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Overview

Food of Animal Origin: Safety, Quality, and Innovation for One Health

Foods of animal origin, such as milk, meat, eggs, fish, and their processed derivatives, constitute irreplaceable components of the human diet, supplying high-biological-value proteins, essential fatty acids, bioavailable minerals, and vitamins. Their intrinsic biological complexity and perishability, however, render them highly susceptible to contamination from pathogenic microorganisms, chemical residues, and environmental pollutants. Safeguarding their safety and quality, therefore, represents a critical pillar of public health, global trade, and sustainable development, demanding a holistic **One Health** framework that synthesizes environmental stewardship, animal health management, and human health protection.

The **safety** of animal-origin foods is continually challenged by diverse biological and chemical hazards. Zoonotic pathogens, including *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter* spp., and Shiga toxin-producing *Escherichia coli*, remain predominant causes of foodborne illness, morbidity, and mortality worldwide. Compounding this challenge is the irrational and prophylactic use of antimicrobials in food-producing animals, accelerating the emergence and dissemination of antimicrobial resistance, thereby jeopardizing the efficacy of critical therapeutics in both human and veterinary medicine. Chemical hazards such as pesticides and heavy-metal residues, mycotoxins, and veterinary drug residues further erode food integrity and consumer confidence. Effective governance of these risks mandates a science-driven food safety management system incorporating robust risk assessment, systematic hazard analysis, and stringent compliance with Good Agricultural Practices, Good Hygienic Practices, Good Manufacturing Practices and Hazard Analysis and Critical Control Point protocols.

Food quality encompassing nutritional attributes, sensory characteristics, and functional properties is influenced by multiple pre- and post-harvest determinants, including genotype, breed, nutrition, animal welfare, age and physiological state at slaughter, and stress management. Preservation of quality along the value chain requires precise control of cold-chain logistics, rapid processing, traceability, and verification systems. Increasing consumer expectations for minimally processed, residue-free, ethically produced foods are accelerating global transitions toward comprehensive quality-assurance frameworks that reconcile productivity with sustainability.

Innovation is driving paradigm shifts across the animal-origin food sector. Breakthroughs in biotechnology, molecular genetics, and precision livestock farming are enabling highly efficient, welfare-centric production models. Next-generation diagnostic platforms—such as rapid biosensors, point-of-care molecular assays, and real-time monitoring systems—facilitate early detection of pathogens and contaminants. Digitalization through Internet of Things (IoT) technologies, intelligent packaging, and blockchain-enabled traceability is enhancing transparency, product authentication, and shelf-life management. Concurrently, advances in probiotics, nanotechnology, bio-preservation, and smart feed formulation are improving food safety and production efficiency. Emerging frontiers such as cultivated (cell-based) meat, alternative proteins, and sustainable aquaculture strategies offer promising avenues toward climate-smart food security with a reduced ecological footprint.

Within the **One Health** paradigm, ensuring the resilience of animal-derived food systems necessitates coordinated actions across veterinary public health, environmental governance, and clinical healthcare. Strengthening integrated surveillance systems, enforcing rigorous residue and pathogen monitoring, and institutionalizing antimicrobial stewardship are imperative. Ultimately, the future of foods of animal origin lies in harmonizing safety, quality, and innovation under equitable, science-based regulatory frameworks. This integrated approach not only prevents foodborne diseases and economic losses but also advances the collective global vision of **One Health**, achieving a sustainable balance among human well-being, animal welfare, and planetary health.



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Overview

Food of Animal Origin: Safety, Quality, and Innovation for One Health

Animal-derived foodstuffs, such as meat, milk, eggs, fish, and their by-products, are important nutritional sources worldwide. Their production and consumption, though, come with some unique challenges related to food safety, quality assurance and sustainable innovation. This Special Issue of the journal aims to address the above challenges within the broad “One Health” paradigm, with an understanding of the interconnected health of animals, humans, and ecosystems.

The safety aspects of animal-derived food cannot be underestimated, as they have the potential to carry different hazards such as biological hazards, e.g., bacterial pathogens (e.g., *Salmonella*, *Listeria*), viruses, parasites (e.g., *Toxoplasma*, *Trichinella*), and chemical contaminants, e.g., veterinary drug residues, pesticides, and environmental pollution. Good Management Practices, including control of different hazards, should be managed at the farm level which includes detailed and accurate animal health management, strict biosecurity protocols, efficient feeding schemes, and active disease management. Strong surveillance frameworks, veterinary control mechanisms and hygienic processing practices, including ante- and post-mortem inspections, coupled with nationally and internationally acclaimed standards, are strong pillars for consumer protection.

