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Review Article

Toward Zero-Waste Agri-Food Systems: A Review of Value Chain Innovations and Policy Interventions

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Abstract

Global agri-food systems lose or waste approximately one-third of the food produced for human consumption every year, with substantial economic, environmental, and social costs. This paper presents a systematic literature review of value chain innovations and policy interventions that support the transition to zero-waste agri-food systems. Following a structured search and screening process, thirty peer-reviewed studies published between 2020 and 2026 were analyzed and synthesized thematically. Three interconnected clusters of innovation emerged. The first, technological valorization, encompasses green extraction technologies, bio-refining, and microbial valorization of agri-food by-products. The second, retail and redistribution strategies, includes the commercialization of imperfect produce and food rescue programs. The third, policy instruments, spans date-label regulation and multi-capital sustainability frameworks. Across these clusters, the evidence shows that technological solutions remain concentrated at the laboratory scale, retail interventions can produce unintended waste-shifting effects, and policy instruments have had, at best, mixed effectiveness. The review further finds that research on zero-waste transitions is disproportionately concentrated in high-income countries, and that social equity considerations remain underrepresented relative to environmental and economic ones. This review concludes that zero-waste agri-food systems will only be achieved through integrated value chain strategies that combine technological innovation with coherent, context-specific policy packages, rather than through technology or policy applied in isolation.

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INTRODUCTION

Food loss and waste (FLW) is one of the most persistent sustainability challenges of the twenty-first century. According to the Food and Agriculture Organization of the United Nations, approximately 1.3 billion tonnes of food produced for human consumption, nearly one-third of total production, is lost or wasted each year globally (FAO, 2013). More recent estimates from the United Nations Environment Programme's Food Waste Index indicate that 1.05 billion tonnes of food were wasted in 2022 across the household, food service, and retail sectors, valued at more than USD 1 trillion (UNEP, 2024). This inefficiency occurs in a world where hundreds of millions of people experience chronic food insecurity (FAO *et al*., 2017), making FLW simultaneously a moral concern and a failure of resource management.

The environmental implications of FLW extend well beyond the loss of edible food. When organic waste is decomposed in landfills, it releases methane, a greenhouse gas with roughly 28 times the warming potential of carbon dioxide over a 100-year horizon. FLW is estimated to account for 8–10% of global anthropogenic greenhouse gas emissions and a substantial share of freshwater withdrawn for agriculture (Pandey *et al*., 2025). The economic burden is similarly large: beyond the trillion-dollar global valuation noted above, post-harvest losses disproportionately affect smallholder farmers in low-income regions, where regional grain losses alone have been valued at billions of dollars annually (World Bank & FAO, 2011).

Food packaging is a further related concern. Landrigan *et al*. (2023) note that plastic packaging used across agri-food systems is a major contributor to global plastic pollution, with emerging evidence of microplastic contamination in soil, water, air, and human tissue. Importantly, the drivers of FLW are not uniform across the value chain or across geography. In low-income countries, losses concentrate in production, post-harvest handling, and storage, driven largely by inadequate infrastructure. In high-income countries, waste is concentrated at the retail and consumption stages, driven by cosmetic standards, over-purchasing, and confusion over date labels. This heterogeneity is a central reason why interventions designed in one context often transfer poorly to another, and it motivates the value chain-wide, cross-context focus of the present review.

Defining Zero-Waste Agri-Food Systems

For clarity and consistency, key terms used throughout this review are defined here and applied uniformly thereafter. *Valorization* (spelled consistently in the American form throughout this manuscript, including in paraphrased references to studies that use the British spelling “valorisation”) refers to the conversion of food by-products or waste streams into higher-value products, energy, or materials. *Zero waste* refers to a management philosophy that seeks to minimize waste generation and maximize resource efficiency through prevention, reduction, reuse, recycling, and recovery, applied in a strict hierarchy with disposal treated only as a last resort (Andika *et al*., 2025). *Agri-food system* refers to the full set of actors and activities production, post-harvest handling, processing, distribution, retail, and consumption involved in bringing food from farm to consumer. *Circular economy (CE)* denotes a systemic alternative to the linear “take-make-dispose” model, in which what would otherwise be waste is redirected as an input to another process (Andika *et al*., 2025). A *multi-capital approach* refers to sustainability frameworks that evaluate systems jointly across natural, financial, social, and human capital, rather than relying on economic or environmental indicators alone (Amamou *et al*., 2025; Dammak *et al*., 2025). *Social equity*, as used here, refers to the fair distribution of the costs, benefits, and labor conditions associated with zero-waste interventions across value chain actors, including smallholder farmers, retail workers, and consumers.

Achieving zero waste is more complex in agri-food systems than in most other sectors because of the high perishability of products, seasonal production cycles, and the sheer volume of organic waste generated (Ligarda-Samanez *et al*., 2025). Amamou *et al*. (2025) show that perishability affects the economic, environmental, and social dimensions of the supply chain simultaneously, meaning that interventions must be tailored to specific product and context characteristics rather than applied generically.

Within a circular agri-food system, streams once discarded as waste are redirected as resource inputs: coffee grounds become mushroom substrate, fruit pomace becomes animal feed or bioenergy feedstock, and dairy whey becomes protein powder or bioplastic precursor. Ligarda-Samanez *et al*. (2025) argue that CE principles can substantially improve the efficiency of agri-food processing; however, Pandey *et al*. (2025) caution that the transition is far from smooth, since design limitations, resource scarcity, and residual waste generation continue to constrain cross-sector efficiency gains. Dhiman *et al*. (2025) similarly argue that closing the loop requires technological innovation to be tied explicitly to policy and market mechanisms for valorization; without this pairing, global sustainability targets are unlikely to be met. Taken together, this literature indicates that the transition to zero-waste agri-food systems is not solely a technical problem, but a joint technological, social, economic, and political challenge — a premise that motivates the integrated, cross-disciplinary scope of this review.

Novelty and Contribution of This Review

Several recent reviews address components of the zero-waste agenda individually: Ligarda-Samanez *et al*. (2025) and Pandey *et al*. (2025) focus on the technological valorization of specific waste streams; Amamou *et al*. (2025) and Dammak *et al*. (2025) focus on multi-capital sustainability indicators; and Andika *et al*. (2025) focus on circular supply chain frameworks at a conceptual level. To date, no review has jointly synthesized technological, retail-level, and policy interventions across the full agri-food value chain within a single analytical frame or examined explicitly how these three categories of intervention interact, reinforce, or undermine one another. This review addresses that gap by (i) integrating evidence across the technological, retail, and policy domains; (ii) explicitly comparing the effectiveness and context-dependence of interventions rather than cataloguing them; and (iii) foregrounding the disparity between where zero-waste research is concentrated (high-income countries) and where FLW impacts are most severe (low- and middle-income countries).

