



Microplastic Contamination in Livestock Products: Emerging Risks for Food Safety and Human Health

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Abstract

Microplastic contamination in livestock products has emerged as a critical food safety concern. This short communication highlights pathways of contamination through feed, water, packaging, and environmental deposition. Evidence of microplastics in milk, meat, and eggs underscores risks to human health, including gastrointestinal disruption, systemic toxicity, and antimicrobial resistance. Detection challenges and mitigation strategies are discussed, emphasizing the need for standardized methodologies and a One Health approach. Early integration of microplastic monitoring into livestock product technology is essential to safeguard food security and consumer health.

Keywords: Microplastics, Livestock Products, Food Safety, Human Health, One Health

INTRODUCTION

Microplastic contamination has emerged as one of the most pressing environmental and food safety challenges of the 21st century. Defined as plastic particles less than 5 mm in size, microplastics (MPs) originate from the degradation of larger plastic debris or are manufactured as microbeads for industrial use (Cole *et al.*, 2011). While much attention has focused on marine ecosystems, recent evidence demonstrates that terrestrial food chains, including livestock production systems, are equally vulnerable (Zeng *et al.*, 2025). Livestock products such as milk, meat, and eggs represent critical dietary staples worldwide, and contamination of these commodities with MPs poses direct risks to human health.

This short communication synthesizes current knowledge on microplastic contamination in livestock products, highlights mechanisms of entry into the food chain, and discusses implications for food safety and public health. Field observations and recent studies

underscore the urgency of integrating microplastic monitoring into livestock product technology and adopting mitigation strategies within a One Health framework.

PATHWAYS OF MICROPLASTIC CONTAMINATION IN LIVESTOCK PRODUCTS

Feed and Water Sources: Livestock are exposed to Microplastics primarily through contaminated feed and drinking water. Agricultural soils irrigated with wastewater or amended with plastic-containing fertilizers accumulate MPs that are ingested by grazing animals (Corradini *et al.*, 2019). Studies have demonstrated that MPs can persist in rumen fluid, disrupting microbial fermentation and nutrient absorption (Brugger *et al.*, 2025). This not only compromises animal health but also facilitates the transfer of MPs into edible tissues and secretions.

Packaging and Processing: Secondary contamination occurs during product handling and storage. Plastic packaging materials used for milk, meat, and eggs can leach MPs, especially under thermal stress or mechanical abrasion (Smith *et al.*, 2018). Dairy products stored in polyethylene containers have shown detectable levels of MPs, raising concerns about consumer exposure through routine consumption.

Environmental Deposition: Airborne MPs generated from urban and agricultural activities can settle on open livestock products during processing or retail display. This pathway is particularly relevant in rural markets where hygienic infrastructure is limited (Zeng *et al.*, 2025).

EVIDENCE OF MICROPLASTICS IN LIVESTOCK PRODUCTS

Milk and Dairy

Recent analytical studies using Raman spectroscopy and pyrolysis-GC/MS have confirmed the presence of MPs in raw and processed milk samples (Zeng *et al.*, 2025). The particles detected include polyethylene, polypropylene, and polystyrene, reflecting common packaging polymers. Chronic ingestion of such particles by humans may disrupt gut microbiota and induce inflammatory responses (Prata *et al.*, 2020).

Meat and Offal

Muscle tissues and organs of cattle, goats, and poultry have been shown to accumulate MPs following prolonged exposure (Brugger *et al.*, 2025). Histological examinations reveal particle deposition in hepatic and renal tissues, raising concerns about bioaccumulation and potential toxicological effects in consumers.

Eggs

Eggshells and albumen have been reported to contain MPs, likely originating from contaminated feed and water (Zhang *et al.*, 2020). Given the widespread consumption of eggs, even low-level contamination represents a significant public health concern.

IMPLICATIONS FOR FOOD SAFETY AND HUMAN HEALTH

Gastrointestinal Effects: Human ingestion of MPs through livestock products can alter gut microbiota composition, impair nutrient absorption, and trigger local inflammation (Prata *et al.*, 2020). Experimental models suggest that MPs act as carriers for pathogenic bacteria and heavy metals, amplifying their toxicity (Smith *et al.*, 2018).

Systemic Toxicity: Translocation of MPs across the intestinal barrier into systemic circulation has been documented (Wright & Kelly, 2017). This raises the possibility of deposition in organs, contributing to oxidative stress, endocrine disruption, and carcinogenesis.

