



Review Article

From feed to food safety: Quantitative evidence and one health implications of postbiotics and parabiotics in livestock and dairy systems

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*Department of Food Hygiene and Quality Control, Faculty of Veterinary Medicine, Urmia University, Urmia, Iran***Abstract**

Foodborne pathogens, antimicrobial resistance, and mycotoxin contamination in animal-derived foods collectively represent a significant one health challenge for livestock and dairy systems. Postbiotics, derived from inactivated microbial cells and their components, confer benefits to the host and have emerged as promising, stable, and safe alternatives to antibiotics and chemical preservatives for human and animal application. However, the effectiveness and consistency of postbiotics interventions remain unclear. This review summarized findings from 19 peer-reviewed studies published between 2015 and 2025 containing quantitative outcomes of postbiotics use in live animal and food. Using a PRISMA-guided methodology, this review systematically compared the efficacy of postbiotics in reducing foodborne pathogens, mycotoxins, and antimicrobial resistance markers across various species, food types. Postbiotics consistently resulted in 1.5 to 6.9 log₁₀ CFU/g reductions in *Salmonella* spp., *Escherichia coli*, and *Listeria monocytogenes*, and reduced aflatoxins (AFM1/AFB1) in dairy products by 40–96%. *In vivo* trials demonstrated 28–58% decrease in selected antimicrobial resistance genes, frequently associated with modulation of the microbiota. These effects were observed across various delivery methods. Quantitative evidence demonstrates that postbiotics fulfill multiple functions, including enhancing food safety and supporting antimicrobial activity. With standardization and validation in real-world conditions, postbiotics could offer a scalable, one-health-aligned strategy that integrates animal nutrition, food processing, and public health.

Keywords: Aflatoxin detoxification, Antimicrobial metabolites, Feed additives, microbial inactivation, Pathogen control, Quantitative synthesis.

Introduction

Livestock and dairy systems were prioritized because of their role as significant transmission pathways for foodborne pathogens, antimicrobial resistance (AMR) determinants, and aflatoxin exposure in humans. Foodborne zoonoses are responsible for approximately 600 million illnesses and 420000 deaths annually (WHO, 2018). Additionally, AMR poses a substantial threat to the efficacy of both veterinary and human medicines (O'Neill, 2016). Mycotoxins, particularly aflatoxins,

frequently contaminate animal-derived foods and contribute to chronic health problems in vulnerable populations (WHO, 2015). These hazards constitute a significant one health challenge require the implementation of integrated and sustainable mitigation strategies. Traditional controls, such as antibiotics, chemical preservatives, and decontamination methods, are limited by the promotion of AMR, the presence of chemical residues, and increasing regulatory restrictions. Consequently, there is a growing interest in

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biological alternatives that improve food safety without compromising quality or contributing to resistance.

In contrast to probiotics, whose effectiveness is linked to microbial viability and environmental conditions, postbiotics retain their biological activity regardless of cell viability (Aguilar-Toalá et al., 2018). This characteristic allows for consistent and controllable applications in both food and livestock systems. According to the International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement, postbiotics are defined as preparations of inanimate microorganisms and/or their components that confer health benefits to the host (Salminen et al., 2021). In this review, postbiotics are considered primarily as inactivated microbial preparations and cell-free microbial preparations containing bioactive components rather than isolated purified metabolites. For conceptual consistency, cell-free supernatants (CFS) are discussed in this review as cell-free microbial preparations, rather than isolated metabolites, in accordance with the ISAPP postbiotic framework. In contrast, parabiotics refer specifically to inactivated microbial cells that confer biological effects (Aguilar-Toalá et al., 2018; Salminen et al., 2021).