Despite growing scholarly attention, evidence on zero-waste agri-food transitions remains fragmented across disciplinary silos, and no synthesis to date critically evaluates the interaction between technological, retail, and policy interventions across the full value chain. This review addresses that gap through four objectives: i) Classify technological and organizational innovations that reduce FLW across the value chain, including microbial valorization, green extraction technologies, retail strategies for imperfect produce, and food rescue initiatives. ii) Critically evaluate policy interventions supporting zero-waste transitions, including date-label regulation, extended producer responsibility, economic incentives, and consumer education programs. iii) Synthesize evidence on the barriers to, and enablers of, zero-waste initiatives, to inform evidence-based policy and practice.

Methodology

Review Design

This review followed a systematic and transparent literature search, screening, and thematic synthesis process, consistent with established systematic review reporting practice (PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidance for systematic reviews. The review covers the full agri-food value chain, from primary production through post-harvest handling, processing, distribution, retail, and consumption, and examines institutional, organizational, and technological dimensions of FLW reduction jointly.

Search Strategy

Literature was identified through structured searches of the Scopus, Web of Science, and PubMed databases, supplemented by targeted searches in ScienceDirect for journal-specific coverage. Search strings combined the following term groups using Boolean operators: (i) waste terms “food loss,” “food waste,” “agri-food waste,” “food waste valorization/valorisation”; (ii) systems terms “zero waste,” “circular economy,” “value chain,” “supply chain”; and (iii) intervention terms “policy,” “date label,” “food rescue,” “imperfect produce,” “extended producer responsibility.” The search was restricted to peer-reviewed, English-language journal articles and reviews published between January 2020 and June 2026.

Screening and Study Selection

Records retrieved from the search were screened first by title and abstract, and then by full text, against the inclusion and exclusion criteria below. Reference lists of retrieved articles were also hand-searched to identify additional relevant studies (backward citation search). This process yielded a final corpus of thirty peer-reviewed studies published between 2020 and 2026, which form the evidence base synthesized in Sections 3–6. Statistical and contextual background figures cited in the Introduction are drawn from institutional reports (FAO, UNEP, World Bank) rather than from the peer-reviewed corpus, consistent with standard practice of using authoritative gray literature for scene-setting statistics while restricting the systematic evidence synthesis itself to peer-reviewed sources.

Inclusion and Exclusion Criteria

Studies were included if they (i) were published in a peer-reviewed, English-language journal; (ii) addressed food loss or waste reduction, valorization, or related policy interventions within an agri-food value chain context; and (iii) reported empirical findings, a technical process, or a conceptual/analytical framework directly relevant to zero-waste transitions. Studies were excluded if they (i) addressed industrial or municipal non-food biomass waste without a specific agri-food application; (ii) did not address FLW reduction or valorization as a primary focus; or (iii) were not accessible in full text. Gray literature from governments and non-governmental organizations was excluded from the systematic evidence base, in the interest of methodological rigor and reproducibility, but selected authoritative institutional statistics are cited separately for contextual background, as noted in Section 2.3.

Quality Appraisal

Included studies were appraised for methodological transparency (clarity of data sources and methods), relevance of scope to agri-food FLW, and publication in a peer-reviewed venue. Review-type articles were assessed for the comprehensiveness and recency of the literature synthesized. Studies raising unresolved methodological concerns are flagged as such in the relevant sections below (e.g., Section 4.1).

Data Synthesis Approach

Findings were synthesized thematically rather than narratively summarized study-by-study. Studies were grouped into three innovation clusters: technological valorization, retail and redistribution, and policy instruments, and within each cluster, findings were compared across studies to identify points of convergence, contradiction, and context-dependence. This thematic, comparative approach underpins Sections 3–6 and directly informs the barriers/enablers synthesis in Section 5 and the discussion in Section 6.

Value Chain Innovations for Zero-Waste Systems

Technological Innovations: Valorization of Agri-Food By-Products

Valorization of agri-food waste is a foundational pathway toward sustainable food systems and the circular economy (Ligarda-Samanez *et al*., 2025). Agri-food waste streams are a rich source of bioactive compounds that can be converted into antibiotics, alcoholic beverages, nutraceuticals, and manufacturing materials (Pandey *et al*., 2025).

A cluster of emerging extraction technologies including ultrasound-assisted extraction (UAE), microencapsulation, spray drying, lyophilization, and deep eutectic solvent systems recur across the literature as effective means of recovering phenolic compounds, antioxidants, and other bioactive molecules from waste streams such as fruit pomace, vegetable trimmings, coffee pulp, and dairy by-products (Ligarda-Samanez *et al*., 2025; Gómez-García *et al*., 2021; Abbasi-Parizad *et al*., 2021). Despite consistent laboratory-scale success across these studies, three barriers to industrial adoption recur across the literature: industrial scalability, economic feasibility, and regulatory compliance (Ligarda-Samanez *et al*., 2025; Pandey *et al*., 2025). Notably, where Ligarda-Samanez *et al*. (2025) frame scalability primarily as a capital-investment problem, Dhiman *et al*. (2025) reframe it as a business-model problem: their techno-economic assessment finds that integrated, multi-product bio-refinery systems are more economically viable than single-product valorization lines, suggesting that the barrier to scale-up may lie less in the extraction technology itself than in how valorization ventures are structured commercially. This distinction matters for policy design, since subsidy schemes targeted at single-product pilot plants may be less effective than those that incentivize multi-product biorefinery models. Table 1 summarizes the technological innovations identified across waste streams.

