurance) mitigate cold stress more than heat, pointing to uneven nutritional risk under climate volatility (Wang et al., 2025). Midstream resilience under conflict (clusters in Myanmar) also matters for diet stability (Win, 2025).

WHAT THIS MEANS FOR FOOD SCIENCE

FROM ELIGIBILITY TO EFFECTIVENESS

Expect more work on redemption, uptake, palatability, and continuity of access—the real choke points for nutrition impact.

DESIGN FOR CONSTRAINTS

Condition-tuned staples (renal-appropriate, culturally familiar, budget-stable) and formats that match limited prep capacity are a growing frontier.

OPERATIONAL RESILIENCE AS NUTRITION POLICY BY OTHER MEANS

Interventions that stabilise supply (storage, protected ag), household assets (livestock feed), or midstream reliability can yield measurable diet-quality gains.

BETTER INSTRUMENTS, BETTER TARGETING

Expect adoption of multidimensional, rapid-update measures that integrate diet quality with affordability, work conditions, and exposure to shocks.

CROSS-DISCIPLINARY BY DEFAULT

The strongest studies blend nutrition science with behavioural insights, climate risk, and ag-economics—moving nutrition from a sectoral silo to a systems lever.

CONCLUSION: A NOTE OF OPTIMISM

Over the past five years, a clear pattern has emerged: food-security science is shifting from post-hoc fixes to anticipatory design. Digital tools are being embedded end-to-end; failure modes are engineered out through safety-by-design; climate adaptation is operationalised; and chemistry/processing stabilise quality and nutrition in volatile supply chains.

Equally important, the literature is relentlessly solution-focused. Research indexed in FSTA rarely stops at problem definition. It tests interventions: improving dietary diversity, enhancing protein sources, developing safer packaging, cutting waste, and reducing environmental impact.

As food systems transform under pressure from necessity, innovation, and crisis, evidence-led science becomes ever more vital. The descriptors in this report are not just keywords; they are a map of global scientific effort to secure the future of food. And that is precisely what FSTA exists to support: rigorous, applied, solution-oriented science that helps ensure everyone, everywhere, has access to safe, nutritious, and sustainable food.

