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Effects Of Chitosan And Whey Powder Supplementation On Mineral Metabolism And Digestive Enzyme Activity In Broiler Chicks: Evidence Synthesis And A Methodological Framework

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Abstract. Improving feed efficiency while reducing reliance on antibiotic growth promoters remains a key challenge in modern broiler production. This paper synthesizes international and CIS literature on chitosan (a cationic biopolymer) and whey powder (a dairy by-product rich in high-biological-value proteins and bioactive peptides), focusing on two mechanistic endpoints: mineral metabolism (Ca, P, Mg) and digestive enzyme activity (amylase, lipase, protease). Using a scoping-review approach, studies published between 2010 and 2026 were mapped across PubMed, Cambridge Core, MDPI, Google Scholar, and open regional databases. Data were extracted on dosage, duration, measurement protocols, and key zootechnical outcomes. The synthesis indicates that chitosan may modulate intestinal barrier integrity, microbiota balance, and mineral bioavailability through adsorption and ion-exchange properties, whereas whey powder may support metabolic stability via high-quality protein fractions and peptides, with downstream effects on gut morphology and nutrient utilization. Local studies from Uzbekistan report beneficial shifts in growth performance, mineral indicators, and bone-related metrics when chitosan and whey are applied in combination. The paper proposes an evidence matrix, a conceptual mechanism model, and practical methodological recommendations for future controlled trials.

Keywords. chitosan; whey powder; broiler chicks; mineral metabolism; calcium–phosphorus; magnesium; digestive enzymes; feed additives; scoping review.

Introduction. Broiler production systems have historically used antibiotic growth promoters to enhance growth rates and feed conversion; however, antimicrobial resistance and food-safety concerns have accelerated regulatory restrictions and stimulated the search for safe functional alternatives [2; 3].

Chitosan, derived from chitin and characterized by a cationic amino-group structure, has attracted attention due to its biodegradability and multifunctional biological activity. Experimental reports suggest that, at optimized doses and molecular characteristics, chitosan can support feed utilization and metabolic status in poultry [1; 23; 24; 25].

Whey powder is a by-product of dairy processing containing whey proteins (e.g., β-lactoglobulin, α-lactalbumin), lactose, and minerals, and is increasingly evaluated as a functional ingredient for intestinal health and performance. Evidence indicates potential improvements in growth, intestinal morphology, and nutrient digestibility, with positive average effects reported in model-based meta-analysis [16; 26; 31].

In Uzbekistan, recent publications have explored combined chitosan-whey strategies in broiler feeding, reporting positive trends in body weight, productivity, mineral indicators, bone-related outcomes, and digestive enzyme activity [4–8; 10]. Yet, heterogeneity in doses, basal diets, and measurement protocols limits direct comparisons and calls for a unified methodological framework.

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This paper aims to map and synthesize the available evidence, emphasizing mineral metabolism and digestive enzyme endpoints, and to provide practical recommendations for standardized future trials.

Main part. Mineral homeostasis—particularly calcium (Ca), phosphorus (P), and magnesium (Mg)—is fundamental for rapid broiler growth, skeletal mineralization, muscle accretion, and resilience. Inadequate Ca/P supply or reduced bioavailability can compromise tibial ash content and bone strength, leading to welfare and economic losses [12; 13].

Feed additives can influence mineral utilization through changes in intestinal morphology, microbiota, and oxidative stress. Oxidative balance and antioxidant defense are increasingly recognized as functional nodes linking gut physiology and metabolic pathways in poultry [14].

Mechanistically, chitosan may interact with negatively charged compounds in the gut, reduce toxin load via adsorption, and modulate the intestinal barrier, with outcomes dependent on molecular weight, degree of deacetylation, and dosage [1; 22].

Whey powder provides high-quality protein substrates and bioactive fractions; studies with whey protein concentrate indicate shifts in performance-related biomarkers and intestinal parameters, suggesting a supportive role for metabolic stability and gut function [28; 27; 10].

A combined chitosan-whey approach may plausibly generate synergy: chitosan can optimize the intestinal milieu and barrier functions, while whey proteins/peptides support anabolic and immunobiochemical processes. Local studies report improvements in Ca/Mg/P indicators and bone-related outcomes under combined supplementation [6; 7].

Table 1 summarizes key compositional and functional attributes relevant to broiler feeding.

Attribute	Chitosan	Whey powder	Relevance to broilers
Core composition	Deacetylated chitin; cationic amino groups	Whey proteins, lactose, minerals	Functional enrichment of diet
Functional effects	Adsorption, antimicrobial, barrier and immunomodulation	Protein substrate, bioactive peptides, potential prebiotic effect	Gut health and metabolic stability
Mineral link	Ion-exchange and mucosal modulation	Ca/P/Mg supply + anabolic support	Bone mineralization and growth
Enzyme activity	Indirect via intestinal milieu	May stimulate digestive secretions via proteins/lactose	Digestibility and FCR
Limitations	Dose and molecular-property sensitivity	Lactose content, technological quality	Needs standardization and cost evaluation

Table 1. Functional attributes of chitosan and whey powder (summary).