Postbiotics may exert their effects through antimicrobial compounds, immune modulation, reinforcement of the gut barrier, and toxin binding. Owing to their stability, biosafety, and dosing consistency, postbiotics and parabiotics strategies are being increasingly investigated for applications in feeds, food matrices, and processing environments (Balakrishna et al., 2026). Although research in this area is expanding, quantitative outcomes directly relevant to food safety, such as microbial level reductions in pathogen levels, percentage reductions in mycotoxins, and decreases in antimicrobial resistance genes, remain fragmented. This review summarized quantitative evidence from 19 peer-reviewed studies on postbiotics in livestock and dairy systems, emphasizing efficacy, mechanistic convergence, and one health relevance across *in vivo*, *ex vivo*, and *in vitro* models of postbiotics application.

Materials and Methods

Study design and review framework

This review used a PRISMA-guided (Haddaway et al., 2020) quantitative narrative synthesis to assess the effects of postbiotics and parabiotics on food safety in livestock and dairy systems. A meta-analysis was not conducted because of substantial heterogeneity in study designs, formulations, and outcome measures.

Literature search strategy

A comprehensive literature search was conducted in four electronic databases including PubMed, Web of Science, Scopus, and ScienceDirect. Studies published between 2015 and 2025 were included in this review. The search strategy combined controlled vocabulary and free-text keywords related to postbiotics and parabiotics, livestock and dairy systems, and food safety outcomes such as pathogen reduction, mycotoxin mitigation, and antimicrobial resistance. An example of the search string used is as follows: (postbiotic or parabiotic or "inactivated bacteria" or "cell-free supernatant") AND (livestock or poultry or dairy or pig or cattle) AND (food safety or pathogen or aflatoxin or antimicrobial resistance). All retrieved records were exported to reference management software (EndNote), and duplicate entries were removed prior to screening.

Study selection process

Study selection was conducted according to the PRISMA 2020 framework (Haddaway et al., 2020), which structured the literature search and screening processes (**Fig. 1**). Titles and abstracts were screened for relevance to postbiotics in food-producing animals, or food matrices. The full texts of articles identified as potentially relevant were subsequently evaluated using predefined inclusion and exclusion criteria.

Inclusion criteria were as follows:

- Studies have investigated postbiotics, defined as inactivated microbial cells or CFS, in accordance with the ISAPP definition.

- Research has been conducted in *ex vivo* food matrices, *in vitro* food safety-relevant models, and *in vivo* livestock systems.
- Studies reported quantitative outcomes for at least one of the following endpoints:
 - Reduction of foodborne pathogens
 - Detoxification of mycotoxins (e.g., AFM1, AFB1)
 - Modulation of antimicrobial resistance or related indicators
 - The study was published as peer-reviewed original research in English.

Exclusion criteria were as follows:

- Studies that focused exclusively on live probiotics without inactivation.
- Absence of numeric or statistically interpretable outcomes.
- Reviews, conference abstracts, and opinion pieces.

Discrepancies identified during screening were resolved through an iterative reassessment of the full texts. The final dataset comprised methodologically comparable yet experimentally diverse studies, as summarized in **Table 1**.

Data extraction and variable definition

Data from eligible studies were systematically extracted using a standardized framework to reduce interpretive bias. The following variables were extracted:

- Model system, including food matrix, *in vitro* model, or animal species
- Postbiotics source and formulation, such as CFS, heat-inactivated cells, or encapsulated metabolites
- Study design, including *ex vivo* preservation, *in vivo* challenge, feeding trial, or *in vitro* assay

- Target hazard, such as pathogens, mycotoxins, antimicrobial resistance genes, immune markers, or microbiota markers
- Peak quantitative outcome, reported as log₁₀ CFU/g or CFU/mL reduction, percentage reduction of toxins or resistance markers, or statistically significant inhibition compared to controls
- Mechanisms of action, as proposed by authors.

For studies that reported multiple time points, the maximum observed reduction under experimental conditions was extracted to facilitate cross-study comparisons.