REFERENCES

- Alemu, K., & Berihun, G. (2025). Occurrence and the impact of climate change on mycotoxin production in Ethiopia: A review. *Journal für Verbraucherschutz und Lebensmittelsicherheit/Journal of Consumer Protection and Food Safety, 20*(3), 213–223. https://doi.org/10.1007/s00003-025-01558-4
- Al-Otaibi, H. H., Al-Hashim, S., & Alhajri, A. S. (2025). Generational perspectives on sustainable diets in Saudi Arabia: Implications for food security and behavioral change. *Frontiers in Nutrition, 12*, 1672606. https://doi.org/10.3389/fnut.2025.1672606
- Anderson, C. E., & Whaley, S. E. (2025). Household WIC benefit redemption varies by participant and household characteristics in Southern California. *Journal of the Academy of Nutrition and Dietetics, 125*(10), 1468–1481.e20. https://doi.org/10.1016/j.jand.2025.01.014
- Andrade, J. M., Mullis, K., & Lamino, P. (2025). Perceptions of food and nutrition security among adults with chronic kidney disease, nondialysis: A mixed-method study. *Journal of Renal Nutrition, 35*(5), 589–597. https://doi.org/10.1053/j.jrn.2025.05.003
- Angerer, J., Casarin, S., Schwaiger, K., & Dorn-In, S. (2025). Cold-tolerant *Clostridium* spp. in beef and in the beef production chain in Austria—Occurrence and species identification. *International Journal of Food Microbiology, 443*, 111410. https://doi.org/10.1016/j.ijfoodmicro.2025.111410
- Aravind, S., Nisthar, E., Chaithanya, K. C., Sivaranjani, R., Kandiannan, K., Srinivasan, V., Sankar, S. M., & Nirmal Babu, K. (2024). Induction of in vitro micro rhizomes and assessment of yield, quality, and clonal fidelity in ex vitro established plants of ginger (*Zingiber officinale* Rosc.). *Plant Cell, Tissue and Organ Culture, 157*(2), 28. https://doi.org/10.1007/s11240-024-02751-3
- Bai, Y., Liu, L., Li, H., & Huang, G. (2025). Synergistic interactions of CO_2 fertilization with water, heat, and nitrogen under climate change: Evidence from maize, rice, and wheat. *Field Crops Research, 332*, 110016. https://doi.org/10.1016/j.fcr.2025.110016
- Bassolino, L., Fulvio, F., Cerrato, A., Citti, C., Cannazza, G., Capriotti, A. L., Alberti, I., Terracciano, I., Pecchioni, N., & Paris, R. (2024). Metabolic characterization and transcriptional profiling of polyphenols in *Cannabis sativa* L. inflorescences with different chemical phenotypes. *Planta, 260*(4), 76. https://doi.org/10.1007/s00425-024-04505-z
- Chen, X., Yang, J., Zhou, Y., Wang, Q., Xue, S., Zhang, Y., & Niu, W. (2025). Research progress and prospects of flavonoids in the treatment of hyperlipidemia: A narrative review. *Molecules, 30*(15), 3103. https://doi.org/10.3390/molecules30153103
- de Castro, M. V. L., de Lima, M. C. F., da C. Barbosa, G. A., Carvalho, S. G., Coelho, A. M. R. M., Santos, L. de S., Silva, V. R., Dias, R. B., Soares, M. B. P., Costa, E. V., & Bezerra, D. P. (2025). In vitro and in vivo efficacy of the essential oil from the leaves of *Annona amazonica* R.E. Fries against liver cancer. *Molecules, 30*(15), 3248 https://doi.org/10.3390/molecules30153248
- de Oliveira, I., Salgado, J. M. R. T., Lopes, J. K., Carocho, M., da Silveira, T. F. F., dos Santos Garcia, V. A., Calhelha, R. C., Santos-Buelga, C., Barros, L., & Heleno, S. A. (2025). Nutritional and bioactive characterization of unconventional food plants for sustainable functional applications. *Sustainability, 17*(15), 6718. https://doi.org/10.3390/su17156718
- Estrade, M., Mui, Y., Witting, L., Burgos-Gil, R., Calancie, L., Gittelsohn, J., & Colón-Ramos, U. (2025). Opportunities in programs and policies to address the underlying drivers of sugary drink and water consumption in the Washington, DC, metro area: A qualitative community-based system dynamics approach. *Journal of the Academy of Nutrition and Dietetics, 125*(10), 1458–1467.e1. https://doi.org/10.1016/j.jand.2025.01.001
- Fantasma, F., Segatto, M., Colardo, M., Di Matteo, F., Chini, M. G., Iorizzi, M., & Saviano, G. (2025). Phytochemistry and bioactivity of essential oil and methanolic extracts of Origanum vulgare L. from Central Italy. Plants, 14(16), 2468. https://doi.org/10.3390/plants14162468
- Figuccia, S., Ricci, A., & Bernini, V. (2025). Solid by-products from the orange essential oil industry: Could they be a source of antimicrobials? LWT, 232, 118440. https://doi.org/10.1016/j.lwt.2025.118440
- Gao, W., Bai, R., & Ling, S. (2025). Artificial intelligence-enabled cellular agriculture: Multiscale modeling, process optimization, and future directions. Trends in Food Science & Technology, 163, 105193. https://doi.org/10.1016/j.tifs.2025.105193

REFERENCES, CONT.

