Review Article:

Immunostimulants in livestock, poultry, and aquaculture: Current applications and future prospects of IgY

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Abstract

The livestock, poultry, and aquaculture industries are essential for global food security and animal protein production. However, infectious diseases continue to cause substantial economic losses through increased mortality, impaired growth performance, reduced productivity, and elevated treatment costs. In response to growing concerns regarding antibiotic resistance and the excessive use of antimicrobial agents, immunostimulants have emerged as promising alternatives for disease prevention and health management. Among these compounds, egg yolk immunoglobulin (IgY) has attracted considerable attention due to its high specificity, safety, cost-effective large-scale production, and broad antimicrobial potential. This review summarizes the current knowledge regarding the use of immunostimulants in livestock, poultry, and aquaculture, with particular emphasis on the biological properties, mechanisms of action, and practical applications of IgY. In addition, the potential role of IgY in improving animal health, enhancing immune responses, reducing mortality, and increasing production efficiency is discussed. The available evidence suggests that IgY may serve as an effective alternative or complementary strategy to antibiotics in modern animal production systems. Its application could contribute to improved sustainability, reduced antimicrobial dependence, and enhanced economic performance across livestock, poultry, and aquaculture industries.

Keywords: IgY; immunostimulants; livestock; poultry; aquaculture; antibiotic alternatives; animal health.

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Introduction

The livestock, poultry, and aquaculture industries are among the most important sectors for supplying animal protein to the growing global population and play a central role in food security and economic development. However, these industries are continually threatened by infectious diseases of viral, bacterial, and parasitic origin. Such diseases not only reduce productivity and increase treatment costs, but also cause major economic losses and may pose risks to public health through zoonotic transmission. In aquaculture, infectious diseases can lead to substantial mortality and severe economic damage to fish and shrimp production systems (Zorriehzahra *et al.,* 2016).

For many years, antibiotics have been the most commonly used strategy for the prevention and treatment of diseases in livestock, poultry, and aquaculture. Nevertheless, the indiscriminate and uncontrolled use of antibiotics has contributed to serious consequences, including antimicrobial resistance (AMR), reduced drug efficacy, residual antibiotics in food products, and environmental concerns. AMR occurs when bacteria, viruses, fungi, and parasites change over time and no longer respond to medications, making infections harder to treat and increasing the risk of disease spread, severe illness, and mortality (Radwan *et al.,* 2023). Therefore, global health policies have increasingly shifted toward reducing antibiotic use and promoting safe, sustainable alternatives.

Among the available alternatives, immunostimulants have attracted considerable attention because they enhance both innate and adaptive immune responses and improve the host's resistance to pathogens. Immunostimulants include a broad range of compounds such as probiotics, prebiotics, plant-derived products, bioactive polysaccharides, vaccines, and passive immune-based preparations. These agents have shown promise in improving disease resistance, reducing dependence on antibiotics, and promoting healthier and more sustainable animal production systems (Li *et al.,* 2015; Hussein *et al.,* 2020).

Within this context, chicken egg yolk immunoglobulin Y (IgY) has emerged as one of the most promising and innovative immune-based approaches. IgY is a specific antibody naturally deposited in the yolk of bird eggs and is capable of recognizing and neutralizing a wide range of pathogens. Compared with conventional antibodies, IgY offers several advantages, including low-cost production, high biosafety, non-invasive harvesting, and minimal risk of inducing allergic reactions in humans and animals. These features have made IgY an attractive tool for passive immunization and disease control in livestock, poultry, and aquaculture (Capotă *et al.,* 2025; Chen *et al.,* 2025).

Evidence from previous studies indicates that IgY can be effective in reducing gastrointestinal and respiratory diseases in livestock, controlling salmonellosis and coccidiosis in poultry, and improving survival against bacterial

and viral infections in aquaculture species. In domesticated animals, egg yolk antibodies have also been reported as effective non-antibiotic production enhancers, supporting growth and health while reducing drug use (Diraviyam *et al.,* 2014; Li *et al.,* 2015). Similarly, in fish and aquatic animals, IgY has shown therapeutic potential against infectious diseases and has been proposed as a valuable tool for disease prevention in aquaculture systems (Zorriehzahra *et al.,* 2016).