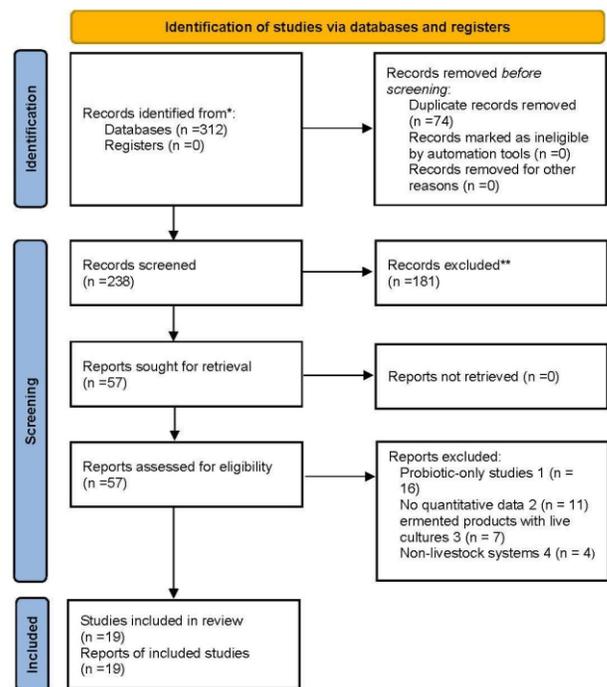


Figure 1. PRISMA flow diagram of the literature search and study selection process for the systematic review of quantitative evidence and one health implications of postbiotics and parabiotics in livestock and dairy systems, including identification, screening, eligibility assessment, and final study inclusion.

Quantitative synthesis and analytical approach

Due to considerable heterogeneity in postbiotics composition, delivery methods, experimental designs, and outcome metrics, a formal meta-

analysis was unsuitable. Therefore, a structured quantitative narrative synthesis was conducted in accordance with PRISMA recommendations for

synthesizing heterogeneous evidence. The analytical framework comprised four complementary steps.

Table 1. Empirical evidence regarding postbiotics and parabiotics in food-producing animals (2015–2025)

Author (Year)	Species / Model	Classification	Preparation Type	Study Design	Target Hazard	Peak % / log ₁₀ Reduction	Mechanistic action
Incili et al., 2022	Frankfurters	Postbiotics	Cell-free supernatant <i>Pediococcus acidilactici</i> CFS + chitosan	<i>Ex vivo</i> (Meat surface) Refrigerated storage	<i>E. coli</i> O157:H7, <i>Salmonella Typhimurium</i> , <i>Listeria monocytogenes</i>	1.58–3.21 log ₁₀ CFU/g	Organic acids & phenolic metabolites
Akgöl et al., 2025	Rainbow trout fillets	Postbiotics	Chitosan edible film + <i>P. acidilactici</i>	<i>Ex vivo</i> (Fish surface) Cold storage	<i>S. Typhimurium</i> , <i>E. coli</i> O157:H7, <i>L. monocytogenes</i>	Inhibition zones 13.42–16.76 mm; reduced spoilage counts	Antimicrobial metabolites + physical barrier effects
Sharafi et al., 2022	High-moisture mozzarella cheese	Postbiotics	<i>Lactobacillus acidophilus</i> LA-5 & <i>Bifidobacterium animalis</i> BB-12 postbiotics in whey	<i>Ex vivo</i> (Cheese matrix) Refrigerated storage	Mesophiles, Psychrophiles, LAB, Yeast & mould	1.5–2.0 log ₁₀ CFU/g reduction	Organic acids, bacteriocins, bioactive metabolites
Kaynakc, 2025	Turkey meat	Postbiotics	Alginate coating + postbiotics (<i>B. bifidum</i> DSM20, 456 & BB12)	<i>Ex vivo</i> (Meat surface) trial	<i>Listeria monocytogenes</i>	~ 1.62 log ₁₀ CFU/g reduction	Antimicrobial metabolites + barrier effect
Jalali et al., 2024	Red meat surface	Postbiotics	Mixed postbiotics (<i>L. rhamnosus</i> + <i>Limosilactobacillus reuteri</i>)	<i>Ex vivo</i> Surface treatment	<i>E. coli</i> , <i>S. aureus</i>	5.54–6.9 log ₁₀ CFU/g reduction	Antimicrobial metabolites + surface application
Valipour et al., 2024	Beef fillets	Postbiotics	Aerosolized postbiotics (<i>Lactiplantibacillus sakei</i>)	<i>Ex vivo</i> (Meat) 15-day storage	<i>Listeria monocytogenes</i>	~ 3.30 log ₁₀ CFU/g over 15 days	Antimicrobial metabolites + aerosol coating
Fahim et al., 2021	Milk powder	Postbiotics	CFS & encapsulated postbiotics (<i>L. plantarum</i> RM1 & <i>L. paracasei</i> KC39)	<i>Ex vivo</i> (Dairy matrix) AFM1 challenge	AFM1 / AFB1	Up to ~60–96% reduction depending on treatment	Toxin binding
Moradkhani et al., 2025	Fermented yogurt	Postbiotics	LAB: <i>L. acidophilus</i> , <i>L. plantarum</i> , <i>L. reuteri</i> , <i>L. rhamnosus</i>	<i>Ex vivo</i> (Dairy matrix)	AFM1	~ 95.2% reduction in yogurt	LAB fermentation & toxin binding/adsorption
Duarte et al., 2024	Growing pigs	Postbiotics	Dietary <i>Lactobacillus</i> postbiotics + bacitracin	<i>In vivo</i> challenge, 28 d	Enterotoxigenic <i>E. coli</i> F18+	No explicit numeric shedding reduction reported	Modulated mucosa-associated microbiota, pattern recognition receptors, immune markers
Zhang et al., 2024	Growing pigs	Postbiotics	<i>Weissella cibaria</i> fermented feed	Field/feeding trial	Antibiotic resistance genes (ARGs)	Significant reductions in multiple ARGs	Microbiota restructuring linked to lowered ARGs