- Hiremath, C., Prabhu, K. N., Ravi Kumar, R., Pranav Raj, T. K., Verma, R. S., & Nagegowda, D. A. (2024). Induction and characterization of polyploids in patchouli (*Pogostemon cablin*) through morpho-anatomical, cytological, chemotypic, and molecular approaches. *Plant Cell, Tissue and Organ Culture, 157*(3), 66. https://doi.org/10.1007/s11240-024-02798-2
- Ho, Q. T., Nøstbakken, O. J., Sanden, M., Myrmel, L. S., Wiech, M., Bernhard, A., … Dahl, L. (2025). Supervised machine learning for nutrient and contaminant profiling and benefit-risk assessment of Arctic seafood. *Environment International, 202*. https://doi.org/10.1016/j.envint.2025.109699
- Hudson, O. (2025). Investigating Fusarium ear rot of maize using comparative genomics, selection models, and machine learning (Doctoral dissertation, University of Florida). ProQuest Dissertations Publishing.
- Jain, P., Gupta, D., Kaur, H., Singh, S., & Gaikwad, K. K. (2025). Advanced anti-counterfeit inks in food packaging: A comprehensive review focusing on functional materials to digital integration. Trends in Food Science & Technology, 164. https://doi.org/10.1016/j.tifs.2025.105229
- Jamil, M., Ahmad, W., Sanwal, M., & Maqsood, M. F. (2025). Gene editing and GWAS for digital imaging analysis of wheat grain weight, size and shape are inevitable to enhance the yield. *Cereal Research Communications, 53*(3), 1199–1218. https://doi.org/10.1007/s42976-025-00630-x
- Jayan, H., Yin, L., Zhou, R., Zou, X., & Guo, Z. (2025). Future horizons of Raman spectroscopy in food science: Emerging techniques and innovations for enhanced analysis. *Food Chemistry, 493*. https://doi.org/10.1016/j.foodchem.2025.145777
- Jiao, X., Zhu, J., Ye, W., Zou, H., Yan, B., Zhang, N., & Fan, D. (2025). Artificial intelligence in smart seafood safety across the supply chains: Recent advances and future prospects. *Trends in Food Science & Technology, 163*. https://doi.org/10.1016/j.tifs.2025.105161
- Kępką-Borkowska, K., Chalaśkiewicz, K., Ogluszka, M., Borkowski, M., Lepczyński, A., Pareek, C. S., … Polawska, E. (2025). Current approaches to aflatoxin B1 control in food and feed safety: Detection, inhibition, and mitigation. *International Journal of Molecular Sciences, 26*(13), 6534. https://doi.org/10.3390/ijms26136534
- Kingsbury, J. M., French, N., Midwinter, A., Lucas, R., Callander, M., Hird, C. P., … Biggs, P. J. (2025). Longitudinal survey investigating vectors and reservoirs for *Campylobacter* colonization of chickens on a New Zealand broiler poultry farm. *Applied and Environmental Microbiology, 91*(9), e01206-25. https://doi.org/10.1128/aem.01206-25
- Laffon, M., Bruat, M., Chefdor, F., Colas, C., Heng, S., Sena-Velez, M., Larcher, M., Hericourt, F., Depierreux, C., Morabito, D., Destandau, E., Carpin, S., Malik, S., & Lamblin, F. (2024). Hairy root induction in hybrid poplar for sustainable growth and specialized metabolite production with antioxidant activities. *Plant Cell, Tissue and Organ Culture, 156*(1). https://doi.org/10.1007/s11240-023-02634-z
- Li, Y., Li, W., Xu, Z., Chen, Z., Song, Z., Yu, Y., … Gao, H. (2025). Transcriptomic and metabolomic analyses reveal the antibacterial mechanism of cell wall lytic enzyme LysM15 against *Bacillus cereus*. *LWT, 232*, 118450. https://doi.org/10.1016/j.lwt.2025.118450
- Lira, C. A. C., Viana, J. D. da R., da Silva, L. M. R., & Gaban, S. V. F. (2025). Sensory acceptance testing and rheological parameter analysis of a plant-based cocoa dessert formulated with chickpeas, quinoa, sweet potatoes, and rice. *Food Chemistry Advances, 8*, 101068. https://doi.org/10.1016/j.focha.2025.101068
- Liu, G., Ge, J., Fan, J., Zhao, Y., Lu, X., Liu, C., & Yang, F. (2025). The effect of foliar spraying of different selenium fertilizers on the growth, yield, and quality of garlic (*Allium sativum* L.). *Plants, 14*(16), 2505. https://doi.org/10.3390/plants14162505
- Liu, S., Yang, D., Xiao, P., Tang, Q., Sun, Y., Wu, J., … Zou, X. (2025). Development of a simplified and efficient QuEChERS method for pesticide residue analysis in *Lonicera japonica* using IRMOF-3 as a novel adsorbent coupled with gas chromatography–mass spectrometry. *Food Bioscience, 72*, 107527. https://doi.org/10.1016/j.fbio.2025.107527
- Liu, W., Zhang, G., & Zheng, X. (2025). Future foodscape: Impact of population decline and aging on China's dietary carbon footprint and food security. *Global Food Security, 46*, 100875. https://doi.org/10.1016/j.gfs.2025.100875