Despite these advantages, practical limitations such as sensitivity to gastrointestinal conditions and the need for advanced delivery technologies still hinder the broad industrial application of IgY. Future progress in this field will depend on the development of novel formulations, improved stability and delivery systems, and the integration of IgY with other immunostimulants such as probiotics, prebiotics, and vaccines. In addition, recent studies have emphasized the expanding applications of IgY in prevention, diagnosis, and immunotherapy, highlighting its strong potential as a sustainable immune-based solution for animal health management (Hussein *et al.,* 2020; Capotă *et al.,* 2025; Chen *et al.,* 2025).

Overall, immunostimulants, particularly IgY-based approaches, may provide effective complementary strategies for improving animal health and productivity while reducing dependence on antibiotics. Continued applied research and investment in this area may play a crucial role in advancing animal health, food safety, and global sustainability (Radwan *et al.,* 2023) (Fig. 1).

Immune system in livestock, poultry, and aquaculture

The immune system in livestock, poultry, and aquaculture serves as a complex and highly coordinated defense mechanism essential for maintaining homeostasis and protecting the host against pathogenic insults. While the fundamental architecture of the immune system comprising innate and adaptive branches is conserved across these species, there are significant physiological and immunological nuances dictated by their respective environments (Zorriehzahra *et al.,* 2016).

In mammals (livestock), the immune system is characterized by sophisticated systemic responses. The innate immune system, representing the first line of defense, utilizes pattern recognition receptors (PRRs) to identify conserved microbial structures known as pathogen-associated molecular patterns (PAMPs). This recognition triggers inflammatory cascades, phagocytosis, and the recruitment of immune cells to the site of infection. Subsequently, the adaptive immune system, mediated by T and B lymphocytes, generates pathogen-specific memory, providing long-term protection (Hussein *et al.,* 2020).

Similarly, poultry possess a specialized immune system adapted for rapid responses to environmental pathogens.