Methodology. A scoping-review design was applied to map the breadth of evidence on chitosan and whey powder (individually and combined) in broiler feeding, with emphasis on mineral metabolism and digestive enzyme activity.

Searches covered 2010–2026 using the keywords “chitosan”, “whey powder”, “whey protein”, “broiler”, “mineral metabolism”, “calcium”, “phosphorus”, “magnesium”, “digestive enzymes”, “amylase”, “lipase”, and “protease”. Data sources included PubMed, Cambridge Core, MDPI (Foods/Polymers/Animals), Google Scholar, and open regional repositories [1; 16; 31].

Inclusion criteria required poultry/broiler models, supplementation with chitosan and/or whey, and reporting of mineral indicators (Ca, P, Mg; bone metrics) and/or digestive enzyme activity. Exclusion criteria included purely technological reports, non-poultry models, or insufficient outcome reporting.

For each eligible source, information was extracted on animal age, basal diet, dose (mg/kg or g/kg), duration, analytical methods, and zootechnical outcomes. Due to substantial heterogeneity in protocols, results were synthesized qualitatively rather than pooled quantitatively [31].

Analysis. Chitosan's effects in poultry appear multi-factorial, with the intestinal ecosystem as a primary entry point. In a 42-day trial, Shi et al. reported improved feed conversion and nitrogen retention within a broad chitosan dose range, suggesting an optimal window around 0.5–1.0 g/kg under their conditions [23].

At the same time, outcomes are not universally positive. High doses or specific molecular profiles may reduce absorption of certain nutrients (e.g., lipid fractions) and alter energy balance, highlighting the need to tailor dose to the basal diet and mineral supply [1].

Evidence for whey powder and whey protein concentrates points to benefits in performance, nutrient digestibility, and intestinal morphology, as well as changes in microbial communities, which can plausibly translate into improved mineral uptake [26; 28; 27; 31].

Tsiouris et al. linked whey supplementation with gut-health indicators and bone morphology parameters, reinforcing the potential connection between intestinal function and mineralization outcomes in broilers [27].

Uzbekistan-based studies report favorable changes in body weight, productivity, Ca/Mg/P indicators, bone-related metrics, and digestive enzyme activity when chitosan and whey are applied jointly [4–8]. These reports support the hypothesis of synergy between barrier/microbiota modulation and high-quality protein/peptide delivery.

Table 2 provides an evidence matrix of selected studies to facilitate comparison and highlight methodological sources of heterogeneity.

Author (year)	Model	Supplement/dose	Key reported effect (summary)	Citation
Rakhmonov et al. (2024)	Broiler chicks	Chitosan + whey	Higher body weight / growth trend	[4]
Rakhmonov et al. (2025)	Broiler chicks	Chitosan + whey	Improved productivity / FCR trend	[5]
Rakhmonov (2025)	Broiler chicks	Combination	Shift in mineral indicators	[6]
Rakhmonov et al. (2026)	Broiler chicks	Combination	Ca/Mg/P and bone metabolism markers	[7]
Rakhmonov & Furkatova (2026)	Experimental model	Bioactive chitosan compounds	Changes in amylase, lipase, protease activity	[8]
Shi et al. (2005)	Broilers (42 d)	Chitosan 0.2–5.0 g/kg	Better FCR and N retention; optimal window	[23]
Pineda-Quiroga et al. (2018)	Broilers	Dry whey + WPC	Performance, digestibility, microbiota shifts	[26]
Tsiouris et al. (2020)	Broilers	Whey in diet	Gut health and bone morphology links	[27]
Al-Marzooqi et al. (2024)	Chickens	Chitosan supplement	Growth, blood indices, meat quality changes	[11]

Table 2. Evidence matrix for chitosan and whey powder in poultry (selected studies).

Results. Across the mapped literature, three outcome domains consistently emerge: (i) growth and feed conversion; (ii) gut function and digestive enzyme activity; and (iii) mineral metabolism and bone

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mineralization. Uzbekistani studies contribute new regional evidence suggesting that combined supplementation can move indicators in a favorable direction across these domains [4–8].

However, cross-study comparability is limited by differences in basal diet composition, enzyme use (e.g., phytase), dose units (mg/kg vs g/kg), and analytical endpoints. Future trials should report standardized panels, including serum Ca/P/Mg, tibial ash or mineral density, and a defined set of digestive enzymes, alongside performance metrics [12; 13].

The conceptual model suggests that chitosan first optimizes the intestinal barrier and reduces adverse luminal factors via adsorption, while whey proteins/peptides provide anabolic and immunobiochemical support. Together, these pathways may stabilize digestive processes and improve mineral uptake, contributing to skeletal outcomes and productivity [1; 31; 7; 27].

Conclusion. Chitosan and whey powder represent promising natural feed additives for broilers, with mechanistic relevance to gut ecology, digestive enzyme activity, and mineral metabolism. The combined approach is supported by emerging local studies and complementary international evidence, yet the field requires stronger standardization of dose rationale and outcome reporting.

Standardized experimental designs, careful control of Ca/P supply and enzyme interactions, and transparent reporting of analytical protocols will strengthen the evidence base and facilitate translation into production practice.

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