Table 1. Continued

Fang et al., 2024	Broilers	Postbiotics	<i>Bacillus subtilis</i> ACCC 11025	Randomized Controlled Trial (RCT), (42 d)	<i>Salmonella</i>	Significant reduction in excreta; lowest counts at 0.015% postbiotic	Gut microbiota modulation (↑ <i>Lactobacillus</i> , ↓ <i>Salmonella</i>), reduced ammonia
Guan et al., 2024	Broilers	Postbiotics	<i>Lactiplantibacillus plantarum</i>	Challenge, 28 d (cell-free supernatant)	<i>Salmonella</i> <i>Enteritidis</i>	Significant attenuation of infection & bacterial burden	Suppressed NLRP3 inflammasome activation & gut microbiota modulation
Edache et al., 2024	Dairy cattle	Postbiotics	<i>Saccharomyces cerevisiae</i>	Field observational study (Yeast fermentation on product)	<i>Salmonella enterica</i> prevalence	Numerically lower prevalence (non-significant)	Association analysis; variability by region/season
Alagbe et al., 2023	Broilers	Parabiotics	Enzymatically treated yeast	Challenge (<i>Eimeria</i>)	<i>Eimeria</i> oocyst shedding	Significant reduction in ileal & excreta oocyst counts	Immune modulation
Adnan et al., 2021	<i>In vitro</i>	Cell-free postbiotics	<i>Pediococcus pentosaceus</i> -derived biosurfactant	<i>In vitro</i> adhesion assays	<i>E. coli</i> adhesion	Anti-adhesion activity observed	Reduced bacterial adhesion
Moon et al., 2019	Mice / macrophage models	Parabiotics	Heat-treated <i>L. plantarum</i>	<i>In vivo</i> & <i>in vitro</i>	Immune activation	↑ NK activity, ↑ TNF α, IL 2, IL 12 vs control	NK/macrophage activation, NF κB signaling
Gonçalves et al., 2017	Dairy cows	Postbiotics	<i>S. cerevisiae</i>	Yeast fermentation on product	AFM1	40–70%	Glucosaminan adsorption
Kareem et al., 2017	Broilers	Parabiotics	Inactivated <i>L. plantarum</i> RG14	RCT	<i>Enterobacteriaceae</i>	1.2–1.6 log ₁₀ CFU/g	Cytokine modulation (↑ IL-10, ↓ pro-inflammatory), gut microbiota modulation
Quintanilla-Pineda et al., 2023	Rainbow trout / Tilapia (<i>in vitro</i>)	Postbiotics	Postbiotics from <i>Weissella cibaria</i> & <i>P. acidilactici</i> isolates	<i>In vitro</i> co-culture challenge	<i>Aeromonas salmonicida</i>	Up to ~4.49 log ₁₀ CFU/mL reduction	Antibacterial metabolites (growth inhibition)