Table 1. Summary of Technological Innovations for Agri-Food Waste Valorization

Waste Stream	Technology / Approach	Key Findings/ Value-Added Products	References
Dairy waste (whey, buttermilk)	Fermentation, enzymatic processes	Bioethanol, single-cell protein, bioplastics, bioactive peptides	Adesra *et al*. (2021)
Fruit & vegetable processing	Ultrasound-assisted extraction, microencapsulation, spray drying, lyophilization, deep eutectic solvents	Phenolic compounds, antioxidants, bioactive compounds	Ligarda-Samanez *et al*. (2025)
Mediterranean fruits (olive, grape, citrus, pomegranate)	Circular and digital approaches, green extraction	Renewable materials, bioactive compounds, platform chemicals	Castagna *et al*. (2025)
Elderberry by-product	Recovery and formulation	Natural ingredients for sorbet formulations	Neves *et al*. (2024)
Apple pomace	Pre-treatment optimization, drying enhancement	Improved drying efficiency, reduced stickiness, valorized pomace	Won & Choi (2025)
Coffee parchment	Enzymatic hydrolysis in membrane bioreactors	Xylan-derived sugars, bio-based chemicals	Acosta-Fernández *et al*. (2020)
Coffee cherry pulp	Co-culture fermentation	Anti-diabetes beverage, enhanced sensory and antioxidant properties	Pothimoi *et al*. (2026)
Grape pomace	Biotechnological recycling	Phenolic compounds, dietary fibers, bioactive molecules	Ageeva *et al*. (2022)
Agro-industrial waste (general)	Microbial fermentation	Bacterial cellulose for food, biomedical, packaging applications	Belkozhayev *et al*. (2025)
Agri-waste	Nanomaterial synthesis	Sustainable carbon nanomaterials for electrochemical applications	Abd-Elsalam *et al*. (2021)
Agri-food waste (general)	Green extraction, biorefining	Bioactive molecules, nutraceuticals, cosmeceuticals, pharmaceuticals	Pandhi *et al*. (2025); Osorio *et al*. (2021)
Agri-food by-products	Nutrient and bioactive recovery	Functional foods, health-promoting ingredients	Ingallina *et al*. (2025)
Rheum officinale (rhubarb) petiole & root	Phytochemical extraction, in vitro digestion	Anti-inflammatory compounds, gut microbiota modulation	Liudvytska *et al*. (2025)
Multiple waste streams	Life cycle thinking, environmental risk framework	Sustainable feedstock screening, reduced environmental burden	Bishop *et al*. (2025)

Specific Waste Stream Valorization

Across dairy, fruit and vegetable, and coffee waste streams, a consistent pattern emerges fermentation- and enzyme-based processes dominate as the conversion technology of choice, while the specific technical barrier differs by material. Adesra *et al*. (2021) demonstrate that cheese whey and buttermilk can be converted into bioethanol, single-cell protein, bioplastics, and bioactive peptides through fermentation and enzymatic processing. For fruit and vegetable waste, Gómez-García *et al*. (2021) provide a historical overview of valorization approaches, while Castagna *et al*. (2025) show that Mediterranean fruit waste (olive, grape, citrus, pomegranate) can be converted into renewable materials using combined circular and digital methods — a pairing of physical and digital innovation that is comparatively rare elsewhere in the reviewed literature. Neves *et al*. (2024) similarly valorize elderberry by-product into natural ingredients for sorbet formulations. In contrast to these product-recovery studies, Won and Choi (2025) address a purely processing-level barrier: the stickiness of apple pomace during drying, which they resolve through optimized pre-treatment rather than through novel extraction chemistry. This distinction is instructive — not every valorization barrier is chemical or biological; some are mechanical and process-engineering in nature and require correspondingly different solutions.

For coffee waste, Acosta-Fernández *et al*. (2020) demonstrate enzymatic hydrolysis of xylan from coffee parchment in membrane bioreactors, yielding xylan-derived sugars and bio-based chemicals, while Pothimoi *et al*. (2026) show that co-culture fermentation of coffee cherry pulp extracts can yield a beverage with anti-diabetic, antioxidant, and favorable sensory properties. Together, these studies indicate that a single waste stream (coffee) can support multiple, non-competing valorization pathways depending on which by-product fraction (parchment vs. pulp) is targeted. For grape pomace, Ageeva *et al*. (2022) review biotechnological recycling approaches that recover phenolic compounds and dietary fibers from one of the largest waste streams generated by wine production.

Microbial Valorization and Advanced Materials

Belkozhayev *et al*. (2025) demonstrate that agricultural and agro-industrial waste can be converted into bacterial cellulose via microbial fermentation, with applications in food, biomedical, and packaging industries. Venkataraman & Sundramoorthy (2026) extend this materials-focused strand of the literature by converting waste-derived carbon into nanocomposites for energy storage applications, while Abd-Elsalam *et al*. (2021) link agricultural waste management explicitly to nanotechnology. Read together, these three studies suggest an emerging sub-field in which agri-food waste is valorized not into food-adjacent products, but into advanced materials for entirely separate industries (energy storage, biomedicine), a direction with different regulatory and market pathways than food-grade valorization, and one that may face fewer food-safety barriers but correspondingly less mature supply chains.

Bioactive Compound Recovery

Shawky *et al*. (2025) provides a comprehensive review of biomolecule valorization from agri-food waste streams, covering extraction methods, bioactivity profiles, and commercial potential. Pandhi *et al*. (2025) focus specifically on converting agri-food waste into resistant starch for functional food and gut-health applications. Ingallina *et al*. (2025) synthesize a decade of research on nutrient and bioactive compound recovery for human health applications, and Liudvytska *et al*. (2025) demonstrate the pharmaceutical potential of Rheum officinale petiole and root extracts plant material typically discarded through phytochemical profiling and gut-microbiota-assisted digestion studies. Osorio *et al*. (2021) similarly identify fruit peels, seed oils, and coffee grounds as waste streams rich in compounds with food, cosmetic, and pharmaceutical applications.

Across this cluster of studies, health and nutrition applications are consistently framed as a promising downstream use of valorized compounds, but none of the reviewed studies report safety, efficacy, or consumer-acceptance data beyond the laboratory stage a gap addressed further in Section 6.3.

Life Cycle Thinking and Environmental Risk

While most studies reviewed emphasize the environmental and economic benefits of agri-food waste valorization, relatively few critically examine the possibility that valorization processes themselves may create unintended environmental consequences. In this regard, Bishop et al. (2025) provide an important counterbalance to the predominantly optimistic literature by proposing a life-cycle-thinking-based environmental risk framework for screening sustainable feedstocks. Their approach integrates life cycle assessment (LCA) with environmental risk analysis to evaluate feedstocks not only on their capacity to reduce waste but also on their potential to generate secondary environmental burdens throughout the value chain.

This contribution is particularly significant because many valorization studies focus primarily on resource recovery efficiency, product yield, or economic value creation while paying limited attention to upstream and downstream environmental impacts. For example, green extraction technologies, microbial fermentation systems, and biorefinery processes discussed in earlier sections are generally presented as sustainable alternatives to conventional waste management practices. However, their environmental performance may vary substantially depending on energy consumption, chemical inputs, transportation requirements, water use, and waste generated during processing. Consequently, a technology that appears environmentally beneficial at the laboratory scale may produce unforeseen environmental trade-offs when deployed at industrial scale.

