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Clostridium perfringens in Poultry: Current Challenges and Future Directions

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ABSTRACT

Clostridium perfringens is a Gram-positive, spore-forming, anaerobic bacterium. It is one of the most important bacterial pathogens in poultry worldwide. It is the main cause of necrotic enteritis, a disease that damages the intestines, reduces nutrient absorption, slows bird growth, and causes major economic losses to the poultry industry. Several predisposing factors and bacterial toxins, including NetB, alpha toxin, perfringolysin O, β2 toxin, and TpeL, influence disease development. Modern molecular techniques such as polymerase chain reaction (PCR), DNA sequencing, and phylogenetic analysis have improved the detection and identification of harmful strains of *C. perfringens*. However, the growing problem of antimicrobial resistance (AMR) has reduced the effectiveness of antibiotics. As a result, alternative control methods such as probiotics, bacteriocins, phage lysins, better biosecurity, and the responsible use of antibiotics are becoming increasingly important. This article discusses the pathogenesis, epidemiology, diagnosis, economic losses, current challenges, and future strategies for the prevention and control of *C. perfringens* infections in poultry.

Keywords: Clostridium, Poultry, Enteritis, Biosecurity, Biofilm

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Introduction

C. perfringens is a Gram-positive, spore-forming, anaerobic bacterium that is widely distributed in the environment and the intestinal tract of healthy poultry birds. It produces more than 17 toxins and is classified into seven toxin types (A–G) based on toxin profiles, with toxinotypes A and G being the most important in poultry diseases [1, 2, 5, 15, 16].

Factors such as coccidiosis, dietary changes, poor management, and intestinal imbalance promote its rapid proliferation, resulting in necrotic enteritis (NE), intestinal damage, poor nutrient absorption, reduced growth performance, and economic losses in the poultry industry [3, 4].

The excessive use of antibiotics for disease prevention and growth promotion has contributed to the emergence of AMR *C. perfringens* strains, limiting the effectiveness of conventional control measures and increasing concerns for both poultry production [6, 17].

Therefore, sustainable control strategies, including probiotics, bacteriocins, phage lysins, improved biosecurity, and prudent antimicrobial use, are being explored to reduce the burden of *C. perfringens*. This review summarizes the current challenges associated with *C. perfringens* in poultry and discusses future directions for its effective prevention and control [1, 3].

Pathogenesis

C. perfringens establishes infection by degrading the intestinal mucus layer through glycoside hydrolases and chitinases, using mucin-derived carbohydrates as nutrients while facilitating bacterial adhesion and microcolony formation on the intestinal mucosa [9]. Following colonization, quorum-sensing systems (Agr and LuxS) together with the VirR/VirS and PilR/PilS regulatory systems activate virulence genes that enhance adhesion, biofilm formation, and bacterial persistence within the intestine [8, 9]. This organism produces major virulence factors, including NetB, alpha-toxin, perfringolysin O (PFO), β2-toxin, and TpeL toxin. They collectively contribute to intestinal tissue damage and disease severity [8]. To understand the mechanism of disease, the pathogenesis of NE is shown in Fig. 1.

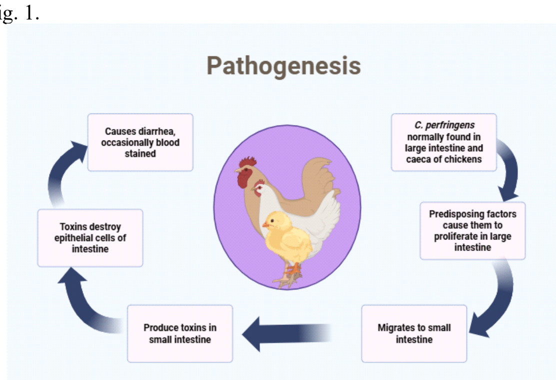

Figure 1. Pathogenesis of necrotic enteritis in broiler chickens destroys epithelial cells of the intestine, leading to blood-stained diarrhea

These toxins and extracellular enzymes disrupt the intestinal epithelium by damaging epithelial cells, forming membrane pores that induce calcium influx, and causing extensive necrosis and sloughing of the intestinal mucosa [9]. As *C. perfringens* infection progresses, biofilm formation on the exposed submucosa promotes bacterial survival and resistance to host defenses, resulting in characteristic necrotic lesions, pseudomembrane formation, and severe intestinal pathology [9].

Epidemiology and Economic losses

Avian necrotic enteritis is most frequently reported in 2–6-week-old broiler chickens, but it also occurs in several other poultry species. This disease is strongly associated with Eimeria spp. infection, and it represents a major cause of economic losses in the poultry industry [10]. Necrotic enteritis (NE) is one of the most economically important diseases of the poultry industry, which causes substantial financial losses due to reduced weight gain in subclinical infections and increased mortality in clinical outbreaks. These production losses significantly affect the overall profitability of broiler production [8].

Advanced Diagnosis

Advanced diagnosis of *C. perfringens* in poultry relies on molecular techniques, particularly polymerase chain reaction (PCR), for detecting toxin genes such as cpa and NetB, thereby improving diagnostic accuracy and specificity. Its confirmation is achieved through DNA sequencing and BLAST analysis, while phylogenetic and multiple sequence analyses are used to characterize genetic diversity and determine the relationship between circulating isolates. These advanced approaches help in accurate epidemiological surveillance and facilitate the identification of highly virulent strains [1317,19].

Current Challenges in the Control of *C. perfringens*

The control of *C. perfringens* remains challenging because it has diverse serotypes and toxin profiles that complicate the prevention and disease management. Furthermore, the increasing emergence of AMR and the limitations of conventional antibiotic therapy emphasize the need for effective alternative control strategies [12, 18, 20].

Future Research Directions and Emerging Alternatives

In the future, researchers should focus on developing effective alternatives to control *C. perfringens.* This includes novel inactivation technologies such as cold plasma, high-intensity ultrasound, and pulsed light. Further studies are needed to understand spore germination, optimize combined (hurdle) treatment strategies, and develop rapid molecular detection methods for the accurate identification of *C. perfringens* and its toxin genes. These approaches may improve disease control while maintaining food quality and reducing reliance on conventional methods [11, 14, 15, 17, 20].

Conclusion

C. perfringens remains a major threat to poultry production because of its role in necrotic enteritis, causing intestinal damage, reduced growth performance, mortality, and economic losses. The increasing emergence of AMR strains highlights the need for sustainable control strategies. Advances in molecular diagnostics and emerging alternatives, including probiotics, bacteriocins, phage lysins, and novel inactivation technologies, offer promising approaches for effective disease control and improved poultry health.

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