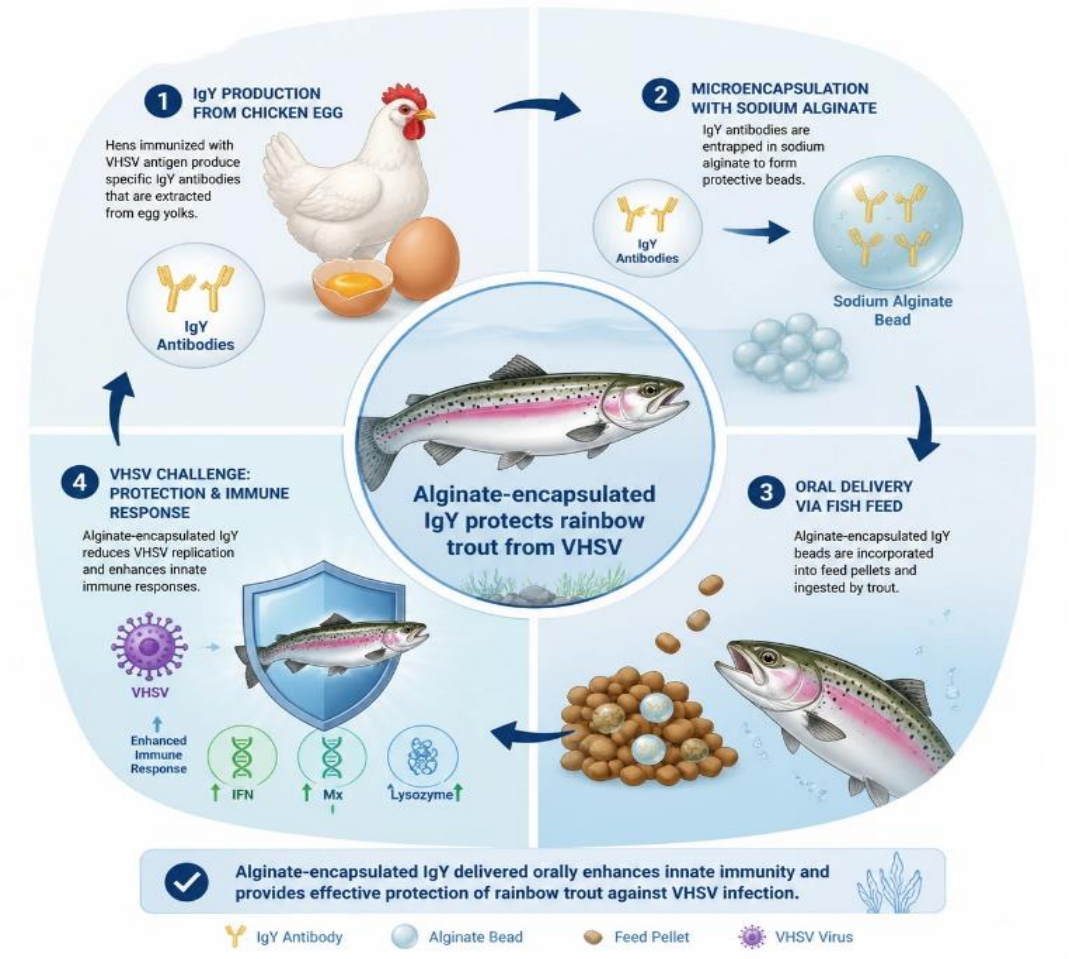

Figure 1: Graphical representation of the integrative role of immunostimulants and IgY technology in modern veterinary medicine. The schematic illustrates the pathway from IgY production in avian hosts to its multifaceted applications in livestock, poultry, and aquaculture. Key mechanisms include the enhancement of passive mucosal immunity, neutralization of enteric and systemic pathogens, and the promotion of growth performance. This approach highlights the transition toward sustainable disease management by reducing reliance on conventional antibiotics and fostering global food security.

Their immune competency is highly dependent on early-life development and the maturation of lymphoid organs such as the bursa of Fabricius. Poultry demonstrate robust innate responses, which, when effectively supported by nutritional and immunomodulatory interventions, significantly enhance resistance to common challenges like salmonellosis and coccidiosis (Radwan *et al.,* 2023).

Aquatic species, however, exhibit a unique immunological profile due to their constant exposure to an aqueous environment teeming with pathogens. The fish immune system relies heavily on innate immunity, which is notably more potent and sophisticated than in higher vertebrates. Their skin, mucus, and gills act as vital physical and chemical barriers. Furthermore, the role of maternal immunity, particularly the transfer of antibodies from broodstock to

offspring, is a critical area of study in aquaculture (Zorriehzahra *et al.,* 2016). Recent advancements in IgY-based technologies have further elucidated how passive immunization can augment these innate defenses, providing a protective buffer for aquatic animals against viral and bacterial outbreaks (Chen *et al.,* 2025; Capotă *et al.,* 2025).

In all three sectors, the efficient orchestration of these immune responses is crucial. However, intensive farming practices can induce physiological stress, leading to immune suppression and increased susceptibility to infectious diseases (Li *et al.,* 2015). Consequently, the integration of immunostimulants such as IgY is considered a strategic approach to boost the overall immunocompetence of the host, particularly during critical developmental stages or periods of high disease pressure (Diraviyam *et al.,* 2014; Capotă *et al.,* 2025).

Immunostimulants used in livestock, poultry, and aquaculture

Given the mounting challenges of antimicrobial resistance (AMR) and the economic burden of infectious diseases, the use of immunostimulants has emerged as a key strategic pillar in modern animal husbandry and aquaculture. These substances are defined as compounds that, by acting on the innate or adaptive immune system, enhance the host's resistance to pathogens (Hussein *et al.,* 2020).

Probiotics, prebiotics, and plant-derived compounds

Probiotics and prebiotics are widely recognized for their role in modulating gut microbiota and improving immune function. In poultry and swine, these additives have been shown to competitively exclude pathogens and enhance intestinal mucosal immunity, thereby serving as non-antibiotic production enhancers (Li *et al.,* 2015). Similarly, plant-derived products, including essential oils and bioactive polysaccharides, have demonstrated significant antioxidant and immunostimulatory properties, helping to reduce the incidence of metabolic and infectious disorders in livestock (Hussein *et al.,* 2020; Radwan *et al.,* 2023).

