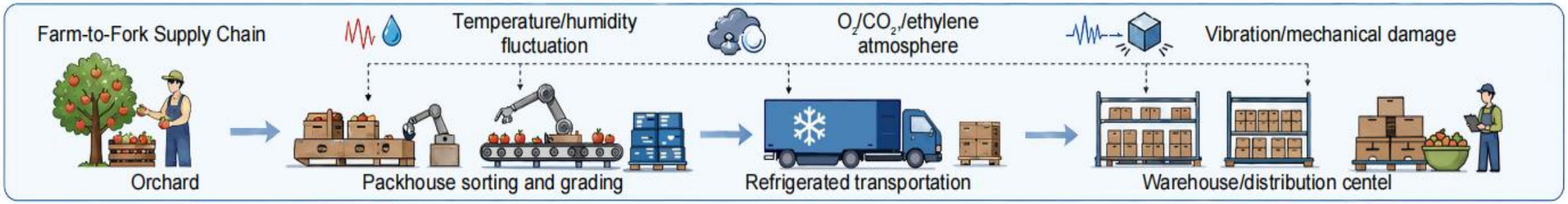
From prediction to actionable mechanisms: Explainable multi-omics AI for farm-to-fork postharvest preservation

Peihua Ma[1], Xiaoxue Jia[1], Bei Fan[1], Boqiang Li[2], Tao Lin[3], Jiping Sheng[4], Cheng-I Wei[5], Yingjian Lu[6], Yizhou Ma[7], Lin Chen[8], Songtao Jiu[9], Fengzhong Wang[1*]

1 Institute of Food Science and Technology, Chinese Academy of Agricultural Sciences, Key Laboratory of Agro-Products Processing, Ministry of Agriculture and Rural Affairs, Beijing 100193, China
2 State Key Laboratory of Plant Diversity and Specialty Crops, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China
3 Beijing Key Laboratory of Growth and Developmental Regulation for Protected Vegetable Crops, College of Horticulture, China Agricultural University, Beijing 100193, China
4 School of Agricultural Economics and Rural Development, Renmin University of China, Beijing 100872, China
5 Department of Nutrition and Food Science, College of Agriculture and Natural Resources, University of Maryland, College Park, College Park, MD 20742, USA
6 College of Food Science and Engineering, Nanjing University of Finance and Economics, Nanjing 210003, China
7 Laboratory of Food Process Engineering, Wageningen University & Research, 6700 AA Wageningen, the Netherlands
8 School of Chemistry, Chemical Engineering and Biotechnology, Nanyang Technological University, Singapore 637459, Singapore
9 Department of Plant Science, School of Agriculture and Biology, Shanghai Jiao Tong University, Shanghai 200240, China

Peihua Ma, Xiaoxue Jia, Bei Fan, Boqiang Li, Tao Lin, Jiping Sheng, Cheng-I Wei, et al. 2026. From prediction to actionable mechanisms: Explainable multi-omics AI for farm-to-fork postharvest preservation. ***iMeta*** 5: e70139.
https://doi.org/10.1002/imt2.70139

Background: postharvest losses and the “black-box” bottleneck



Why is a new postharvest AI framework needed?

13.3%

Food loss from harvest to retail

>25%

Even higher losses for fruits and vegetables

19%

Additional waste at the consumer level

The bottleneck

AI can predict risk,
but it still cannot fully explain
“why it spoils” or “how to prevent it.”

Peihua Ma et al. From prediction to actionable mechanisms: Explainable multi-omics AI for farm-to-fork postharvest preservation. iMeta, 2026.