Antimicrobial Resistance: Microplastics provide surfaces for microbial colonization and biofilm formation. Resistant pathogens adhering to MPs can be transmitted via livestock products, exacerbating the global antimicrobial resistance crisis (Zeng *et al.*, 2025).

Food Security and Consumer Confidence: Detection of MPs in staple livestock products undermines consumer trust and may affect market access, particularly in export-oriented economies. Regulatory agencies face increasing pressure to establish permissible limits and monitoring protocols.

Detection and Analytical Challenges: Accurate quantification of MPs in livestock products remains challenging due to their heterogeneity in size, shape, and polymer type. Advanced techniques such as Fourier-transform infrared spectroscopy (FTIR), Raman microscopy, and pyrolysis-GC/MS are increasingly employed (Zeng *et al.*, 2025). However, standardization of methodologies is urgently needed to ensure comparability across studies.

MITIGATION STRATEGIES

A comprehensive mitigation strategy to curb microplastic (MP) contamination in livestock products must integrate rigorous on-farm interventions with robust regulatory frameworks and stakeholder engagement. At the farm level, preventive measures should begin with source control: procurement protocols that mandate certified, low-MP feed and routine spectroscopic screening of feed batches using FTIR or Raman spectroscopy to detect and quantify polymeric contaminants, coupled with supply-chain audits to trace and eliminate contaminated inputs. Water safety requires multi-barrier treatment systems sedimentation, fine filtration, and membrane technologies such as ultrafiltration or nanofiltration designed and validated for particle removal efficiencies at the micrometer and submicrometer scale, with periodic integrity testing and maintenance schedules. Post-harvest, replacing conventional

plastic contact materials with inert alternatives glass, stainless steel, or certified biodegradable polymers with proven low-shedding profiles reduces secondary contamination during processing, storage, and transport; packaging selection must be guided by migration and abrasion testing under realistic thermal and mechanical stress. At the policy level, regulators should establish science-based threshold values for MPs in animal-derived foods, informed by toxicological and exposure assessments, and embed MP surveillance into routine food safety inspections using standardized sampling, extraction, and analytical protocols to ensure comparability across laboratories. Complementary measures include mandatory reporting of MP findings, incentives for industry adoption of low-MP technologies, and targeted capacity building to equip veterinary and food safety laboratories with analytical capabilities. Finally, sustained public-facing education campaigns and farmer training programs are essential to translate technical guidance into practice, promote best management practices on farms, and foster consumer awareness; these efforts must be coordinated within a One Health framework that links environmental monitoring, animal production practices, and human health surveillance to evaluate intervention effectiveness and adapt strategies as new evidence emerges.

ONE HEALTH APPROACH

A One Health approach to microplastic contamination frames the problem as an integrated environmental, veterinary, and public-health challenge that requires coordinated surveillance, shared methodologies, and joint policy responses. Operationalizing One Health entails harmonized monitoring of environmental reservoirs (soil, water, air), agricultural inputs (feed, fertilizers), livestock tissues and secretions, and human exposure biomarkers to enable source-to-sink tracing and quantitative risk attribution. Interdisciplinary risk assessment couples' environmental fate and transport models with animal bioaccumulation kinetics and human dietary intake scenarios to identify high-leverage intervention points. Practically, this requires accredited cross-sector laboratory networks using standardized analytical techniques (e.g., FTIR, Raman, pyrolysis-GC/MS), sentinel animal surveillance to detect early bioaccumulation, and coordinated mitigation measures such as source reduction, advanced water and feed filtration, and low-shedding packaging. Governance mechanisms national One Health platforms or task forces should align research priorities, regulatory thresholds, and communication strategies. Engaging farmers, processors, and consumers through targeted training and transparent risk communication ensures feasible implementation. By linking environmental monitoring, veterinary practice, and public-health assessment, One Health

delivers evidence driven pathway to reduce microplastic exposure and protect food safety (WHO, 2019).

CONCLUSION

Microplastic contamination in livestock products represents an emerging risk to food safety and human health. Evidence from recent studies demonstrates that MPs infiltrate milk, meat, and eggs through feed, water, packaging, and environmental deposition. Their ingestion by humans can disrupt gut microbiota, induce systemic toxicity, and contribute to antimicrobial resistance.

This short communication underscores the need for urgent research, standardized detection methods, and robust mitigation strategies. Integrating microplastic monitoring into livestock product technology and adopting a One Health approach will be critical to safeguarding food security and public health in the coming decades.

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