Outcome-based stratification

The studies were categorized into four primary domains including reduction of pathogens in food matrices; mitigation of mycotoxins in dairy systems; outcomes of *in vivo* pathogen or disease challenges and modulation of microbiota and markers of antimicrobial resistance.

Peak-effect comparison

Peak reductions within each domain were compared across the following categories: 1) food matrices, including meat, fish, and dairy products, 2) animal

species, such as poultry, pigs, and ruminants, and 3) postbiotics formulations and delivery types.

Mechanism–outcome mapping

Mechanisms of action were systematically compared with quantitative outcomes to identify recurring patterns, such as antimicrobial metabolite activity, toxin adsorption, immune modulation, and microbiota restructuring.

Evidence weighting

Studies were assigned greater interpretive weight if they met the following criteria such as reported

explicit quantitative reductions; included appropriate control groups and conducted statistical analyses and employed *in vivo* or food system-relevant experimental models.

Assessment of methodological limitations

Due to study heterogeneity, formal risk-of-bias tools were not applied. However, common methodological limitations were qualitatively assessed, including the following:

- Absence of standardized metrics for postbiotic dosing
- Insufficient experimental durations
- Inconsistencies in microbial enumeration and analytical methodologies
- Limited replication of studies under field or industrial conditions
- These methodological limitations were considered during data synthesis and interpretation.

Rationale for PRISMA-guided narrative synthesis

The PRISMA-guided approach facilitated transparent study selection, explicit eligibility criteria, and a structured quantitative comparison. Additionally, it maintains flexibility in incorporating mechanistic insights from diverse experimental systems. This methodology establishes a robust framework for synthesizing emerging evidence on postbiotics in food safety and livestock production.

Results

Study characteristics

Nineteen peer-reviewed studies published between 2015 and 2025 met the inclusion criteria (**Table 1**). These studies included *in vivo* livestock trials involving poultry, swine, and ruminants, *ex vivo* food matrices such as meat, fish, and dairy products, and *in vitro* models. Postbiotics are mainly derived from lactic acid bacteria, *Bacillus* species, and yeasts and are administered through dietary supplementation, CFS, fermented feeds, or edible films and coatings. The primary hazards targeted were foodborne

pathogens, aflatoxins (AFM1/AFB1), and antimicrobial resistance genes.

Quantitative reduction of foodborne pathogens

Postbiotics applications consistently reduced the prevalence of major foodborne pathogens, including *Salmonella* spp., *E. coli*, *L. monocytogenes*, and *S. aureus*, across various experimental models (**Table 1**). Maximum reductions ranged from 1.5 to 6.9 log₁₀ CFU/g. *Ex vivo* meat and fish systems demonstrated reductions of 1.6 to 3.3 log₁₀ CFU/g, while surface-applied mixed-strain postbiotics achieved reductions exceeding 5 log₁₀ CFU/g in red meat (Jalali et al., 2024). *In vivo* studies involving poultry and swine have reported significant decreases in pathogen shedding or overall burden.