Three key contributions

1. Building an XAI-ready data ecosystem

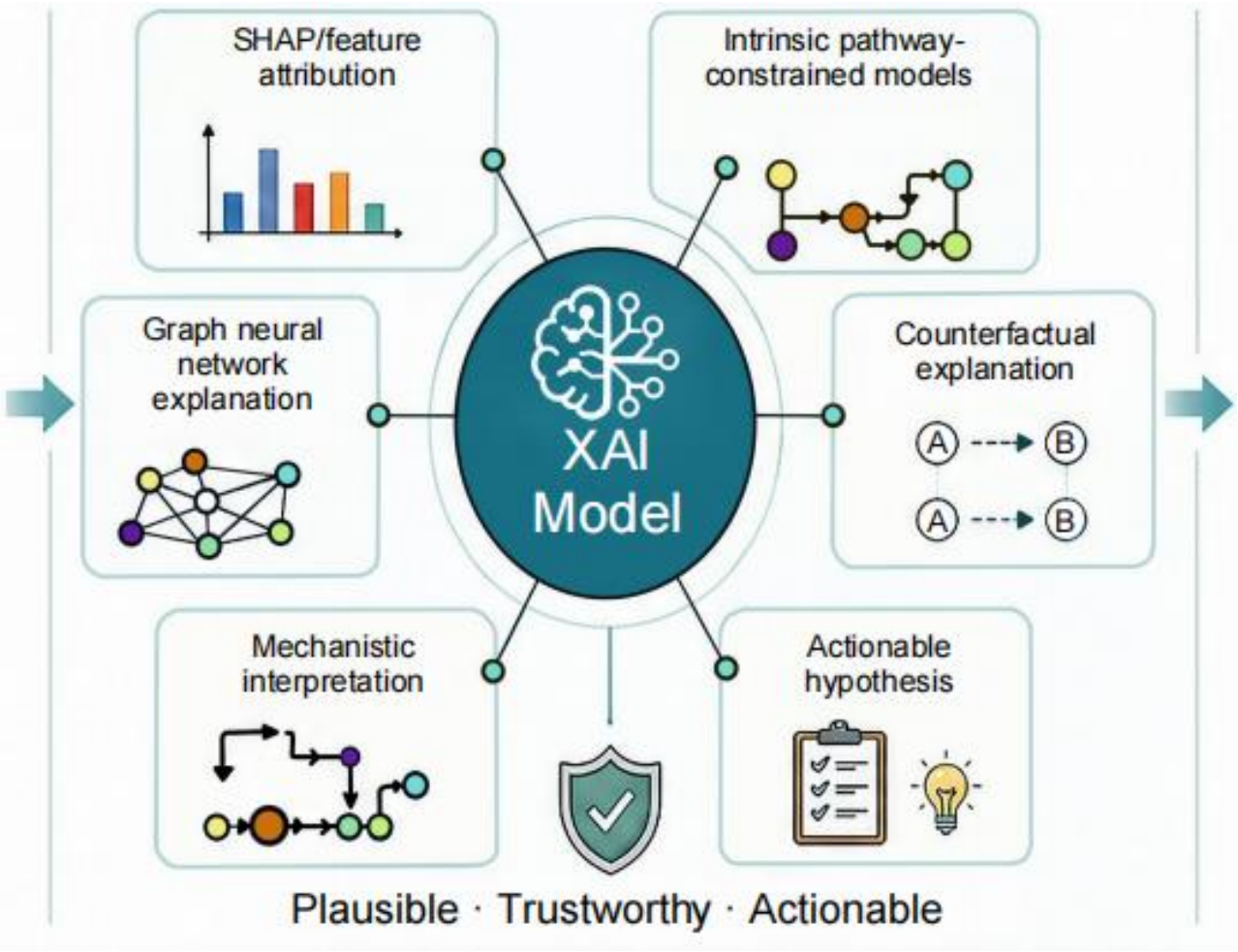
Integrating host omics, microbiome profiles, environmental exposure, and imaging/spectroscopy data.