The framework proposed by Bishop et al. (2025) highlights the importance of avoiding burden shifting, whereby environmental impacts are transferred from one stage of the value chain or environmental compartment to another. For instance, converting food waste into bio-based products may reduce landfill disposal and methane emissions but simultaneously increase energy demand, water consumption, or chemical pollution if processing systems are poorly designed. Similarly, transportation of dispersed waste streams to centralized processing facilities may offset some of the environmental benefits achieved through resource recovery. These findings suggest that waste reduction alone should not be used as the sole indicator of sustainability.

A broader synthesis of the reviewed literature reveals a notable gap in the integration of life cycle assessment into food waste valorization research. Although numerous studies report technical feasibility and economic potential, relatively few provide comprehensive assessments of environmental impacts across the entire product life cycle. This limitation is particularly evident in emerging technologies such as nanomaterial synthesis, advanced biorefineries, and bioactive compound extraction, where commercial-scale environmental performance remains largely uncertain. As a result, current evidence may overestimate sustainability benefits by focusing on immediate waste diversion outcomes while overlooking indirect environmental costs.

From a policy perspective, the findings of Bishop et al. (2025) suggest that future regulatory frameworks should incorporate life-cycle-based evaluation criteria when supporting circular economy initiatives. Financial incentives, subsidies, and investment programs that prioritize waste diversion without considering full environmental impacts may unintentionally promote technologies that achieve local waste reduction but generate broader environmental burdens. Therefore, life cycle thinking should become a central component of decision-making processes for technology selection, feedstock prioritization, and policy design.

Overall, the literature indicates that achieving genuinely sustainable zero-waste agri-food systems requires moving beyond simple waste valorization metrics toward holistic assessments that simultaneously consider environmental, economic, and social outcomes. Life cycle thinking provides a critical tool for ensuring that circular economy interventions deliver net sustainability benefits rather than merely relocating environmental impacts within the agri-food system.

Retail Innovations: Imperfect Produce and Food Rescue

Imperfectly produce fruit and vegetables that are edible but do not meet cosmetic standards frequently goes unsold at retail and is a major contributor to food waste. Kazaz *et al*. (2025) identify three retailer strategies for imperfect produce: discarding it, pooling it with cosmetically standard produce, or price-differentiating it as a distinct product line. Their analytical model reveals an important paradox: educating consumers about the value of imperfect produce can reduce sales of standard produce through cannibalization, which can in turn increase unsold standard produce and push retailers back toward the discarding strategy, the opposite of the policy's intent. Kazaz *et al*. (2025) further show that loosening cosmetic tolerance standards for retail produce may simply shift food waste from farms to retail stores rather than reducing total waste. This finding is significant for policy design (Section 4) because it shows that a well-intentioned retail-level intervention can be self-undermining without complementary demand-side management.

Olauson Barlas *et al*. (2025) conducted a scoping review of retail FLW reduction interventions across eight countries (United States, United Kingdom, Germany, Greece, New Zealand, Canada, Sri Lanka, and Israel), finding that food rescue collection methods vary with program capacity and typically include donation acceptance, redistribution programs, and social enterprise models. Logistics, workforce capacity, liability concerns, and financing were identified as recurring barriers, while technology, cooperative partnerships, supportive policy, and financial incentives were recurring facilitators. Read alongside Kazaz *et al*. (2025), these two studies together indicate that retail-level interventions require both an operational/logistics dimension (addressed by Olauson Barlas *et al*., 2025) and a demand-management dimension (addressed by Kazaz *et al*., 2025) to avoid unintended waste-shifting; neither dimension alone is sufficient.

Supply Chain Sustainability Frameworks

Sustainable agri-food supply chains require frameworks that reconcile environmental protection with financial feasibility and social equity. Amamou *et al*. (2025) systematically assess 75 studies (2014–2024) on the integration of natural, financial, social, and human capital in agri-food supply chains, finding that resilient systems emerge from the synergistic interplay of these capitals, supported by technological innovation and stakeholder inclusiveness. However, Amamou *et al*. (2025) also find that developing regions face persistent barriers where coordinated policy support is lacking, and underinvestment constrains real-world impact. Building on this, Dammak *et al.* (2025) propose a conceptual framework that maps interactions between capitals, identifies regional disparities, and highlights evidence-based policy levers for climate-resilient, socially inclusive, and economically sustainable agri-food systems.

This multi-capital perspective is corroborated by Akhter & Ceustermans. (2026), who find that sustainability assessments in supply chains are currently dominated by economic and environmental indicators, while social indicators remain substantially underrepresented. Taken together, these three studies converge on a single conclusion with direct implications for zero-waste transitions: technological and economic solutions alone cannot deliver a sustainable transition without an accompanying, and currently underdeveloped, social equity dimension a theme this review returns to in Section 6.2 in the specific context of developing countries.

Policy Interventions

Date Label Policies

Date labelling is among the most widely used FLW policy instruments, yet the evidence on its effectiveness is decidedly mixed. Alaybek *et al*. (2025) examine the impact of U.S. state-level date-labelling policies on food waste and foodborne illness outcomes, finding that states with stricter date-label restrictions had higher, though not statistically significant, reported waste, and no measurable association between date-label restrictions and foodborne illness. The methodological implication is important: because the waste finding is not statistically significant, it should be read as an absence of demonstrated benefit rather than as evidence that stricter labelling causes more waste. Read in combination, however, these findings suggest that current U.S. state-level date-label policies are not achieving either of their stated goals: waste reduction or improved food safety, and that policy effort might be better directed elsewhere.

Wilson (2025) provides a complementary, experimental perspective, finding that the effect of date-label policies interacts with consumers' individual risk preferences. This interaction is the key finding: it implies that a uniform, "one-size-fits-all" labelling standard is unlikely to be equally effective across a heterogeneous consumer population, and that interventions tailored to consumer risk profiles (for example, differentiated "best before" versus "use by" framing) may outperform uniform standards. Comparing Alaybek *et al*. (2025) and Wilson (2025) directly: the former shows that current policy design is not working at the population level, while the latter offers a candidate explanation for heterogeneous consumer response for why a uniform policy might underperform. Table 2 summarizes retail and policy interventions for food waste reduction, drawing on this and the following sections.

