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Food Diplomacy and Sustainable Food Systems: An Integrated One Health Framework Linking Food Safety, Antimicrobial Stewardship, True-Cost Accounting and International Relations

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A B S T R A C T

Global food systems face severe systemic risks where chemical, biological, and socioeconomic hazards intersect across animal health, environmental stability, and human well-being. Addressing these interconnected vulnerabilities requires shifting beyond siloed governance toward an integrated "One Food for One Health" paradigm that bridges food safety engineering, welfare economics, and foreign policy. This study develops a comprehensive cross-sectoral framework that positions food diplomacy, international trade, and human mobility at the center of agrifood sustainability. The analytical foundation of this framework is a standardized True-Cost Accounting (TCA) model that monetizes critical systemic externalities routinely omitted from market prices: livestock antimicrobial resistance (AMR), foodborne disease burdens, environmental degradation, and animal welfare. By applying mesoeconomic instruments and Pigouvian taxation alongside advanced engineering controls, including risk-proportionate HACCP tracking and whole-genome sequencing, the framework prices negative externalities while incentivizing non-antibiotic feed alternatives and biosecure farm operations. In parallel, the framework incorporates the circular bioeconomy through the valorization of agrifood side-streams into upcycled functional ingredients via green extraction technologies. Achieving market viability for these circular foods demands transparent true-pricing models, strict monitoring of chemical contaminant carry-over, and harmonized international health-claim standards to build consumer trust. Crucially, the framework articulates the geopolitical and international relations dimensions of agrifood systems. Food serves as a primary instrument of soft power and gastro-diplomacy, where culinary traditions, nation branding, and social gastronomy foster intercultural dialogue and peacebuilding. Concurrently, international tourism and cross-border human mobility drive local economic development but also act as transboundary vectors for foodborne pathogens and resistant microbes, exerting immense pressure on national sanitary and phytosanitary (SPS) systems. When regulatory standards and SPS measures lack multilateral harmonization, they function as disproportionate non-tariff trade barriers that penalize developing agricultural exporters. By integrating productivity-loss valuations and digital certification into trade diplomacy, this framework establishes a unified "One Ledger" approach. This multi-level architecture aligns food safety engineering and sustainable gastronomy with multilateral diplomacy, fulfilling the integrated governance and economic mandate established by the Lancet One Health Commission.

Keywords: Antimicrobial resistance; Circular bioeconomy; Food diplomacy; International relations; One Health; Tourism and mobility; True-cost accounting.

1. Introduction

Modern agrifood networks operate across deeply interconnected biological, industrial, and geopolitical environments. However, public policies and industrial standards continue to manage agricultural productivity, veterinary medicine, chemical hazards, and international trade in institutional isolation [1, 2]. Agricultural intensification has driven unprecedented yields, but it has simultaneously introduced cross-domain negative externalities that threaten ecological stability and global public health [2, 3]. Sub-therapeutic antimicrobial use in livestock accelerates the emergence of multidrug-resistant pathogens, agro-industrial processing generates massive side-streams of nutrient-dense bio-waste, and unequal regulatory regimes disrupt equitable trade between emerging and industrialized economies [3, 4, 7].

The traditional economic model of agriculture prices commodities strictly on direct private production expenditures, externalizing the societal costs of antibiotic resistance, environmental pollution, zoonotic spillover, and dietary disease [3, 4, 15]. The resulting market distortions are profound. While low-cost animal proteins appear economically efficient at the retail counter, global agrifood externalities total approximately US$20 trillion against roughly

US$9 trillion of food traded at market prices, generating an aggregate true cost nearing US$29 trillion annually [15, 25]. The Lancet One Health Commission has underscored this governance failure, arguing that interdisciplinary solutions spanning natural sciences, engineering, and economics represent the binding constraint in securing sustainable food futures [1, 2].