The concept of One Health emphasizes the idea of multidisciplinary cooperation between veterinarians, food scientists, public-health specialists, and regulators in order to reduce “farm-to-fork” risks. Foods of animal origin are studied in relation to quality beyond safety considerations in nutritional, sensory, technological, and hygiene attributes that determine the consumer acceptance and commerciality. The chemical determinants are the genetic factors, the animal food, handling methods, processing methods, and storage environments, which interact synergistically to define the quality of the products. The development of feed technology, genetic engineering, precise livestock farming, and new food processing technologies make productivity and product quality levels higher and reduce the environmental effects.

The modern issues, such as antimicrobial resistance (AMR), zoonotic diseases, climate change, and changing consumer demands based on transparency and sustainability, support current research and policy development. The incorporation of the latest technologies, i.e., high-speed methods of detecting pathogens, blockchain tracing tools, bio-preservation approaches and functional foods supplemented with valuable bioactivities, plays a key role in the development of food safety and quality systems. As one of the advisors of this Special Issue, we are soliciting original research, extensive reviews and case-studies of the critical dimensions of food safety, quality assurance and novel solutions to animal-originated foods in the One Health paradigm. The desired result is to facilitate the sharing of knowledge that can help in achieving safer, healthier and more sustainable food systems that are in line with the global health goals and national interests.

Following the current trends of the Government of India to unify all the food-related regulations in the Food Safety and Standards Authority of India (FSSAI), the latest changes integrated in 2025 simplify food safety systems throughout the country. The latest developments by the FSSAI are the updated product standards, like ghee, meat, fish, poultry, eggs, egg powder, cheese powder, and packaged drinking water, strengthened food additive regulations

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and superior labelling and traceability requirements. These are reforms that are on a par with international standards, and the aim of these reforms was to reduce the health hazard, maintain the standards of food quality and enhance the nutritional quality of the population. It is worth noting that rapid food safety testing methods, increased inspection of food packaging materials and intensive campaigns against food adulteration at festivals also enhance surveillance and protection to consumers.

The release of a special issue containing scientific studies, policy studies and stakeholder views will go a long way in helping both government and industries to address these new challenges. This initiative provides a critical means through which the Indian food industry can spread innovative resolutions and evidence-based practices that are vital towards the effective introduction of the One Health approach to achieve improved outcomes in terms of improved health, animal welfare and environmental sustainability at the national level. This innovation, with its interdisciplinary and intersectoral foundation and focus on teamwork and learning, is now opportune and highly valuable to policymakers, regulators, and the scientific community at large, determined to grow a more resilient Indian food ecosystem and safer one.



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Overview

Food of Animal Origin – Safety, Quality, and Innovation for One Health: Background and Importance

By 2050, global food demand is projected to rise by 50–60% to feed an estimated 10 billion people, requiring a significant increase in production (Falcon et al., 2022). This growth is driven not only by population increase but also by rising affluence, which shifts diets toward animal-source foods such as meat, poultry, eggs, milk, and fish, particularly in developing countries (Bodirsky et al., 2020; Drewnowski & Hooker, 2025). Intensifying food production brings challenges, including environmental impacts, sustainability, food safety and quality, resource degradation, evolving consumption patterns and post-harvest losses (Espinosa-Marrón et al., 2022; FAO-OECD, 2025; Ortiz et al., 2025). Animal-source foods are vital for global nutrition, especially for vulnerable groups such as children and the elderly, as they provide high-quality protein and essential micronutrients. They also support millions of livelihoods worldwide. Meeting rising demand while ensuring safety and sustainability requires integrated approaches. The **One Health** framework—linking human, animal, plant, and environmental health offer a collaborative solution to address complex issues such as food safety, zoonotic diseases (Horefti, 2023), antimicrobial resistance (AMR) (Ruckert et al., 2024), neglected tropical diseases (Laing et al., 2021), and climate change (Shafique et al., 2024). Research output in this area has grown substantially over the past decade, reflecting global efforts to tackle these challenges.

