frontiers | Frontiers in Science

TYPE Frontiers in Science Editorial
PUBLISHED 30 September 2025
DOI 10.3389/fsci.2025.1698997

OPEN ACCESS

EDITED BY
Frontiers in Science Editorial Office,
Frontiers Media SA, Switzerland

*CORRESPONDENCE
Francesco Branca
francesco.branca@unige.ch

RECEIVED 04 September 2025
ACCEPTED 12 September 2025
PUBLISHED 30 September 2025

CITATION
Branca F. Alternatives to animal-source foods for sustainable, equitable, and healthy food systems.
Front Sci (2025) 3:1698997.
doi: 10.3389/fsci.2025.1698997

Alternatives to animal-source foods for sustainable, equitable, and healthy food systems

Francesco Branca*

Institute of Global Health, University of Geneva, Geneva, Switzerland

KEYWORDS

animal-source foods, alternative proteins, ultra-processed foods, life cycle assessment, sustainable food systems

An Editorial on the Frontiers in Science Lead Article

Hybrid alternative protein-based foods: designing a healthier and more sustainable food supply

Key points

- Animal-source foods (ASFs) have a significantly negative impact on the environment and on human health, contributing to greenhouse gas emissions, extensive planetary resource use, noncommunicable diseases, zoonoses, and antimicrobial resistance.
- ASF alternatives, including products derived from plants, microbes, fungi, insects, and cultivated cells, hold promise for diversifying protein sources; however, their health, nutritional, and safety implications remain insufficiently evaluated.
- The transformative potential of ASF alternatives depends on a comprehensive assessment of their health, environmental, and social impacts, alongside policies that ensure sustainable and just food systems.

Contrary to their intended purpose of feeding people, current food systems are harming both human health and the planet (1). Food production accounts for 24% of global greenhouse gas (GHG) emissions, uses 68% of freshwater resources, and occupies 37% of land (2). Food demand is projected to rise by 35%–56% by 2050, driven by population growth (3). Of the different food groups, animal-source foods (ASFs) have the greatest environmental impact. Their overconsumption, particularly for red and processed meat, is also associated with a higher risk of noncommunicable diseases (NCDs). Intensive animal farming further contributes to health risks, including an increased risk of zoonotic disease emergence and the development of antimicrobial resistance (4). Proposed solutions to reduce the impact of food systems on planetary boundaries include (i) dietary shifts toward plant-based food, (ii) technological innovations, and (iii) food waste reduction (5).

Dietary shifts

Increasing the proportion of plant-based foods in diets means adopting patterns long practiced across many cultures. The most urgent shift is needed among populations that consume excessive amounts of ASFs. While there is likely no minimum requirement for meat intake, dietary guidelines recommend between 100 and 500 g/week (4), with flexitarian diets suggesting even less (6). However, in some high-income countries (HICs), average consumption exceeds 700 g/week. Protein requirements are estimated at approximately 50 g/person/day, but intake in many HICs is approximately double this amount. These trends are largely shaped by cultural preferences and a food environment that supports such dietary patterns.

Alternatives to ASFs

To replace ASFs while mimicking their qualities, a range of alternatives has been developed using plants, microbes, fungi, insects, or cultured animal cells and is outlined in greater detail in the Frontiers in Science lead article by Kaplan and McClements (7). These products require fewer resources (land, water, and energy) and emit fewer GHGs than conventional animal products, although outcomes depend on specific processing methods. The use of alternatives to ASFs may also address health concerns, as it is possible to alter the content of nutrients that may be responsible for negative health effects, such as lipid composition. However, the rapid expansion of alternative products underscores the need for a deeper understanding of their health impacts, assessed across multiple dimensions including food safety and chronic disease risk. For example, chemical and microbiological contaminants, toxic compounds, and allergens must be monitored at every stage of production. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have begun to map relevant hazards in cultured meats (8).

Nutrient composition is a primary focus for developers; for instance, they pay particular attention to protein digestibility and quality (e.g., protein digestibility-corrected amino acid score, also known as PDCAAS), micronutrient content, and antinutritional factors. However, critics of the reductionist approach (nutritionism) stress the need for holistic assessments that consider the overall dietary pattern to which foods contribute along with their cultural, social, and economic impacts.

Physiological and health impacts

Comprehensive evaluations are still lacking on how alternatives to animal proteins affect metabolic pathways (such as lipid, protein, glucose, and mineral status and balance), satiety, the gut microbiome, or cell replication. Few clinical studies have assessed the impact of alternatives to ASFs on human health. Exposomic approaches, which consider the combined effects of natural and manufacturing-related compounds, may help to enable more robust safety assessments.

The discussion on ultra-processed foods (UPFs) is particularly relevant. While some alternatives to ASFs (e.g., tempeh) are modifications of traditional preparations, many others involve complex processes and would be classified as UPFs under the Nova system (9). UPFs typically consist of ingredients extracted from their original food matrices and combined with additives to enhance palatability. In fact, they are often designed to be hyperpalatable and, therefore, prone to overconsumption.