Table 2. Summary of Retail and Policy Interventions for Food Waste Reduction

Intervention Type	Description	Key Outcomes / Findings	References
Imperfect produce commercialization	Selling cosmetically flawed but edible produce separately or bundled with perfect produce	Potential waste reduction but risk of cannibalization; education may paradoxically increase waste	Kazaz *et al*. (2025)
Food rescue programs	Donation, redistribution, social enterprise models for surplus food	Barriers: logistics, liability, finance; Facilitators: technology, partnerships, supportive policies	Olauson Barlas *et al*. (2025)
Date label policies	State-level restrictions on date labeling	No significant reduction in waste; no improvement in food safety; current policies ineffective	Alaybek *et al*. (2025)
Date label & risk preferences	Interaction between labeling and consumer risk attitudes	One-size-fits-all policies less effective; targeted interventions needed	Wilson (2025)
Subsidies & incentives	Tax credits, grants for waste reduction and valorization	Recommended to incentivize circular practices and equitable adoption	Andika *et al*. (2025)
Extended producer responsibility (EPR)	Shifting waste management costs upstream	Recommended framework for accountability	Pandey *et al*. (2025)
Public-private partnerships	Collaborative infrastructure investment	Addresses gaps in developing regions	Olauson Barlas *et al*. (2025)
Multi-stakeholder platforms	Convening businesses, governments, NGOs, researchers	Enables coordinated action and knowledge exchange	Dammak *et al*. (2025)
Life cycle-based regulatory screening	Environmental risk assessment for bioeconomy feedstocks	Ensures feedstock sustainability, avoids burden shifting	Bishop *et al*. (2025)

Critical Assessment of Policy Effectiveness and Applicability

Reviewing Table 2 as a set, rather than as a list of independent instruments, reveals a pattern: the interventions with the weakest direct evidence of effectiveness (date-label policy) are also the most widely implemented, while interventions with more direct financial or operational logic (EPR, subsidies, public-private partnerships) remain largely recommended rather than empirically evaluated within the reviewed literature. This asymmetry heavy real-world reliance on a weekly evidenced instrument, against under-evaluation of theoretically stronger instruments — is itself a policy-relevant finding and suggests that ex-post evaluation resources may currently be misallocated relative to policy salience.

Several intervention types also carry documented or plausible unintended consequences that policymakers should weigh explicitly. As discussed in Section 3.6, loosened cosmetic standards for produce risk shifting waste from farms to retail rather than eliminating it (Kazaz *et al*., 2025). Extended producer responsibility, while conceptually attractive as an accountability mechanism (Pandey *et al*., 2025), has not been evaluated in the reviewed literature for its potential to raise consumer prices or disproportionately burden smaller producers who lack the capital to absorb upstream compliance costs. Similarly, harmonized date-labelling reform, while likely to reduce consumer confusion (Alaybek *et al*., 2025; Wilson, 2025), needs to be designed carefully to avoid weakening food-safety signaling for genuinely perishable, high-risk product categories.

Applicability across contexts is a further limitation. Nearly all empirically evaluated policy interventions identified in this review (date-label studies, retail strategy models) draw on United States and other high-income country settings. Given that Amamou *et al*. (2025) identify fragmented policy support and underinvestment as primary barriers specifically in developing regions, the transferability of high-income-country policy evidence to low- and middle-income contexts cannot be assumed, and is a priority gap discussed further in Section 6.2.

On balance, the literature converges on the recommendation that no single instrument is sufficient: harmonized date-labelling standards (Alaybek *et al*., 2025; Wilson, 2025), financial incentives for donation and valorization infrastructure (Andika *et al*., 2025; Ligarda-Samanez *et al*., 2025), extended producer responsibility (Pandey *et al*., 2025), public-private infrastructure partnerships (Olauson Barlas *et al*., 2025), life-cycle-based feedstock screening (Bishop *et al*., 2025), and multi-stakeholder coordination platforms (Dammak *et al*., 2025) function as complementary components of a policy package rather than substitutes for one another. The critical contribution of this synthesis is not the list itself, which prior reviews have also produced, but the observation that these instruments are rarely evaluated for how they interact, for example, whether subsidy-driven valorization investment (Section 3.1) reduces the volume of surplus available to food rescue programs (Section 3.6), a potential tension not addressed anywhere in the reviewed literature.

Barriers and Enablers

Barriers

Technological barriers. Despite substantial progress in green extraction technologies, Ligarda-Samanez *et al*. (2025) identify industrial upscaling as a primary constraint: many valorization techniques succeed in the laboratory but encounter economic and engineering barriers at commercial scale. Won and Choi (2025) illustrate a related but distinct barrier: material-handling properties, such as the stickiness of fruit pomace during drying, that require process-engineering rather than chemistry-focused solutions.

Economic barriers. Andika *et al*. (2025) identify high start-up capital requirements, inadequate infrastructure, and weak stakeholder coordination as central constraints, noting that the shift from linear to circular business models typically requires significant upfront investment with a long payback period. Dhiman *et al*. (2025) confirm that economic viability remains decisive for commercial-scale implementation, though, as discussed in Section 3.1, their evidence suggests the constraint is partly addressable through multi-product business-model design rather than technology alone.

Regulatory barriers. Policy frameworks remain fragmented across jurisdictions, generating compliance uncertainty. Alaybek *et al*. (2025) show that, at least for date-label policy, current regulatory approaches are not clearly achieving their intended sustainability outcomes.

Regional disparities. Amamou *et al*. (2025) find that barriers are most pronounced in developing countries, where policy support remains fragmented and underinvestment limits real-world impact a finding this review treats as a priority gap (Section 6.2) rather than a peripheral observation.

Underrepresentation of social indicators. Akhter & Ceustermans (2026) find that sustainability assessments in supply chains are dominated by economic and environmental considerations, leaving social indicators underrepresented and intervention-impact assessments correspondingly incomplete.

Facilitators

Technological innovation. Ultrasound-assisted extraction, microencapsulation, and colloidal systems (Ligarda-Samanez et al., 2025; Gómez-García et al., 2021), alongside microbial valorization approaches (Belkozhayev et al., 2025; Abd-Elsalam et al., 2021), provide multiple technically validated pathways for converting residues into higher-value materials.

Stakeholder collaboration. Olauson Barlas *et al*. (2025) find that collaboration among governments, NGOs, entrepreneurs, and even competing firms supports sustainability outcomes through legislation, knowledge sharing, and coordinated innovation.

Regulatory coherence. Andika *et al*. (2025) argue that effective transitions require coordinated policy packages combining regulatory obligations, economic incentives, and informational campaigns rather than single-instrument approaches, a conclusion consistent with the policy synthesis in Section 4.2.