2. Turning black-box models into mechanistic explanations

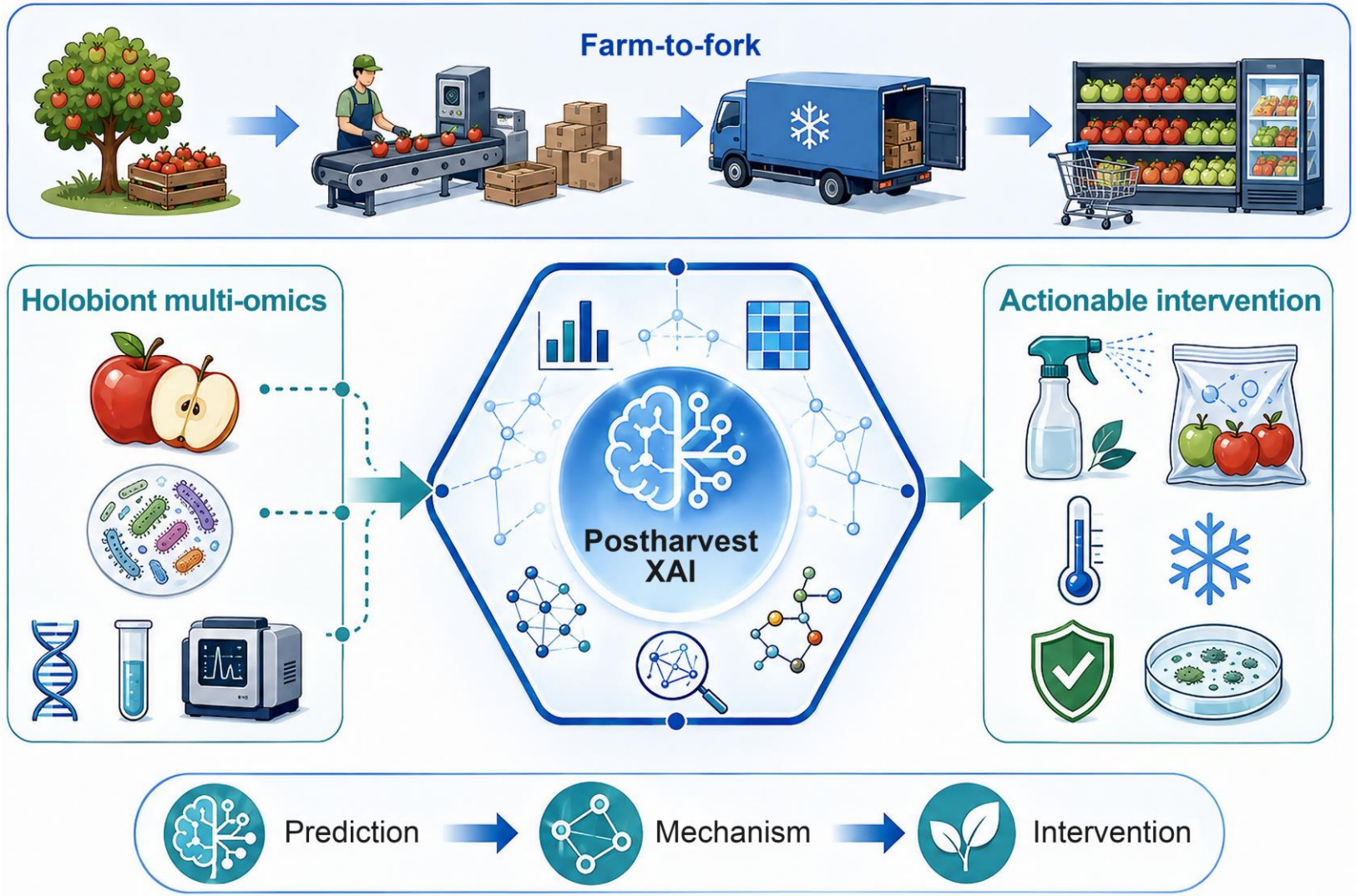
Using SHAP, GNN explanation, and counterfactual reasoning to identify key drivers.

3. Enabling actionable postharvest intervention

Connecting model attribution to coatings, packaging, biocontrol, and targeted intervention.



Graphical abstract: overall concept of postharvest XAI



Graphical abstract. Across the farm-to-fork chain, XAI connects multi-omics data, mechanism-oriented interpretation, and actionable intervention.