Vaccines and bioactive polysaccharides

Vaccination remains the most effective prophylactic measure in intensive production systems. However, its efficacy can be limited by the immunosuppressive effects of environmental stressors. To overcome these limitations, research is increasingly focusing on the use of bioactive polysaccharides and other natural adjuvants that can prime the immune system, leading to more robust and long-lasting vaccine-induced immunity (Radwan *et al.,* 2023).

Passive immunization: The role of IgY

Passive immunization through the administration of specific antibodies represents a promisingcornerstone approach to disease control, particularly when rapid protection is required. Among these, Immunoglobulin Y (IgY)

derived from the egg yolk of hyper-immunized chickens is increasingly valued for its specificity and effectiveness against a wide spectrum of bacteria and viruses (Capotă *et al.,* 2025). In aquaculture, the administration of IgY has been shown to neutralize major pathogens, providing a critical defensive barrier where traditional vaccination may be technically challenging or slow to act (Zorriehzahra *et al.,* 2016; Chen *et al.,* 2025). Furthermore, systematic reviews and meta-analyses have validated the efficacy of IgY in mitigating the severity of gastrointestinal infections and reducing neonatal mortality in various domesticated animals (Diraviyam *et al.,* 2014). The versatility of IgY ranging from feed additives in poultry to targeted therapeutic applications in fish positions it as a valuable tool in the transition toward sustainable and antibiotic-free production systems (Hussein *et al.,* 2020; Capotă *et al.,* 2025).

Applications of IgY in livestock, poultry, and aquaculture

The application of Immunoglobulin Y (IgY) has expanded significantly across animal production sectors, offering a versatile platform for both disease prevention and therapeutic intervention. By providing immediate, pathogen-specific passive immunity, IgY serves as an essential tool during critical growth stages or high-risk periods in industrial farming (Capotă *et al.,* 2025).

Livestock and poultry applications

In livestock, particularly in neonates, the gastrointestinal tract is highly susceptible to infections caused by pathogens such as *Escherichia coli*. Oral administration of specific IgY has been shown to effectively neutralize these pathogens in the gut lumen, thereby reducing neonatal mortality (Diraviyam *et al.,* 2014; Li *et al.,* 2015). In the poultry industry, the focus has shifted toward controlling colonization of *Salmonella* and coccidiosis parasites. Recent research highlights that supplementing diets with IgY not only improves intestinal homeostasis but also acts as a potent regulator of immune performance, effectively reducing the reliance on synthetic antibiotics (Hussein *et al.,* 2020). This integration of IgY technology offers a scalable, residue-free solution for large-scale operations (Radwan *et al.,* 2023).

Aquaculture applications

Aquaculture faces unique difficulties due to the high density of stocks and the rapid spread of waterborne pathogens. Recent advances have highlighted the potential role of IgY in passive immunotherapy within this sector. IgY antibodies are now being effectively utilized to counter major bacterial infections, such as vibriosis (*Vibrio parahaemolyticus*, *V. harveyi*, and *V. splendidus*) and bacterial septicemia (*Aeromonas hydrophila* and *A. salmonicida*), as well as viral threats including the Nervous Necrosis Virus and White Spot Syndrome Virus. Unlike traditional treatments, IgY can be administered through various routes

including feed, oral intake, immersion, and injection making it highly adaptable to different aquaculture systems (Qiu *et al.,* 2025). Studies have demonstrated that specific IgY formulations not only increase antibody titers but also significantly enhance the phagocytic activity in fish, shrimp, and sea cucumbers, leading to lower infection incidence and improved survival rates during disease outbreaks (Qiu *et al.,* 2025; Chen *et al.,* 2025). As the industry transitions toward sustainable production, these multifaceted applications of IgY are becoming critical for ensuring food security and environmental health (Capotă *et al.,* 2025).

Future perspectives of immunostimulants with emphasis on IgY

The future of disease management in livestock, poultry, and aquaculture lies in the synergy between conventional biosecurity and advanced, targeted immunological interventions. While current applications of IgY have demonstrated significant success, the next phase of development focuses on optimizing production efficiency, delivery systems, and multivalent efficacy.