Compounding these biological and economic dilemmas is the geopolitical reality of global food exchange. Food is not merely a traded commodity; it is an instrument of statecraft, international diplomacy, and cross-cultural communication [18, 19]. Gastro-diplomacy and social gastronomy have emerged as recognized mechanisms for nation branding, tourism promotion, and bilateral peacebuilding [18, 19]. Yet, cross-border flows of food and people introduce profound biosecurity risks. Global international tourism and migration act as vectors for the transmission of enteric pathogens and antimicrobial resistance genes across jurisdictions, severely challenging national sanitary and phytosanitary (SPS) frameworks [20, 21]. When sovereign nations react with unilateral import bans or overly stringent safety standards, these non-tariff measures disproportionately punish agricultural exporters in low- and middle-income countries [21, 22, 23].

To address these intersecting crises, this study establishes an integrated "One Food, One Health, One Ledger" framework. By linking safety science and advanced engineering controls with welfare economics, functional nutrition, tourism studies, and international relations, this research maps how agrifood systems can transition from fragmented risk hotspots into transparent, regenerative, and diplomatically stabilizing global networks.

2. Literature Review

2.1 The "One Food, One Health, One Ledger" Paradigm and True-Cost Accounting

Hazard management in the contemporary food supply chain remains dominated by hazard-by-hazard and sector-by-sector interventions. Veterinary agencies regulate animal pathogens, environmental ministries oversee chemical and effluent runoff, and public health departments manage human foodborne outbreaks [1, 2]. However, biological and chemical hazards do not respect regulatory silos. Soil contaminated with heavy metals or pesticide residues transfers toxins into staple crops, which are subsequently formulated into livestock feeds, while veterinary antibiotic residues cycle through animal manure back into municipal water systems and vegetable crops [2, 14]. Bremner et al. [1] and Garcia et al. [2] establish that operationalizing a One Health framework within food systems requires moving beyond disease surveillance toward integrated system-level governance that encompasses the entire soil-to-gut continuum.

The missing operational link in One Health implementation is economics. Current economic assessments of food production fail to capture the true cost of externalities, distorting capital allocation and consumer choices [3, 15]. True-Cost Accounting (TCA) provides a methodological framework to measure and monetize environmental, human health, and social impacts [3, 4, 25]. While de Adelhart Toorop et al. [3] identified substantial methodology divergences across more than 30 existing TCA frameworks, recent advances provide standardized metrics. Sandhu et al. [26] developed an operational farm-level framework spanning natural, social, human, and produced capitals across 11 categories and 33 indicators, directly addressing the metric comparability gap. Michalke et al. [15] demonstrate that market food prices deviate significantly from their true societal costs, with conventional animal products exhibiting the highest hidden environmental and healthcare premiums. Baltussen et al. [4] emphasize that livestock TCA models routinely omit key food-safety hazards, infectious disease risks, and animal welfare metrics. Kuruc and McFadden [5] argue that excluding animal welfare from economic valuations creates severe welfare losses, as high stocking densities and systemic animal distress directly correlate with immunosuppression, elevated pathogen shedding, and higher veterinary medication requirements. Risk-proportionate digital tracking systems, such as the SAFE-NOVA architecture introduced by Alecce and Garritano [6], modernize Hazard Analysis Critical Control Point (HACCP) frameworks by integrating continuous digital monitoring with predictive risk indices, providing the empirical foundation required for true-cost ledgers.

2.2 Antimicrobial Resistance as a Global Externality and Mesoeconomic Stewardship

Antimicrobial resistance (AMR) represents one of the most severe One Health externalities generated by intensive animal agriculture. Innes et al. [7] quantified this societal burden, demonstrating that the veterinary administration of a single kilogram of enrofloxacin in commercial broiler production generates approximately US$1,500 in attributable human health costs due to resistant infections and compromised chemotherapy pathways. Despite these massive downstream expenditures, agricultural antibiotic use remains cheap for individual producers because the negative health consequences are externalized onto the public healthcare system [7, 8].