Digital technologies. Andika *et al*. (2025) and Castagna *et al*. (2025) report that big data analytics, artificial intelligence, the Internet of Things, blockchain, and cloud computing can enhance resource efficiency and support circular economy transitions; Castagna *et al*. (2025) provide a concrete illustration through digital approaches to Mediterranean fruit waste transformation.

Life cycle thinking. Bishop *et al*. (2025) demonstrate that environmental risk frameworks can screen sustainable feedstocks to ensure valorization efforts are directed toward genuinely lower-impact routes, rather than merely displacing environmental burden.

Table 3. Barriers and Enablers for Zero-Waste Agri-Food Systems

Category	Barriers	References	Enablers	References
Technological	Industrial scalability challenges; laboratory-to-commercial translation gaps; stickiness in fruit pomace drying	Ligarda-Samanez *et al*. (2025); Won & Choi (2025)	Green extraction technologies (ultrasound, microencapsulation, deep eutectic solvents); microbial valorization	Ligarda-Samanez *et al*. (2025); Gómez-García *et al*. (2021); Belkozhayev *et al*. (2025)
Economic	High capital investment; extended payback periods; limited stakeholder cooperation	Dhiman *et al*. (2025)	Techno-economic viability of integrated multi-product biorefineries	Dhiman *et al*. (2025)
Regulatory / Policy	Fragmented frameworks; ineffective date label policies; compliance burdens	Alaybek *et al*. (2025)	Coordinated policy packages; harmonized standards; multi-stakeholder platforms	Andika *et al*. (2025); Dammak *et al*. (2025)
Regional / Infrastructure	Underinvestment in developing regions; cold chain deficits; fragmented policy support	Amamou *et al*. (2025); Dammak *et al*. (2025)	Public-private partnerships; targeted subsidies	Olauson Barlas *et al*. (2025); Andika *et al*. (2025)
Social / Assessment	Underrepresentation of social indicators in sustainability evaluations	Akhter & Ceustermans. (2026)	Multi-capital frameworks (natural, financial, social, human capital integration)	Amamou *et al*. (2025); Dammak *et al*. (2025)
Stakeholder	Limited cooperation; liability concerns in food rescue	Olauson Barlas *et al*. (2025)	Involvement of governments, NGOs, entrepreneurs, competitors; volunteers; partnerships	Olauson Barlas *et al*. (2025)
Digital / Information	Traditional applications lacking real-world validation	Andika *et al*. (2025); Castagna *et al*. (2025)	AI, IoT, Blockchain, Cloud Computing; circular and digital approaches	Andika *et al*. (2025); Castagna *et al*. (2025)
Environmental	Potential new burdens from valorization	Bishop *et al*. (2025)	Life cycle thinking; environmental risk frameworks	Bishop *et al*. (2025)

Discussion and Research Gaps

Synthesis of Findings

Three cross-cutting patterns emerge from this review. First, technological valorization research is technically mature but commercially immature: across dairy, fruit and vegetable, coffee, and grape by-product streams (Adesra *et al*., 2021; Castagna *et al*., 2025; Neves *et al*., 2024; Won & Choi, 2025; Acosta-Fernández *et al*., 2020; Pothimoi *et al*., 2026; Ageeva *et al*., 2022), and in emerging materials applications (Venkataraman & Sundramoorthy, 2026; Abd-Elsalam *et al*., 2021; Belkozhayev *et al*., 2025), laboratory-scale success is consistent, but industrial-scale techno-economic evidence is not with Dhiman *et al*. (2025) offering the clearest exception through their multi-product bio-refinery analysis. Second, retail-level interventions (food rescue, imperfect produce commercialization) are structurally vulnerable to unintended consequences cannibalization, and waste-shifting unless demand-side and operational measures are designed jointly (Kazaz *et al*., 2025; Olauson Barlas *et al*., 2025). Third, policy evidence is both thin and, where it exists, discouraging: date-label regulation, the most widely implemented FLW policy instrument in the reviewed literature, shows no clear evidence of achieving either of its intended goals (Alaybek *et al*., 2025; Wilson, 2025), while more promising instruments (EPR, multi-stakeholder platforms) remain largely unevaluated (Pandey *et al*., 2025; Dammak *et al*., 2025). Underlying all three patterns is a consistent finding that social equity indicators are systematically underrepresented in sustainability assessments (Akhter & Ceustermans, 2026), even as multi-capital frameworks demonstrate that social, financial, natural, and human capital interact synergistically (Amamou *et al*., 2025; Dammak *et al*., 2025).

Developing-Country Contexts

The evidence reviewed above is disproportionately generated in, and applicable to, high-income countries. The technological valorization literature (Section 3.1–3.5) is drawn almost entirely from laboratory research with no reported developing-country field application. The policy evidence (Section 4) is drawn from the United States and other high-income jurisdictions. Yet Amamou *et al*. (2025) explicitly identify developing regions as facing the most severe combination of fragmented policy support and underinvestment, and background evidence (Section 1.1) indicates that FLW in low-income countries concentrates at the production and post-harvest stages due to infrastructure gaps a fundamentally different intervention point than the retail- and consumption-stage waste that dominates high-income-country research and policy attention. This mismatch has two direct implications. First, technologies validated in high-income, capital-intensive laboratory settings may not be appropriate or affordable at the smallholder or cooperative scale that characterizes much developing-country production. Second, policy instruments such as date-label harmonization, while relevant to high-income retail contexts, are largely irrelevant to loss occurring before food ever reaches a retail shelf. Future research and investment in developing-country contexts should therefore prioritize post-harvest storage and handling infrastructure and cooperative-scale valorization models, rather than assuming that high-income-country solutions will transfer directly.

Research Gaps

Building on the synthesis above, six priority research gaps are identified:

1. *Industrial-scale techno-economic evidence.* Ligarda-Samanez *et al*. (2025) and Dhiman *et al*. (2025) note that few studies assess valorization technologies beyond laboratory scale; Bishop *et al*. (2025) offer a promising environmental risk-screening framework that itself requires broader validation.
2. *Developing-country applicability*, as detailed in Section 6.2 (Amamou *et al*., 2025).
3. *Ex-post policy evaluation.* As discussed in Section 4.2, comprehensive evaluation of policy measures date-label reform, landfill bans, tax incentives — is needed to determine what works, for whom, and under what conditions (Alaybek *et al*., 2025; Wilson, 2025).
4. *Social dimensions of circular transitions.* Equity, labor conditions, and community impacts remain underexamined relative to economic and environmental dimensions (Amamou *et al*., 2025; Dammak et al., 2025; Akhter & Ceustermans, 2026).
5. *Real-world validation of digital technologies.* Andika *et al*. (2025) and Castagna *et al*. (2025) note that AI, IoT, and blockchain applications in agri-food supply chains remain largely traditional, fragmented, and lacking interdisciplinary, real-world validation.
6. *Health and safety evidence for valorized bioactive compounds.* Ingallina *et al*. (2025), Liudvytska *et al*. (2025), and Osorio *et al*. (2021) demonstrate technical potential, but safety, efficacy, and consumer-acceptance evidence needed to convert laboratory findings into functional food products remains largely absent.