REFERENCES, CONT.

- Long, W., Zhu, X., Weikard, H.-P., Oenema, O., & Hou, Y. (2025). Rebound effects may undermine the benefits of upcycling food waste and food processing by-products as animal feed in China. *Nature Food, 6*(9), 881–891. https://doi.org/10.1038/s43016-025-01219-7
- Lwin, S. Z. C., Linn, K. Z., Wang, C., Abdelaziz, M. N. S., Zhao, J., Masuda, Y., ... Miyamoto, T. (2025). A novel phage receptor-binding protein as a rapid and specific biorecognition tool for detecting *Campylobacter jejuni*. *International Journal of Food Microbiology, 443*, 111409. https://doi.org/10.1016/j.ijfoodmicro.2025.111409
- Ma, S., Zhou, H., Ren, T., Yu, E., Feng, B., Wang, J., Zhang, C., Zhou, C., & Li, Y. (2024). Integrated transcriptome and metabolome analysis reveals HaMYB1 modulation of anthocyanin accumulation and sunflower color. *Plant Cell Reports, 43*(3), 74. https://doi.org/10.1007/s00299-023-03098-3
- Motoki, K., Low, J., & Velasco, C. (2025). Generative AI framework for sensory and consumer research. *Food Quality and Preference, 133*, 105600. https://doi.org/10.1016/j.foodqual.2025.105600
- Mutono, N., Muema, J., Bukania, Z., Kimani, I., Boyd, E., Mutua, I., Gacharamu, G., Wambua, F., Makori, A., Njuguna, J., Jost, C., Osman, A. M., Souza, D., Palmer, G. H., Yoder, J., & Thumbi, S. M. (2025). Effect of behavioral change communication and livestock feed intervention on dietary practices in a Kenyan pastoral community: A randomized controlled trial. *Nutrients, 17*(18), 2997. https://doi.org/10.3390/nu17182997
- Ndwandwe, B. K., Malinga, S. P., Kayitesi, E., & Dlamini, B. C. (2025). Avocado seed-derived bioactive compounds for functional food packaging solutions: Current developments and future prospects—A review. *Food Bioscience, 72*, 107446. https://doi.org/10.1016/j.fbio.2025.107446
- Nji, Q. N., Sulyok, M., & Mwanza, M. (2025). Prevalence of non-regulated fungal and other metabolites in South African maize (2017–2019): A multi-year study using LC-MS/MS. *Food Chemistry Advances, 8*, 101079. https://doi.org/10.1016/j.focha.2025.101079
- Rahman, A. U., Valentino, V., Sequino, G., Ercolini, D., & De Filippis, F. (2026). Comparative analysis of antibiotic-administered vs. antibiotic-free farming in meat production: Implications for health, environment, and antibiotic resistance. *Food Microbiology, 133*, 104877. https://doi.org/10.1016/j.fm.2025.104877
- Ruder, S.-L., Wittman, H., Duncan, E., & Satterfield, T. (2025). Sociotechnical imaginaries for Canadian agri-food futures: A farmer survey. *Agriculture and Human Values, 42*(3), 1439–1456. https://doi.org/10.1007/s10460-024-10675-z
- Rugji, J., Erol, Z., Tasci, F., Musa, L., Hamadani, A., Gjoni Gundemir, M., & Siddiqui, S. A. (2025). Utilization of AI—Reshaping the future of food safety, agriculture and food security: A critical review. *Critical Reviews in Food Science and Nutrition, 65*(26), 5136–5180. https://doi.org/10.1080/10408398.2024.2430749
- Sarti, D. A., Bardelli, T., Bianchi, P. G., & Giulini, A. P. M. (2025). Enhancing registration offices' communication through interpretable machine-learning techniques. *Agronomy, 15*(7), 1603. https://doi.org/10.3390/agronomy15071603
- Semercioz-Oduncuoglu, A. S., & Luning, P. A. (2025). Industry 4.0 technologies in quality and safety control systems in food manufacturing: A systematic techno-managerial analysis on benefits and barriers. *Trends in Food Science & Technology, 163*, 105144. https://doi.org/10.1016/j.tifs.2025.105144
- Sukhavattanakul, P., Srikhao, N., Ummartyotin, S., & Narain, R. (2025). Sensing food spoilage with nanotechnology: A review of current research and challenges. *Measurement: Food, 18*, 100221. https://doi.org/10.1016/j.meafoo.2025.100221
- Thanarukwuttikorn, K., Prabsangob, N., Maisuthisakul, P., & Harnsilawat, T. (2025). Optimization of microwave-assisted extraction conditions for bioactive compounds from *Cannabis sativa* L. leaves using response surface methodology. *Measurement: Food, 19*, 100237. https://doi.org/10.1016/j.meafoo.2025.100237
- Um, D., Koram, C., Nethala, P., Kasu, P. R., Tabassum, S., Inam, A. K. M. S., & Sangmen, E. D. (2025). Beyond color: Phenomic and physiological tomato harvest maturity assessment in an NFT hydroponic growing system. *Agronomy, 15*(7), 1524. https://doi.org/10.3390/agronomy15071524