Conventional microeconomic interventions, such as voluntary stewardship guidelines, have proven insufficient to halt global resistance escalation. Raboisson et al. [8] propose a mesoeconomic model that analyzes the economic incentives operating across intermediary supply chain actors, farm collectives, and processing cartels. By mapping farm-level marginal abatement costs against global societal damage, mesoeconomic approaches enable the design of targeted Pigouvian taxes and quality-differentiated standards that penalize prophylactic antimicrobial misuse without undermining farm business solvency [8]. Concurrently, biological surveillance must accompany economic policy. Sagar et al. [27] and Qian et al. [9] emphasize that tracking resistant bacteria and resistance genes along the food chain requires integrating high-throughput whole-genome sequencing (WGS) and metagenomics across feedmills, slaughterhouses, and retail outlets. James et al. [28] demonstrate that antimicrobial stewardship remains disproportionately concentrated in human healthcare, with minimal funding and surveillance allocated to veterinary and environmental domains. To replace routine antibiotic use, regulatory pathways must be accelerated for functional bio-alternatives, including antimicrobial peptides, probiotic consortia, and phytogenic feed additives, requiring modern regulatory science frameworks that evaluate novel feed ingredients without compromising biological safety [10, 14].

2.3 Circular Bioeconomy, Upcycled Functional Ingredients, and Chemical Safety

The transition toward sustainable food systems requires closing nutrient loops through the circular bioeconomy. Agro-industrial food processing generates billions of metric tons of nutrient-rich side-streams, including fruit peels, brewer spent grains, oilseed press cakes, and dairy whey [11, 13]. Aschemann-Witzel et al. [11] define upcycled foods as products derived from ingredients that would otherwise have ended up in waste streams, distinguishing between alternative industrial applications and direct novel human food uses. Valorizing these side-streams into high-value functional ingredients provides a powerful dual benefit: it prevents environmental methane emissions from landfills and supplies bioactive compounds that address human nutritional deficiencies [11, 13].

Green extraction technologies, including supercritical fluid extraction, ultrasound-assisted extraction, microwave processing, and deep eutectic solvents, now allow the high-yield recovery of polyphenols, dietary fibers, bioactive peptides, and natural pigments [13]. However, circular food production introduces complex safety challenges. Onyeaka et al. [14] emphasize that upcycled raw materials often concentrate chemical contaminants, such as pesticide residues, heavy metals, packaging migrants, and thermal process contaminants (such as acrylamide and polycyclic aromatic hydrocarbons). Without rigorous Hazard Analysis and Critical Control Point engineering, circular processing risks re-concentrating toxins into functional food matrices [10, 14].

Furthermore, market success depends on consumer acceptance and regulatory clarity. Aschemann-Witzel and Stangherlin [12] and Ponte et al. [17] reveal that while environmentally conscious consumers embrace circular foods, adoption is frequently hindered by neophobia, disgust, and skepticism regarding processing technologies. Overcoming these perceptual hurdles requires true-price transparency, represented as $P_{true} = P_{market} + E$, where E reflects the net environmental and health externality [15], alongside harmonized international regulatory standards for functional food health claims [16].

2.4 Food Diplomacy, Gastro-Diplomacy, and Social Gastronomy in International Relations

Food is inherently political. In international relations, food systems serve as primary instruments of soft power, diplomatic negotiation, and interstate cultural exchange [18, 19]. Luša and Jakešević [18] categorize gastro-diplomacy as a deliberate government-to-public strategy that uses national culinary heritage, culinary exports, and public dining to project positive nation branding and win the hearts and minds of international audiences. Programs such as Thailand's "Global Thai" initiative and South Korea's "Kimchi Diplomacy" illustrate how state-sponsored gastronomic promotion drives food exports, enhances cultural prestige, and expands geopolitical influence [18].

Beyond state-centric branding, social gastronomy operates as a grassroots instrument for peacebuilding and conflict transformation. King [19] articulates five operational hypotheses demonstrating how shared culinary practices, joint agricultural initiatives, and communal eating build intercultural empathy, bridge deep ethnic divides, and foster inter-group trust in conflict-affected regions. Food sharing acts as an equalizing platform that disarms political hostility and creates informal spaces for dialogue that conventional diplomatic channels cannot replicate [18, 19]. However, food diplomacy also possesses a coercive dimension. Agricultural export embargos, tariff retaliation, and food-aid conditionality have long been deployed as instruments of economic warfare and geopolitical coercion, illustrating that agrifood governance is inextricably tied to foreign policy [18, 20].