Figure 1. XAI framework for farm-to-fork postharvest preservation

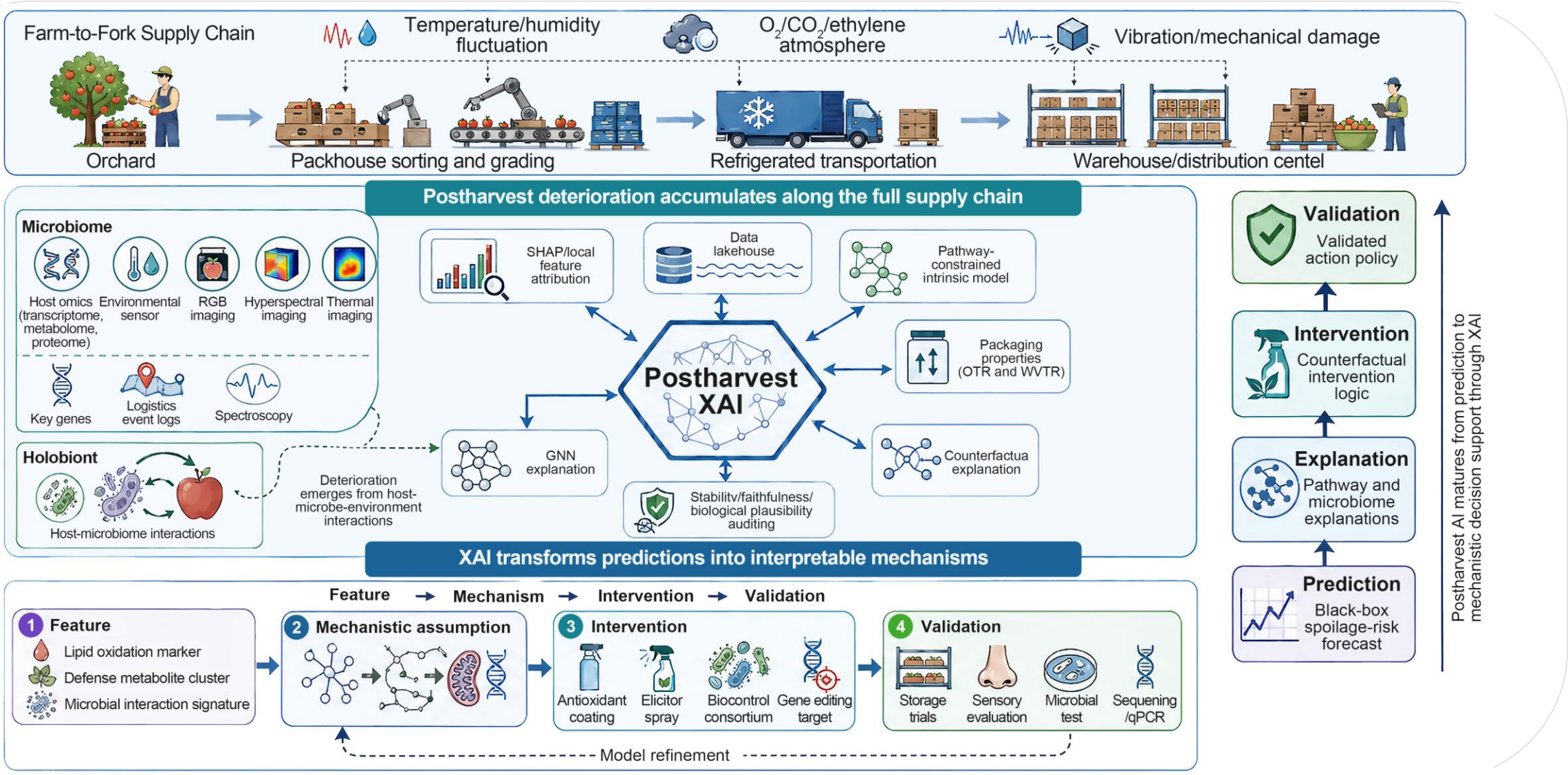


Figure 1 illustrates supply-chain perturbations, multimodal data, XAI explanation modules, intervention strategies, and a validation loop.