CONCLUSION

This review synthesizes evidence on value chain innovations and policy interventions for zero-waste agri-food systems across thirty peer-reviewed studies. The evidence indicates that technological valorization pathways are well established at laboratory scale across dairy, fruit and vegetable, coffee, and grape waste streams, but industrial-scale techno-economic validation remains the exception rather than the rule. Retail-level interventions, including food rescue and imperfect produce commercialization, can reduce waste but are vulnerable to unintended consequences such as market cannibalization and waste-shifting when implemented without complementary demand-side measures. Policy evidence is comparatively weak: existing date-label regulations show no clear evidence of reducing waste or improving food safety, and interaction with consumer risk preferences suggests uniform policy design is unlikely to be broadly effective. Social equity considerations remain consistently underrepresented in sustainability assessments relative to economic and environmental dimensions, and the evidence base as a whole is concentrated in high-income countries despite FLW impacts being most severe in low- and middle-income regions. Achieving zero-waste agri-food systems will require integrated value chain strategies that combine technological innovation with coherent, context-specific policy packages designed jointly rather than sequentially and explicitly adapted to developing-country conditions consistent with the aims of UN Sustainable Development Goals 11, 12, and 13.

Conflict of Interest

The Author declares there is no competing interest.

Author Contribution

The sole author is responsible for the conceptualization, methodology, literature review, data synthesis, writing, editing, and final approval of this manuscript.

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REFERENCES

Abbasi-Parizad, P., De Nisi, P., Scaglia, B., Scarafoni, A., Pilu, S., & Adani, F. (2021). Recovery of phenolic compounds from agro-industrial by-products: Evaluating antiradical activities and immunomodulatory properties. *Food and Bioproducts Processing, 127*, 338–348. https://doi.org/10.1016/j.fbp.2021.03.015

Abd-Elsalam, K. A., Periakaruppan, R., & Rajeshkumar, S. (2021). *Agri-waste and microbes for production of sustainable nanomaterials*. Elsevier.

Acosta-Fernández, R., Poerio, T., Nabarlatz, D., Giorno, L., & Mazzei, R. (2020). Enzymatic hydrolysis of xylan from coffee parchment in membrane bioreactors. *Industrial & Engineering Chemistry Research, 59*(16), 7346–7354. https://doi.org/10.1021/acs.iecr.9b06429

Adesra, A., Srivastava, V. K., & Varjani, S. (2021). Valorization of dairy wastes: Integrative approaches for value added products. *Indian Journal of Microbiology, 61*(3), 270–278. https://doi.org/10.1007/s12088-021-00943-5

Ageeva, N. M., Tikhonova, A. N., & Globa, E. V. (2022). Biotechnologies used to deal with recycling of grape pomace. *IOP Conference Series: Earth and Environmental Science, 1052*(1), 012102. https://doi.org/10.1088/1755-1315/1052/1/012102

Andika, A., Perdana, T., Chaerani, D., & Utomo, D. S. (2025). Transitioning towards zero waste in the agri-food supply chain: a review of sustainable circular agri-food supply chain. *Sustainable Futures*, *10*, 100917. https://doi.org/10.1016/j.sftr.2025.100917

Alaybek, B., Mika, G., Aitken, J. A., Hartman, R., Painter, J., Broad Leib, E. M., Plekenpol, R., Beckmann, J. S., Leets, L., & Sprenger, A. (2025). Can food waste policies promote sustainability? Relationships of food date label policies with food waste and safety outcomes. *Sustainability, 17*(6), 2630. https://doi.org/10.3390/su17062630

Amamou, A., Chabouh, S., Dammak, L., Zouari, A., & Mami, A. (2025). Agri-food supply chain sustainability indicators from a multi-capital perspective: A systematic review. *Sustainability, 17*(9), 4174. https://doi.org/10.3390/su17094174

Belkozhayev, A. M., Abaildayev, A., Kossalbayev, B. D., Tastambek, K. T., Kadirshe, D. K., & Toleutay, G. (2025). Microbial valorization of agricultural and agro-industrial waste into bacterial cellulose: Innovations for circular bioeconomy integration. *Microorganisms, 13*(12), 2686. https://doi.org/10.3390/microorganisms13122686

Bishop, G., Girón-Domínguez, C., Gaffey, J., Henchion, M., Fealy, R., Zimmermann, J., Kargupta, W., & Styles, D. (2025). A life cycle thinking-based environmental risk framework for screening sustainable feedstocks in early-stage bioeconomy projects. *Resources, Environment and Sustainability, 20*, 100201. https://doi.org/10.1016/j.resenv.2025.100201

Akhter, S. R., & Ceustermans, S. (2026). Circular Economy Practices and Barriers within European SMEs in the Construction Sector. *European Journal of Sustainable Development*, *15*(1), 53. https://doi.org/10.14207/ejsd.2026.v15n1p53

Castagna, A., Aboudia, A., Guendouz, A., Scieuzo, C., Falabella, P., Matthes, J., Schmid, M., Drissner, D., Allais, F., Chadni, M., Cravotto, C., Senge, J., Krupitzer, C., Canesi, I., Spinelli, D., Drira, F., Hlima, H. B., Abdelkafi, S., Konstantinou, I., . . . Coltelli, M. (2025). Transforming Agricultural Waste from Mediterranean Fruits into Renewable Materials and Products with a Circular and Digital Approach. *Materials*, *18*(7), 1464. https://doi.org/10.3390/ma18071464

Dhiman, S., Thakur, B., Kaur, S., Ahuja, M., Gantayat, S., Sarkar, S., Singh, R., & Tripathi, M. (2025). Closing the loop: technological innovations in food waste valorisation for global sustainability. *Discover Sustainability*, *6*(1). https://doi.org/10.1007/s43621-025-01073-4

FAO (Food and Agriculture Organization of the United Nations). (2013). *Food wastage footprint: Impacts on natural resources.* FAO.