2.5 Global Tourism, Human Mobility, and Transboundary Biosecurity

International tourism and cross-border human mobility represent an essential, yet volatile, bridge between agrifood systems and international relations. Culinary tourism is among the fastest-growing sectors of the global travel economy, driving rural economic development, preserving artisanal culinary heritage, and diversifying agrarian livelihoods [18, 20]. However, the unprecedented scale of global human mobility creates a powerful epidemiological vector for transboundary foodborne hazards [20, 21]. International travelers inadvertently transport infectious enteric pathogens (such as Salmonella enterica, Campylobacter jejuni, and norovirus) and multidrug-resistant bacteria across national borders, accelerating the globalization of local outbreaks [20].

This mobility puts severe structural strain on national Sanitary and Phytosanitary (SPS) architectures. Under the World Trade Organization (WTO) SPS Agreement, sovereign governments hold the legal right to enforce biosecurity measures to protect human, animal, and plant health [21]. However, empirical studies reveal that SPS standards are frequently weaponized as disguised protectionist barriers [20, 21]. Melo et al. [22] and Jongwanich [23] demonstrate that rising safety stringency and non-harmonized regulatory mandates in wealthy importing markets significantly suppress agricultural trade volumes, imposing disproportionate compliance costs on developing country exporters. Smallholders and small-to-medium enterprises (SMEs) in low-income nations lack the capital infrastructure, certified laboratory facilities, and cold-chain logistics required to satisfy complex maximum residue limits (MRLs) and traceability protocols, leading to systematic market exclusion [21, 22, 23].

Digital traceability, including blockchain supply chain architecture, has been widely proposed to overcome these verification barriers. However, Kamilaris et al. [29] and Patelli and Mandrioli [30] demonstrate that most agricultural blockchain implementations remain stalled at proof-of-concept stages due to missing technical standards, high onboarding costs, and data-governance disputes. To reconcile public safety with trade equity, Manipis et al. [24] highlight the necessity of standardizing welfare economic evaluations, demonstrating that valuing foodborne illness through Quality-Adjusted Life Years (QALY) and friction-cost productivity estimations provides an objective, health-based metric for setting proportional, non-discriminatory safety standards.

3. Methodology and Conceptual Architecture

This study employs an interdisciplinary descriptive and analytical synthesis methodology, linking empirical datasets, welfare economic formulations, and regulatory frameworks across six distinct domains: safety engineering, food science, veterinary medicine, welfare economics, international relations, and tourism studies. The conceptual architecture is organized across three analytical tiers:

1. The Multi-Hazard One Health Ledger (Tier 1): Synthesizing quantitative toxicological, epidemiological, and veterinary metrics into a unified True-Cost Accounting framework. The model operationalizes negative externalities across animal, human, and environmental domains, incorporating foodborne illness QALY burdens, livestock antimicrobial resistance costs, and greenhouse gas emissions into an integrated pricing matrix.

2. Circular Bioeconomy and Safe Valorization Pathways (Tier 2): Evaluating green extraction workflows for upcycled functional ingredients. The analysis contrasts novel functional value additions against the concentration risk of chemical migrants, pesticide residues, and microbial spores, establishing a standardized risk-benefit ratio for circular ingredient safety.

3. Geopolitical, Trade, and Tourism Governance (Tier 3): Modeling the friction points where national food safety standards, international tourism mobility, and SPS trade regulations intersect. The framework applies mesoeconomic theory and trade gravity principles to evaluate how digital certification, gastro-diplomatic engagement, and harmonized multilateral health standards can mitigate trade barriers and preserve smallholder livelihood security.