Figure 2. From conventional AI prediction to XAI mechanism discovery and intervention

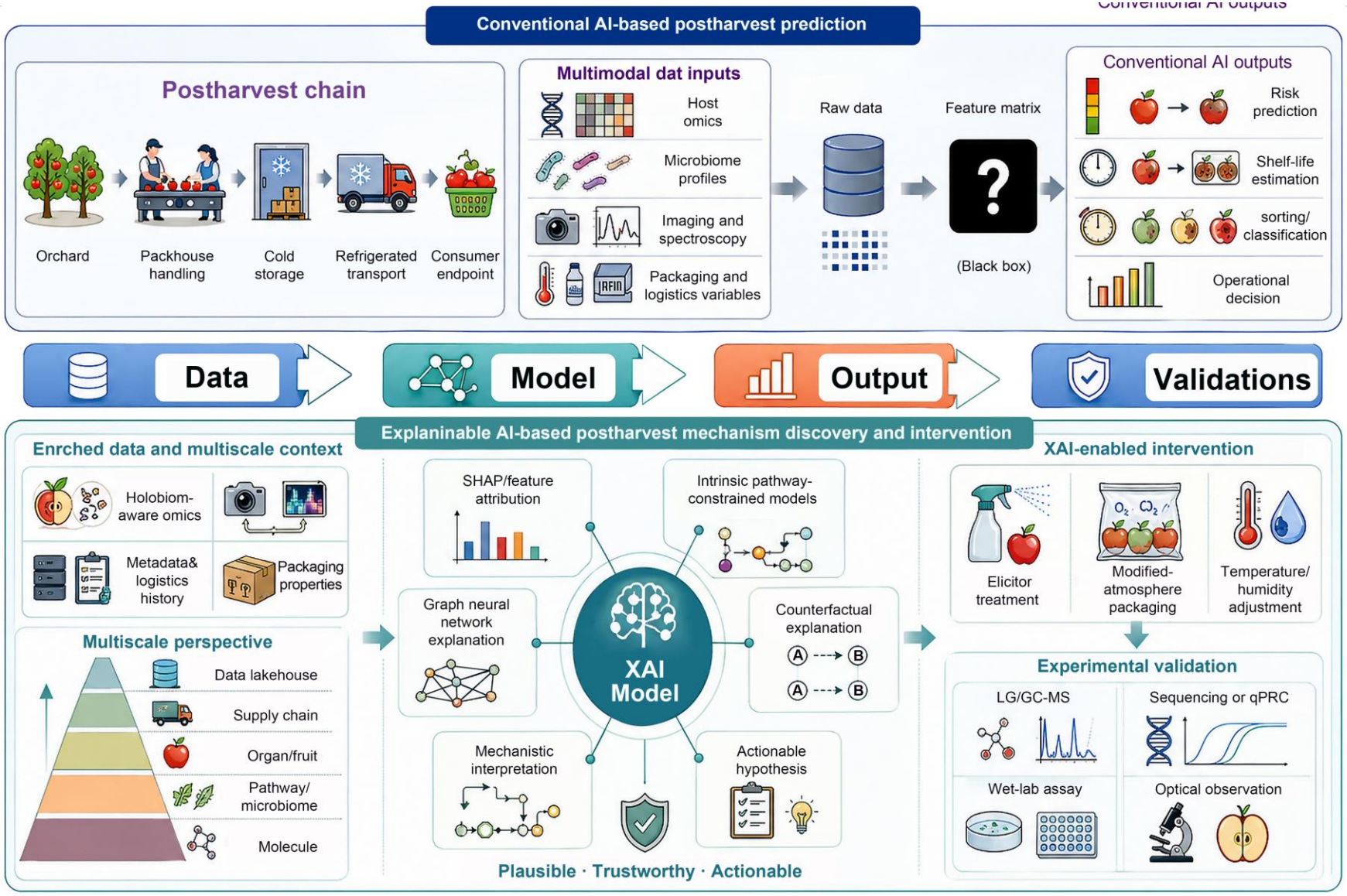
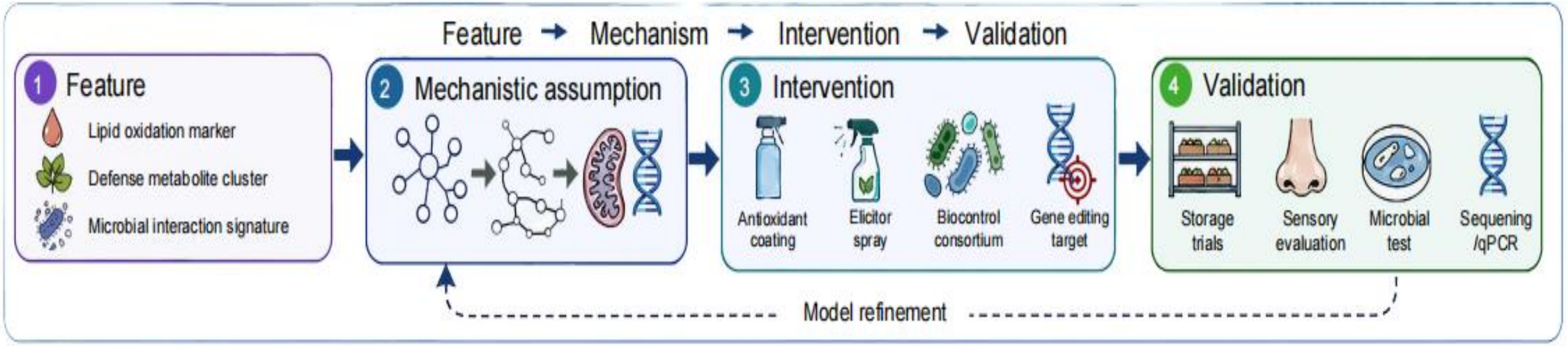