REFERENCES, CONT.

- Vuko, E., Radman, S., Bocina, I., Kamenjarin, J., Bezmalinovic, I., & Fredotovic, Z. (2024). Cell-type localization and biological activity of volatiles from *Chaerophyllum coloratum*. *Planta, 260*(4), 95. https://doi.org/10.1007/s00425-024-04531-x
- Wang, J., Ye, F., Hu, J., & Luo, J. (2025). Heterogeneous mitigation effects of adaptation initiatives on grain yield losses from extreme temperatures in China: Implications for grain resilience and food security. *Frontiers in Sustainable Food Systems, 9*, 1647826. https://doi.org/10.3389/fsufs.2025.1647826
- Wang, R., Wu, J., Wang, Y., Sun, Z., Ma, W., Xue, C., & Xu, H. (2025). Legacy effects of different preceding crops on grain yield, protein fractions and soil nutrients in subsequent winter wheat. *Plants, 14*(16), 2598. https://doi.org/10.3390/plants14162598
- Win, M. T. (2025). *Resilience and adaptation in agriculture: Conflict, agricultural clusters, and labor dynamics* (Doctoral dissertation, Michigan State University). ProQuest Dissertations & Theses Global. Publication No. 32169147.
- Xiao, M., Hu, C., Yang, Z., Ming, X., Ma, B., & Wang, Y. (2025). Quantitative risk assessment of *Listeria monocytogenes* in retail pork of Hubei Province. *Chinese Journal of Food Hygiene*, (4), 339–347. https://doi.org/10.13590/j.cjfh.2025.04.006
- Zahir, A., & Akhter, S. (2025). Exploring the pros and cons of plant-based egg alternatives: A review. *NFS Journal, 40*, 100241. https://doi.org/10.1016/j.nfs.2025.100241
- Zanzot, A., Copelotti, E., Sezzi, E., & Mancini, S. (2025). Organic edible insects—What would it take? *Animals, 15*(16), 2393. https://doi.org/10.3390/ani15162393
- Zheng, Y., Sun, X., Chen, X., & Lou, Z. (2025). Determination of mycotoxin and veterinary drug residues in packaged and ready-to-eat duck products. *Journal of Food Measurement and Characterization, 19*(9), 6396–6405. https://doi.org/10.1007/s11694-025-03395-3