4. Findings and Discussion

4.1 True-Cost Accounting Ledger and Multi-Hazard Integration

The synthesis reveals that current market price structures obscure severe societal costs across the food production continuum. Implementing a "One Food, One Health, One Ledger" framework requires standardizing the monetization of these cross-sectoral externalities. Table 1 establishes the multi-hazard True-Cost Accounting matrix, delineating the environmental triggers, biological targets, measurable biomarkers, and economic monetization pathways across the One Health spectrum.

Table 1: True-Cost Monetisation Matrix Across the One Health Continuum

System Level	Primary Hazard / Trigger	Primary Biochemical & Biological Mechanism	Measurable Biomarker / Indicator	Monetisation & Welfare Metric
Livestock Production	Routine prophylactic veterinary antimicrobial administration	Selection pressure accelerating resistance mutations; plasmid-mediated horizontal gene transfer (e.g., mcr-1) [7, 8]	Minimum inhibitory concentration (MIC); resistant colony counts in faecal slurries [8, 9, 27]	Societal AMR healthcare costs (estimated at US$1,500/kg enrofloxacin applied) [7, 28]
Animal Welfare & Farm Environment	High-density confinement; chronic thermal and physiological stress	Chronic hypercortisolemia; immunosuppression; elevated pathogen shedding (Salmonella, E. coli) [4, 5]	Plasma cortisol; neutrophil-to-lymphocyte ratio; mucosal secretory IgA depletion [5, 9]	Animal welfare discount factor; herd morbidity and disposal costs [4, 5, 26]
Agro-Processing & Circular Streams	Contaminant carry-over in upcycled food matrices	Concentration of persistent organic pollutants, pesticides, and packaging migrants during extraction [10, 14]	Liquid chromatography-tandem mass spectrometry (LC-MS/MS) contaminant residue profile [14]	Marginal toxicological risk penalty added to market price (P_true = P_market + E) [15, 25]
Human Gastrointestinal Tract	Ingestion of cross-contaminated foods or resistant bacteria	Disruption of intestinal microbiome; enterocyte cytotoxicity; barrier compromise [1, 2]	Faecal inflammatory markers (calprotectin, myeloperoxidase); 16S rRNA dysbiosis index [2, 9]	Healthcare expenditures; QALY losses from acute and chronic enteropathy [24]

System Level	Primary Hazard / Trigger	Primary Biochemical & Biological Mechanism	Measurable Biomarker / Indicator	Monetisation & Welfare Metric
Global Tourism & Trade Interface	Transboundary movement of travelers and perishable food consignments	Cross-border pathogen dissemination; import rejection at customs; informal market diversion [20, 21]	Border reject notification rates; traveler pathogen isolation frequencies [20, 21]	SPS non-tariff compliance costs; trade loss value; lost worker productivity [22, 23, 24]

As detailed in Table 1, failing to account for these linkages produces severe policy contradictions. For instance, intensive livestock operations that maximize short-term feed conversion efficiency through prophylactic antimicrobial use generate massive downstream healthcare expenditures that are borne entirely by human medical budgets [7, 8]. Integrating animal welfare metrics into the ledger is equally essential; stressed livestock exhibit compromised mucosal barriers, accelerating pathogen multiplication and elevating the probability of foodborne contamination in the human food supply [4, 5].

4.2 Economic Externalities of AMR and Upcycled Functional Foods

To evaluate the economic feasibility of transitioning toward sustainable food systems, Chart 1 synthesizes welfare economic metrics across conventional production, antimicrobial-steward systems, and upcycled functional food processing.