Figure 2 compares conventional postharvest AI prediction with the XAI-driven workflow for mechanism discovery, intervention design, and experimental validation.

Mechanism discovery: feature → mechanism → intervention → validation



How can XAI outputs become testable interventions?

1 Feature identification

Wavelengths, genes, metabolites, microbes

2 Mechanism mapping

Lipid oxidation, defense metabolism, interaction pathways

3 Intervention design

Coatings, elicitors, biocontrol, modified-atmosphere packaging

4 Experimental validation

Storage, sensory testing, microbiology, sequencing

Key transition: from "Will it spoil?" to "Why does it spoil?" and "How can we prevent it?"

main messages

- From prediction to mechanism: AI should not only predict, but also explain.
- From data to validation: multi-omics supports a closed validation loop.
- From black box to action: model outputs should guide preservation decisions.

Peihua Ma, Xiaoxue Jia, Bei Fan, Boqiang Li, Tao Lin, Jiping Sheng, Cheng-I Wei, et al. 2026. From prediction to actionable mechanisms: Explainable multi-omics AI for farm-to-fork postharvest preservation. ***iMeta*** 5: e70139. https://doi.org/10.1002/imt2.70139

iMeta: To be top journals in biology and medicine

WILEY

"***iMeta***" launched in 2022 by iMeta Science Society, impact factor (IF) **33.2**, ranking top 65/22400 in the world. It aims to publish innovative and high-quality papers with broad and diverse audiences. Its scope is similar to *Cell*. The average citation is > 40 in 2025, similar to *Nature* and *Science*. Its unique features include video abstract, bilingual publication, and social media with 600,000 followers. Indexed by **SCIE/ESI**, **PubMed**, **Google Scholar** etc.

"***iMetaOmics***" launched in 2024, indexed by **ESCI**, **PubMed**, **Google Scholar**, with a **target IF>15, and its scope is similar to** *Nature Communications*, *Science Advances*, *Advanced Science*, *Nucleic Acids Research*, etc.

"***iMetaMed***" launched in 2025, with a target IF>15, similar to *Med, Cell Reports Medicine, eBioMedicine, eClinicalMedicine* etc.

Society: http://www.imeta.science
Publisher: https://wileyonlinelibrary.com/journal/imeta
iMeta: https://wiley.atyponrex.com/journal/IMT2
Submission: iMetaOmics: https://wiley.atyponrex.com/journal/IMO2
iMetaMed: https://wiley.atyponrex.com/journal/IMM3

iMetaScience
iMetaScience

office@imeta.science
imetaomics@imeta.science

Promotion Video

Update 2026/3/30