Mycotoxin reduction in dairy matrices

Eight studies reported aflatoxin reductions ranging from 40% to 96% (**Table 1**), with the greatest efficacy observed in fermented dairy products, such as yogurt, which achieved approximately 95% reduction (Moradkhani et al., 2025). Significant reductions were also observed in milk powder, cheese, and liquid milk under both experimental and natural contamination conditions.

Modulation of antimicrobial resistance markers

Five *in vivo* studies observed a 28–58% reduction in the abundance of antibiotic resistance genes (ARGs), including tetracycline resistance genes (*tet*), macrolide resistance genes (*erm*), sulfonamide resistance genes (*sul*), and β-lactamase genes (*bla*), following dietary postbiotic supplementation in pigs and poultry (**Table 1**). These reductions were accompanied by microbiota restructuring, as determined by quantitative PCR or metagenomic analysis.

Additional biological outcomes

Additional benefits include enhanced gut morphology, modulation of immune responses, and a decrease in parasitic load, such as *Eimeria* oocysts. No adverse effects on growth performance or product quality were reported.

Discussion

This review provides consistent quantitative evidence supporting the efficacy of postbiotics and parabiotics as multifunctional interventions in livestock production and food matrices. Although experimental models and formulations vary, pathogen reductions of 1.5–6.9 \log_{10} CFU/g have been consistently reported, especially in *ex vivo* meat systems and controlled *in vivo* challenge models. Antimicrobial metabolites produced during fermentation, such as organic acids, bacteriocins, and biosurfactants, primarily inhibit pathogens in food matrices (Incili et al., 2022; Jalali et al., 2024; Valipour et al., 2024). In contrast, parabiotics derived from inactivated microbial cells exert host-mediated effects, including cytokine modulation, enhancement of mucosal immunity, and improved intestinal barrier integrity (Kareem et al., 2017; Moon et al., 2019). These complementary mechanisms account for the cross-system efficacy observed in livestock and food safety applications.

Mycotoxin mitigation in dairy systems has been identified as a consistently reproducible outcome. Yeast-derived fermentation products and bacterial metabolite preparations reduce AFM1 contamination by 40–96%, primarily through adsorption to microbial cell wall polysaccharides and sequestration mediated by metabolites (Fahim et al., 2021; Gonçalves et al., 2017). These results are particularly significant for high-risk dairy products, where chemical detoxification options are limited. Although evidence for antimicrobial resistance mitigation is still emerging, current findings are promising. Reductions in ARG abundance observed in feeding trials are likely attributable to microbiota restructuring rather than direct antimicrobial effects (Zhang et al., 2024). This ecological mechanism aligns with one health strategies that aim to reduce the selective pressure associated with antibiotic use.

Outcomes across studies were not uniform. Field observational studies exhibited greater variability compared to controlled experiments, underscoring the influence of environmental and management factors. Furthermore, inconsistencies in postbiotic characterization, dosing metrics, and reporting standards restrict the comparability of cross-studies. Future research should emphasize the development of standardized postbiotic production protocols,

harmonized efficacy metrics, and the implementation of long-term, multi-site livestock trials. The integration of metabolomics, microbiome profiling, and host transcriptomics is essential for establishing mechanistic biomarkers and clarifying dose–response relationships.

Conclusion

This review summarized recent quantitative evidence regarding the food safety potential of postbiotics and parabiotics in livestock and dairy systems. Pathogen reduction and mycotoxin mitigation outcomes are consistently robust across experimental models; however, evidence for modulation of antimicrobial resistance is currently limited. Standardization of postbiotic characterization, harmonized reporting metrics, and long-term field validation are necessary prerequisites for large-scale implementation. Despite these challenges, postbiotics and parabiotics offer promising complementary approaches that integrate animal nutrition strategies with food safety objectives within the one health framework.

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Conflicts of interest

The author declares that there are no conflicts of interest regarding the publication of this paper. The author confirms that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclaimer

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