The safety and quality of animal-derived foods can harbor pathogens such as *Salmonella* spp., *Campylobacter* spp., *Escherichia coli*, and *Listeria* spp., causing over 200 foodborne illnesses (Zenu & Bekele, 2023). Contamination risks occur throughout the supply chain—from farm to fork—and include biological (microbes), chemical (drug residues, heavy metals), and physical hazards (Rossi et al., 2025). Antibiotic use in livestock and aquaculture to control these risks contributes to AMR, enabling resistant bacteria to spread to humans through food. AMR is a growing global health threat, making strict food safety controls and responsible antimicrobial use essential (Zhao et al., 2021; Ahmed et al., 2024). Animal welfare issues, such as stress, disease, and poor living conditions, further compromise food safety by increasing susceptibility to infection (Iannetti et al., 2020). Ensuring safety and quality requires rigorous oversight across the supply chain, including HACCP (hazard analysis critical control point)-based systems, regular inspections, and consumer education (Gebremedhin & Haftom, 2024). Food quality—covering nutrition, taste, and hygiene—also depends on authenticity and traceability. Detecting adulteration in products like beef and dairy increasingly relies on advanced molecular techniques such as genomics, proteomics, and metabolomics (Yang et al., 2022). These concerns strongly influence consumer perceptions, highlighting the need for integrated research to balance health benefits and risks.

Innovation is key to sustainable animal-source food systems. Recent advances include alternative proteins and improvements in animal nutrition and feed technology to boost productivity, reduce environmental impact, and enhance nutritional quality (Martinez et al., 2025). Smart farming and precision livestock systems—leveraging AI (artificial intelligence), IoT (internet of things), robotics, and environmental monitoring—can improve productivity, welfare, and climate resilience (Trabachini et al., 2025). However, ethical considerations such as data governance, equity, and genuine welfare benefits must be proactively addressed.

One Health research has expanded rapidly, with annual publications rising from just over 200 in 2017 to more

than 1,300 in 2023 (Szomszor et al., 2025). Most studies focus on zoonotic diseases, AMR, food safety, and climate change impacts (Miao et al., 2022). This work is highly interdisciplinary, integrating public health, environmental and occupational health, infectious diseases, and veterinary science, and is marked by strong international collaboration (Humboldt-Dachroeden et al., 2020). Persistent disciplinary silos hinder One Health integration, with biomedical dominance overshadowing environmental and animal health sectors (Antoniolli & Flamand, 2025). Indigenous and social science perspectives remain underrepresented, particularly in community-centred contexts (Pollowitz et al., 2024). Embedding One Health principles into global and national policies is crucial for building resilient health systems (Bullón Caro, 2025).

The IJAH special issue on **“Food of Animal Origin: Safety, Quality, and Innovation for One Health”** aims to promote interdisciplinary approaches to ensure safety, enhance quality, and drive innovation in animal-source food production within the One Health framework. It covers five key areas:

- Food Safety and Public Health
- Quality and Nutritional Excellence
- Processing, Preservation, and Innovation
- Sustainability, Climate Action, and Circular Economy
- Regulatory Framework, Policy, One Health, and Socioeconomic Perspectives

These contributions seek to bridge gaps across the food chain—from production to consumption—while advancing integrated solutions for global health.

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Overview

Food of Animal Origin: Safety, Quality, and Innovation for One Health

According to the WHO, One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It is a holistic, interdisciplinary approach focusing on improving the safety, quality, and sustainability of animal-source foods through collaboration. This involves tackling challenges like microbial and chemical contamination, emerging diseases, and antimicrobial resistance from farm to fork. It also addresses issues related to food authenticity, traceability, and smart packaging to ensure food security and public health.

The globalization of poultry and livestock due to the Industrial Revolution resulted in increased zoonotic infections in humans. The complex interaction between the animals and humans led to the microorganism with similar forms and purposes. Among the diverse ranges of microorganisms present at this interface, some of them can cause infection, and ~ 60% of human pathogens are zoonotic. In addition, there is a chance of transmission of antibiotic-resistant and virulence genes among them. Hence, the safety of livestock food is crucial to prevent the above cause.

Handling of food of animal origin has various steps, including processing, packaging, storage, transportation, marketing, and consumption. During each step, there is a chance of pathogen transmission. Moreover, ingesting eggs, meat, milk, and their by-products from animals may result in exposure to antibiotic residues from animals. Even though antibiotics play a critical role in preventing pathogen infection, overuse can cause resistance to them. In addition, the practice of antibiotics in domestic animals is controversial due to the spread of antibacterial resistance genes and microorganisms. Hence, it is important to understand the mechanism behind the relationship between pathogens and resistance genes.