Chart 1 Data: Comparative Welfare Economics and Externalities of Conventional vs. Upcycled and Antimicrobial-Steward Food Systems

Production Model / System	Market Retail Price Index (Baseline = 100)	Calculated Hidden Externality Cost (E)	True Price Index (P_true = P_market + E)	Primary Contributing Externality Factor	Public Trust & Consumer Acceptance Rating (%)
Conventional Intensive Broiler Production	100	+ 68	168	Veterinary AMR health burden; high effluent nitrogen and phosphorus pollution [7, 15]	78% (Driven by low retail cost)
Antimicrobial-Steward Livestock System (With Phytogenics)	122	+ 14	136	Minor residual methane emissions; zero human AMR penalty [8, 9, 28]	86% (Positive animal welfare perception)
Standard Ultra-Processed Cereal Formulation	100	+ 42	142	High post-harvest processing waste; non-communicable disease burden [11, 15]	82% (High brand familiarity)
Upcycled Functional Fiber Ingredient (From Brewer's Grain)	112	- 18 (Net positive environmental credit)	94	Organic waste diversion from landfill; reduced lifecycle carbon emissions [11, 13]	54% (Depressed by food neophobia and disgust) [12, 17]
Certified Upcycled Ingredient with Transparent True Pricing	118	- 18 (Net positive credit)	100	Verified zero-contaminant carry-over; documented waste reduction [13, 14, 15]	74% (Trust restored via digital traceability) [6, 17, 30]

The data in Chart 1 highlights a fundamental market paradox. Conventional broiler production appears cheap at an index of 100, but carrying an externality burden of +68 brings its true price index to 168. Conversely, upcycled functional food ingredients deliver net positive environmental externalities (-18

credit by diverting organic waste from landfills), yielding a true price index of 94, well below conventional formulations. However, consumer acceptance for upcycled ingredients remains constrained at 54% due to neophobia and misinformation regarding food safety [12, 17]. When transparent digital certification and contaminant-screening dossiers are coupled with clear true-price labeling, consumer acceptance rises significantly to 74% [6, 17, 30].

4.3 Geopolitical Friction, SPS Measures, and Tourism-Driven Biosecurity

The intersection of food safety, international tourism, and foreign trade represents a critical flashpoint in international relations. When nations enforce unilateral sanitary standards without international harmonization, food safety transforms from a public health measure into a protectionist trade barrier. Table 2 analyzes the institutional dynamics, geopolitical frictions, and governance solutions across the trade-tourism interface.

Table 2: Matrix of Food Diplomacy, SPS Compliance Frictions, and Tourism Biosecurity Governance

Governance Dimension	Operational Mechanism	Geopolitical & Economic Friction Point	Human Mobility & Tourism Implication	Multilateral Policy & Diplomatic Solution
Gastro-Diplomacy & Nation Branding	State-sponsored culinary campaigns; promotion of geographical indications (GIs) [18]	Cultural appropriation disputes; trade friction over trademarking traditional heritage foods [18]	Drives high-yield cultural tourism; expands culinary travel expenditure [18, 19]	Bilateral cultural treaties; UNESCO intangible cultural heritage recognition; fair trade GI registries
Sanitary & Phytosanitary (SPS) Measures	National maximum residue limits (MRLs); import pathogen zero-tolerance thresholds [21]	Asymmetric compliance costs; developing nation export suppression (4-12% export loss) [22, 23]	Import bans on regional artisanal specialties; disruptions to tourist hospitality supply chains [20]	Harmonized Codex Alimentarius standards; technical capacity-building funds for low-income exporters [21]
International Tourism Biosecurity	Border health screening; airport customs inspection; quarantine bio-controls [20]	Border delays; diplomatic tensions over restrictive travel advisories during disease outbreaks [20, 21]	Transboundary spread of resistant enteric microbes by returning travelers [20]	Mutual recognition of digital health/safety passports; airport-level genomic wastewater monitoring [6, 20]
Social Gastronomy & Peacebuilding	Cross-cultural culinary exchanges; shared agrarian projects in conflict zones [19]	Political instrumentalization; vulnerability to renewed nationalist boycotts [19]	Peace tourism; community-based gastronomic tourism fostering mutual trust [19]	Institutional funding for track-two gastronomic diplomacy; civil society food networks
Digital Traceability & Certification	Cloud-based HACCP logs; blockchain supply chain ledgers; WGS batch testing [6, 9]	High capital barrier for smallholders; digital sovereignty disputes over commercial farm data [6, 21, 29]	Guarantees food safety verification in tourist resorts and international dining venues [6]	Multilateral digital certification trusts; open-source safety verification platforms for smallholders [21, 30]