Engineering and multivalency

To maximize the therapeutic impact, future research is increasingly directed toward the development of "multivalent IgY." By engineering antibodies capable of neutralizing multiple pathogens or various strains of a single pathogen simultaneously, researchers can provide broader spectrum protection (Qiu *et al.,* 2025). Furthermore, the integration of recombinant DNA technology with egg-yolk antibody production promises to lower costs and increase the yield of high-affinity antibodies, potentially improving the economic feasibility of large-scale applications (Capotă *et al.,* 2025).

Innovation in delivery mechanisms

A primary challenge for the future is ensuring the stability of IgY as it passes through the harsh gastrointestinal environments of different species. Innovative approaches, such as micro-encapsulation and the use of pH-sensitive nanomaterials, are currently being explored to protect IgY from proteolytic degradation in the gut, thereby enhancing its bioavailability (Chen *et al.,* 2025). In aquaculture, research is shifting toward advanced immersion and biofilm-based delivery systems, which allow for the sustained release of antibodies directly into the aquatic environment, ensuring constant protection for the stock (Qiu *et al.,* 2025).

Precision immunostimulation

The shift toward "Precision Livestock and Aquaculture" necessitates a transition from broad-spectrum stimulants to precise, diagnostic-led therapy. Future strategies will likely involve real-time monitoring of herd/population health via biosensors, followed by the immediate, customized delivery of targeted IgY therapies

(Zorriehzahra *et al.,* 2016). This integration of rapid diagnostics with passive immunization will minimize unnecessary drug use, thereby mitigate the risk of antibiotic resistance and promote sustainable production practices in line with global environmental standards (Qiu *et al.,* 2025; Radwan *et al.,* 2023).

Conclusion

Infectious diseases have consistently posed a major challenge to the livestock, poultry, and aquaculture industries, resulting in significant economic and public health consequences. While the indiscriminate use of antibiotics has helped control diseases in the short term, it has long-term implications, including the emergence of antimicrobial resistance, reduced drug efficacy, and concerns regarding food safety and environmental impact. In this regard, the utilization of immunostimulants as a sustainable and safe alternative or supplement to antibiotics has gained increasing importance. A review of various immunostimulants demonstrates that probiotics, prebiotics, plant-derived compounds, bioactive polysaccharides, and vaccines each play an effective role in improving immune responses and enhancing animal resistance. Among these, Immunoglobulin Y (IgY) has emerged as a promising complementary approach. This antibody, which is naturally stored in the egg yolk of birds, offers advantages such as large-scale production feasibility, high biosafety, and the specific ability to neutralize pathogens. Numerous studies have indicated that IgY can be effective in reducing the incidence of gastrointestinal and respiratory diseases in livestock, controlling salmonellosis and coccidiosis in poultry, and increasing survival rates against bacterial and viral diseases in aquaculture. Despite these advantages, limitations such as sensitivity to gastrointestinal conditions and the need for advanced technologies to improve stability continue to hinder the widespread industrial application of IgY. The future of this field depends on the development of novel formulations, the combination of IgY with other immunostimulants, and increased awareness among industry stakeholders. In conclusion, it can be stated that immunostimulants, particularly IgY, outline a clear prospect for enhancing health and productivity in livestock and aquaculture. Continued applied research and investment in this area could represent a significant step toward reducing antibiotic dependency, improving animal welfare, and enhancing global food security. Furthermore, advancements in IgY formulation technologies, its integration with probiotics, prebiotics, and vaccines, as well as novel applications in diagnostics and immunotherapy, have created a clear vision for the sustainable development of the livestock, poultry, and aquaculture sectors. Given the reduction in antibiotic reliance and the decrease in treatment costs, IgY concurrently possesses high biological and economic value, and it can be positioned as one of the fundamental

pillars for enhancing health and productivity in animal production industries (Capotă *et al.,* 2025).

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Conflict of Interest
The authors declare that there is no conflict of interest.

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Ethical Considerations
This article is a review and does not involve any direct experimentation on animals or humans.

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