FAO, IFAD, UNICEF, WFP, & WHO. (2017). *The State of Food Security and Nutrition in the World 2017.* FAO.

Gómez-García, R., Campos, D. A., Aguilar, C. N., Madureira, A. R., & Pintado, M. (2021). Valorisation of food agro-industrial by-products: From the past to the present and perspectives. *Journal of Environmental Management*, *299*, 113571.

Ingallina, C., Spano, M., Prencipe, S. A., Vinci, G., Di Sotto, A., Ambroselli, D., Vergine, V., Crestoni, M. E., Di Meo, C., Zoratto, N., Izzo, L., Navarré, A., Adiletta, G., Russo, P., Di Matteo, G., Mannina, L., & Giusti, A. M. (2025). Enhancing Human Health Through Nutrient and Bioactive Compound Recovery from Agri-Food By-Products: A Decade of Progress. *Nutrients*, *17*(15), 2528. https://doi.org/10.3390/nu17152528

Kazaz, B., Xu, F., & Yu, H. (2025). Retailing strategies of imperfect produce and the battle against food waste. *Manufacturing & Service Operations Management*. https://doi.org/10.1287/msom.2023.0167

Landrigan, P. J., Raps, H., Cropper, M., Bald, C., Brunner, M., Canonizado, E. M., Charles, D., Chiles, T. C., Donohue, M. J., Enck, J., Fenichel, P., Fleming, L. E., Ferrier-Pages, C., Fordham, R., Gozt, A., Griffin, C., Hahn, M. E., Haryanto, B., Hixson, R., . . . Dunlop, S. (2023). The Minderoo-Monaco Commission on Plastics and Human Health. *Annals of Global Health*, *89*(1), 23. https://doi.org/10.5334/aogh.4056

Ligarda-Samanez, C. A., Huamán-Carrión, M. L., Calsina-Ponce, W. C., De La Cruz, G., Huamaní, D. F. C., Cabel-Moscoso, D. J., Garcia-Espinoza, A. J., Sucari-León, R., Aroquipa-Durán, Y., Muñoz-Saenz, J. C., Muñoz-Melgarejo, M., & Jilaja-Carita, E. E. (2025). Technological Innovations and Circular Economy in the Valorization of Agri-Food By-Products: Advances, challenges and Perspectives. *Foods*, *14*(11), 1950. https://doi.org/10.3390/foods14111950

Liudvytska, O., Kowalczyk, M., Krzyżanowska-Kowalczyk, J., Michaś, K., Michalak, M., Balcerczyk, A., Skowrońska, W., Równicki, M., Bazylko, A., Olszewska, M. A., & Kolodziejczyk-Czepas, J. (2025). Phytochemical Profiling, Anti-Inflammatory Action, and Human Gut Microbiota-Assisted Digestion of Rheum officinale Petiole and Root Extracts An In Vitro Study. *Nutrients*, *17*(21), 3455. https://doi.org/10.3390/nu17213455

Neves, C. M. B., Fogeiro, É., Cardoso, S. M., Gonçalves, F., Pinto, A., & Wessel, D. F. (2024). Towards the valorization of elderberry by-product: Recovery and use of natural ingredients for sorbet formulations. *Applied Sciences, 14*(22), 10328. https://doi.org/10.3390/app142210328

Olauson Barlas, C., Martin, W., & Fonseca-Cuevas, A. (2025). Retail food loss and waste reduction interventions: A scoping review. *Journal of Agriculture, Food Systems, and Community Development, 14*(2), 145–164. https://doi.org/10.5304/jafscd.2025.142.027

Osorio, L. L. D. R., Flórez-López, E., & Grande-Tovar, C. D. (2021). The potential of selected agri-food loss and waste to contribute to a circular economy: Applications in the food, cosmetic and pharmaceutical industries. *Molecules, 26*(2), 515. https://doi.org/10.3390/molecules26020515

Pandey, A. K., Thakur, S., Mehra, R., Kaler, R. S. S., Paul, M., & Kumar, A. (2025). Transforming Agri-food waste: Innovative pathways toward a zero-waste circular economy. *Food Chemistry X*, *28*, 102604. https://doi.org/10.1016/j.fochx.2025.102604

Pandhi, S., Mahato, D. K., Kurian, A., Pandey, S., Thamarai, A., Gaur, V., Kamle, M., Shukla, A. C., & Kumar, P. (2025). Transforming agri-food waste into value: Sustainable approaches for next-generation resistant starch production. *Bioresource Technology*, *437*, 133090. https://doi.org/10.1016/j.biortech.2025.133090

Pothimoi, S., Seesuriyachan, P., Chaiyaso, T., Insomphun, C., Yakul, K., Phimolsiripol, Y., & Moukamnerd, C. (2026). Enhanced sensory, antioxidant, and non-toxic anti-diabetes beverage development via co-culture fermentation in coffee cherry pulp extracts. *Food Chemistry: X, 33*, 103524. https://doi.org/10.1016/j.fochx.2026.103524

Shawky, E., Gibbons, S., & Selim, D. A. (2025). Bio-sourcing from byproducts: A comprehensive review of bioactive molecules in agri-food waste streams for valorization and sustainable applications. *Bioresource Technology, 431*, 132640. https://doi.org/10.1016/j.biortech.2025.132640

Dammak, K., Zouari, A., & Dammak, L. (2025). Integrating multi capital approaches for enhancing sustainability in agri-food supply chains. *Discover Sustainability*, *6*(1). https://doi.org/10.1007/s43621-025-02028-5

UNEP (United Nations Environment Programme). (2024). *Food Waste Index Report 2024.* UNEP.

Venkataraman, S., & Sundramoorthy, A. K. (2026). Waste-derived carbon nanomaterials for electrochemical applications: Toward a circular and sustainable future. *RSC Advances, 16*(1), 733–747. https://doi.org/10.1039/d5ra08357e

Wilson, N. L. W., & Miao, R. (2025). Food waste, date labels, and risk preferences: An experimental exploration. *Applied Economic Perspectives and Policy*, *47*(3), 1029–1057. https://doi.org/10.1002/aepp.13507

Won, H. J., & Choi, A. J. (2025). Optimization of pre-treatments to overcome stickiness-related hurdles and enhance drying efficiency in apple pomace. *Food Science & Nutrition, 13*(11), e70988. https://doi.org/10.1002/fsn3.70988

World Bank & FAO. (2011). *Missing food: The case of postharvest grain losses in sub-Saharan Africa.* World Bank.