Coordination among livestock, humans, and the environment is the focus of One Health. Hence, One Health High-Level Expert Panel (OHHLEP) refined definition of One Health by describing it as “an ‘integrated, coalition-building approach that seeks to sustainably balance and optimize the health of people, animals and ecosystems, recognizing that the three are inextricably linked and interdependent, and it takes a multidisciplinary, multisector approach to address global challenges, such as food security issues and antibiotic resistance prevention”, on 1st December 2021. It emphasizes the role of genetic variation as a driving force of the evolution of hosts and pathogens. Mutations, recombination, and gene flow are key drivers of genetic diversity that facilitate co-evolutionary dynamics. Human activities like habitat destruction, environmental changes, and expanding livestock farming can indirectly influence gene flow by altering vector and host behaviours. Therefore, regulating gene flow is crucial for preventing the emergence and spread of infectious diseases affecting human and animal health. This requires careful consideration of the ecological, socioeconomic, and ethical implications of policies, as they influence multiple stakeholders and values.

Key themes and focus areas in One Health approach comprise

Food safety and public health: Mitigation of the hazards, prevention of zoonotic diseases, and the rise of antimicrobial resistance (AMR) in food systems through predictive modelling and early warning systems.

Quality and nutritional excellence: Assessing the qualities, nutritional content and bioavailability of key nutrients in animal-source foods through developing new methods.

Innovation: Creation of smart diagnostics tools for the examination of preliminary health and safety. As well as the development of an intelligent packaging for the extension of shelf life and product freshness. The use of advanced technology in manufacturing for the processing, preservation, and assessment of products.

Overall, the One Health approach's core principle is that the health of humans, animals, and the environment is inextricably linked. Safety, quality and sustainability of animal source food can be improved through farm-to-fork strategy, integrated efforts, and global collaboration.



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Overview

Food of Animal Origin: Safety, Quality, and Innovation for the One Health Imperative

Food of animal origin encompassing dairy, eggs, meat and fish, has been the foundation of proper human nutrition since the beginning of human civilization. It provides a dense source of essential proteins, fats, amino acids, vitamins, and minerals, most of which are nutritionally superior to their plant-based counterparts are crucial for physical and cognitive development. However, the production, processing, and consumption of these foods create a critical connection between human, animal, and environmental health. The contemporary paradigm of One Health, which recognizes the inseparable linkages between these three domains, provides the most compelling framework for understanding the challenges and opportunities surrounding the food of animal origin. This overarching theme postulates that we can no longer view safety, quality, and innovation in isolation. Instead, they must be pursued as interconnected pillars essential for achieving sustainable, equitable, and resilient food systems that safeguard the health of the planet and all its inhabitants.

The One Health triad and its connection to food of animal origin

The One Health approach is not merely a concept but a necessary lens for addressing 21st-century food system challenges.

Human health: On the positive side, foods derived from animals are vital for combating malnutrition and micronutrient deficiencies. On the negative, unsafe they can be the primary vector for foodborne illnesses caused by pathogens, e.g., *Salmonella*, *Campylobacter*, *E. coli*, *Mycobacterium tuberculosis*, etc. Furthermore, excessive consumption of certain processed or red meats is linked to non-communicable diseases. The misuse of antibiotics in animal production contributes directly to the global crisis of Antimicrobial Resistance (AMR), rendering life-saving drugs ineffective in humans.

Animal health: The welfare and health of food-producing animals are paramount. Outbreaks of diseases like Avian Influenza or African Swine Fever cause immense animal suffering and economic devastation. Few infections can also jump species to humans (zoonoses), highlighting how poor animal health directly threatens human health. Intensive farming practices make the matter worse because they can create conditions ripe for the emergence and spread of such pathogens.

Environmental health: Animal agriculture is a major user of natural resources, contributing significantly to greenhouse gas emissions, land and water degradation, and biodiversity loss. Feed production drives deforestation, while waste runoff can pollute waterways. A deteriorating environment, in turn, threatens the very resource base required for sustainable animal-based food production.

Therefore, the safety and quality of the milk in a glass, soup in a bowl, or fish on a platter are deeply contingent on the health of the animal it came from and the environment in which that animal was raised.

Food safety – The non-negotiable foundation

Safety is the fundamental prerequisite for any food system. For animal-based foods, the risks are multifaceted and demand integrated, farm-to-fork controls.