Consumption of UPFs has been linked to adverse health effects via multiple mechanisms, including nutrient profiles, altered food matrices (e.g., easier chewing and faster nutrient absorption), microbiome disruption, exposure to additives and packaging materials, and high palatability leading to overconsumption (10). Growing public concern has already contributed to the establishment of public policies aimed at reducing UPF consumption (11), and manufacturers of alternative proteins are aware of this sensitivity.

Social and economic dimensions

Concerns also extend beyond health. A greater reliance on highly processed alternatives could reduce the importance of fresh, locally produced foods. This has social and economic implications, accelerating the concentration of food production to the hands of a few global corporations that prioritize profits over people's health and environmental sustainability. Therefore, to fully realize their value, alternative proteins must address not only nutritional and safety concerns but also broader social and economic impacts. As illustrated by Kaplan and McClements (7), hybrid products, combining modern technological ingredients with traditional plant and animal components, represent one pathway forward. For example, plant-derived proteins could be paired with animal cells to provide a source of vitamins, minerals, and bioactive compounds while maintaining favorable nutrient profiles.

Environmental assessment and policy implications

Environmental impacts also require clearer evaluation. Life cycle assessments must capture the full range of inputs and outputs to enable realistic comparisons with conventional foods and with dietary strategies emphasizing minimally processed plant-based foods (such as whole grain cereals, fruit, vegetables, nuts, and legumes). Future scenarios should also account for changing environmental conditions that will affect both crop and livestock production.

Ultimately, the role of alternative proteins must be considered within comprehensive national food policies. These may be particularly valuable in contexts where ASF production is

constrained (e.g., in countries with little territorial extension such as Singapore) or where overconsumption must be curbed for health and sustainability reasons (e.g., in HICs). A risk-benefit assessment approach that integrates product design, dietary context, and broader societal impacts is needed. Initiatives aimed at democratizing the production of alternative ASFs (e.g., New Harvest) or promoting decentralized/localized manufacturing could help to ensure more equitable outcomes.

Conclusion

Alternative proteins are a valuable resource that should be considered as part of integrated policies aimed at building healthier, more sustainable, and just food systems. However, this potential can only be realized through comprehensive research that addresses nutritional, physiological, safety, environmental, and socio-economic dimensions, alongside careful integration into food policy.

Statements

Author contributions

FB: Writing – review & editing, Writing – original draft, Conceptualization.

Funding

The author declared financial support was received for this work and/or its publication. The author was invited, with expenses covered, by the National University of Singapore to attend a meeting on alternative proteins in August 2025.

Conflict of interest

The author declared that this work was conducted in the absence of financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author declared that no generative AI was used in the creation of this manuscript.

Publisher's note

References

1. Global Panel on Agriculture and Food Systems for Nutrition. *Foresight 2.0. Future food systems: for people, our planet, and prosperity*. GLOPAN (2020). Available at: https://www.glopan.org/foresight2/

2. Searchinger T, Waite R, Hanson C, Ranganathan J, Dumas P. *World Resources Report. Creating a sustainable food future*. World Resources Institute (2019). Available at: https://research.wri.org/wrr-food.

3. van Dijk M, Morley T, Rau ML, Saghai Y. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. *Nat Food* (2021) 2(7):494–501. doi: 10.1038/s43016-021-00322-9

4. World Health Organization. *Red and processed meat in the context of health and the environment: many shades of red and green. Information brief*. Geneva: WHO (2023). Available at: https://www.who.int/publications/i/item/9789240074828

5. Springmann M, Clark M, Mason-D'Croz D, Wiebe K, Bodirsky BL, Lassaletta L, et al. Options for keeping the food system within environmental limits. *Nature* (2018) 562(7728):519–25. doi: 10.1038/s41586-018-0594-0

6. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT–*Lancet* Commission on healthy diets from sustainable food systems. *Lancet* (2019) 393(10170):447–92. doi: 10.1016/S0140-6736(18)31788-4

7. Kaplan DL, McClements DJ. Hybrid alternative protein-based foods: designing a healthier and more sustainable food supply. *Front Sci* (2025) 3:1599300. doi: 10.3389/fsci.2025.1599300

8. Food and Agriculture Organization of the United Nations, World Health Organization. *Food safety aspects of cell-based food*. Rome: FAO (2023). doi: 10.4060/cc4855en

9. Monteiro CA, Cannon G, Moubarac J-C, Levy RB, Louzada MLC, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr* (2018) 21(1):5–17. doi: 10.1017/S1368980017000234

10. Lane MM, Gamage E, Du S, Ashtree DN, McGuinness AJ, Gauci S, et al. Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. *BMJ* (2024) 384:e077310. doi: 10.1136/bmj-2023-077310

11. Popkin BM, Barquera S, Corvalan C, Hofman KJ, Monteiro C, Ng SW, et al. Towards unified and impactful policies to reduce ultra-processed food consumption and promote healthier eating. *Lancet Diabetes Endocrinol* (2021) 9(7):462–70. doi: 10.1016/S2213-8587(21)00078-4