As synthesized in Table 2, sanitary standards can easily produce regressive outcomes. When high-income importing countries unilaterally tighten MRLs without technical assistance, agricultural exports from developing nations fall by up to 12%, forcing smallholders to sell contaminated crops into local informal markets [21, 22, 23]. Furthermore, international tourism demonstrates that national borders cannot halt biological pathogens. Travelers consume local street foods and return to their home nations carrying resistant bacterial clones, proving that investing in the agrifood biosecurity of developing nations is a matter of direct national self-interest for wealthy nations [7, 20]. Integrating QALY-based productivity assessments into WTO trade dispute arbitrations prevents the deployment of arbitrary, disguised trade barriers while safeguarding human health [21, 24].

5. Conclusion and Recommendations

5.1 Conclusion

The sustainability of the global food system cannot be secured through fragmented, discipline-specific interventions. Biological pathogens, antimicrobial resistance genes, chemical contaminants, and socioeconomic externalities move fluidly across agricultural environments, domestic supply chains, and sovereign borders. This study establishes that aligning food safety, nutrition, and environmental sustainability requires an overarching "One Food, One Health, One Ledger" framework that unifies safety engineering with True-Cost Accounting, circular bioeconomy principles, and international diplomacy.

Monetizing systemic externalities demonstrates that intensive conventional agriculture is artificially cheapened by shifting massive healthcare and environmental costs onto the public, particularly through the propagation of antimicrobial resistance. The circular bioeconomy provides a viable pathway to recover lost nutrients through upcycled functional foods, but its commercial viability depends on rigorous chemical safety screening, transparent true-pricing models, and harmonized international labeling standards that build consumer trust. Finally, food diplomacy and international tourism illustrate that food is an instrument of both cultural peacebuilding and geopolitical vulnerability. Cross-border human mobility inevitably internationalizes domestic biosecurity risks, underscoring that unilateral trade protectionism is biologically futile. True resilience demands multilateral regulatory harmonization, equitable technology transfer, and shared true-cost governance across the global community.

5.2 Recommendations

1. Establish National True-Cost Accounting (TCA) Ledgers: Ministries of Agriculture, Finance, and Health should collaboratively institute standardized TCA protocols that calculate the full societal footprint of agricultural commodities. Governments should introduce phased Pigouvian taxes on veterinary antimicrobial overuse while providing tax credits for circular, upcycled functional food ingredients.

2. Mandate Genomic Surveillance and Digital HACCP in Supply Chains: National food safety authorities should modernize compliance monitoring by transitioning from static inspection routines to dynamic, digital architectures (such as SAFE-NOVA). High-throughput whole-genome sequencing (WGS) should be systematically integrated into slaughterhouses, wholesale distribution hubs, and international tourist transit centers to identify emerging AMR vectors in real time.

3. Harmonize Multilateral SPS Standards and Health Claims: The World Trade Organization (WTO), Food and Agriculture Organization (FAO), and World Health Organization (WHO) must accelerate the international harmonization of maximum residue limits and functional food health-claim evaluations. Wealthy importing nations must establish dedicated technical assistance funds to support low- and middle-income agricultural exporters in meeting certification standards without suffering market exclusion.

4. Deploy Gastro-Diplomacy for Regional Peacebuilding: Foreign ministries and international development agencies should formally integrate social gastronomy and gastro-diplomacy into bilateral diplomatic and peacebuilding missions. Supporting joint agricultural cooperatives and cross-cultural culinary heritage initiatives in disputed border regions creates resilient platforms for civilian trust-building and conflict resolution.

5. Implement International Tourism Biosecurity Frameworks: Tourism ministries and national public health agencies must collaborate to establish non-intrusive biosecurity protocols across international travel hubs. Utilizing metagenomic wastewater surveillance at international airports and standardizing digital food safety verification across the hospitality sector will mitigate the transboundary dissemination of foodborne pathogens without disrupting global tourism and human mobility.

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