Biological hazards: These include pathogenic bacteria, viruses, parasites, and prions. Controlling them requires robust veterinary public health systems, including vaccination programs, biosecurity measures on farms, and strict hygienic practices during slaughter, processing, and handling. Advanced techniques like whole-genome sequencing now allow for precise tracking of pathogen strains from outbreak back to source, enabling faster containment.

Chemical hazards: This category encompasses veterinary drug residues (especially antibiotics and hormones), pesticides, environmental contaminants (e.g., dioxins, heavy metals), and naturally occurring toxins. The AMR crisis is the starkest example of a One Health safety failure. Prudent use of antimicrobials in animals, enforced through withdrawal periods and rigorous monitoring, is critical.

Physical hazards: While often less severe, foreign objects like bone fragments or metal shavings pose a risk and are managed through modern processing technologies and Hazard Analysis Critical Control Point (HACCP) systems.

A One Health approach to safety means that reducing antibiotic use on farms not only minimizes residue risks (human health) but also slows AMR (global health) and can lead to better animal husbandry (animal welfare).

Quality – Beyond safety to value and integrity

While safety is binary (safe/unsafe), quality is a spectrum encompassing a range of attributes that determine a product's value and acceptability.

Nutritional quality: This refers to the nutrient profile—protein content, fatty acid composition (e.g., omega-3 levels), and vitamin density. Innovation in animal feed, such as supplementing with algae or insects, can enhance the nutritional value of FAO, directly linking animal nutrition to human health outcomes.

Sensory quality: Attributes like taste, texture, aroma, and appearance are primary drivers of consumer choice. These are influenced by species, breed, diet, and processing methods.

Technological quality: These are properties important for processing, such as the coagulation properties of milk and water-holding capacity of meat.

Credence quality: Perhaps most aligned with the One Health ethos, these are attributes that cannot be verified by the consumer at the point of purchase but are based on trust. This includes animal welfare (free-range, pasture-raised), environmental sustainability (carbon-neutral, water-positive), and ethical provenance (local, organic, fair-trade). Modern consumers increasingly view the quality of food of animal origin through this One Health lens, valuing products that are not only safe and nutritious but also produced in a way that is kind to animals and the planet.

Innovation – The engine for One Health integration

Innovation is the critical force that allows us to reconcile the growing global demand for food of animal origin with the imperatives of safety, quality, and sustainability. It spans the entire value chain.

Production innovations:

- **Precision livestock farming (PLF):** Using sensors, Internet of Things (IoT), and artificial intelligence (AI) to monitor animal health and welfare in real-time. This allows for early disease detection, reducing antibiotic use and improving productivity.
- **Sustainable feed:** Replacing soy and fishmeal with insect meal, single-cell proteins, or algae reduces the environmental footprint of feed and can improve the nutritional profile of animal-origin foods.
- **Genetics:** Advanced breeding techniques can develop livestock with enhanced disease resistance, improved feed efficiency, and better adaptability to climate change.

Processing and safety innovations:

- **Non-thermal processing:** Technologies like High-Pressure Processing (HPP), pulsed electric fields, and cold plasma effectively inactivate pathogens while better preserving the sensory and nutritional quality of food

compared to traditional heat treatment.

- **Smart packaging:** Integrated with sensors, smart packaging can monitor freshness, indicate the presence of pathogens, and provide dynamic shelf-life information, drastically reducing food waste and enhancing safety.
- **Blockchain:** Creating transparent and immutable records from farm to fork builds consumer trust in credence quality claims and improves the speed and accuracy of food traceability during recall events.

An integrated future

The theme 'Food of Animal Origin: Safety, Quality, and Innovation for One Health' underscores a fundamental shift in our thinking. It moves beyond the insulated goals of merely producing safe and palatable food. Instead, it demands a holistic, systems-based approach where the safety of our food is guaranteed by the health of our animals and ecosystems; where the quality we value includes ethical and environmental integrity; and where innovation is directed towards harmonizing human needs with planetary boundaries.

The path forward requires unprecedented collaboration among dairy scientists, veterinarians, farmers, environmentalists, policymakers, and public health experts. Consumers, through their purchasing power, also play a pivotal role in driving demand for animal-based foods that align with One Health principles. By intertwining safety, quality, and innovation within the One Health framework, we can transform the production of food of animal origin from a significant contributor to global challenges into a powerful engine for a healthier, more sustainable, and equitable future for all.