FIMEK

Journal of Agronomy, Technology and Engineering Management
ISSN 2620-1755

Review

Colibacillosis in Modern Poultry Production

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Received: 19 July 2023; Accepted: 29 October 2023

Abstract: Colibacillosis, a bacterial infection caused by pathogenic *Escherichia coli* strains, poses significant challenges to contemporary poultry farming. This paper provides a succinct overview of key aspects related to the disease. Colibacillosis manifests with respiratory, enteric, and systemic clinical signs, impacting broilers, layers, and breeders. The etiology involves virulent *E. coli* strains with specific adhesion and invasion mechanisms. The avian immune response plays a crucial role, influenced by factors such as age, stress, and vaccination. The epidemiology exhibits global prevalence, influenced by geographical, seasonal, and farm-specific factors. Control strategies encompass biosecurity measures, vaccination, responsible antimicrobial use, genetic selection, and environmental management. Comprehensive understanding and proactive management of colibacillosis are essential to mitigate economic losses and sustain the health and productivity of poultry in modern production systems. In conclusion colibacillosis remains a significant challenge in modern poultry production, with economic implications for the industry. Efforts to control and manage colibacillosis in poultry production should take into consideration these multifaceted factors and focus on prevention, early detection, and responsible antimicrobial use.

Keywords: *E. coli*; colibacillosis; poultry; birds; diseases; virulence.

1. Introduction

Poultry farming has become a cornerstone of global agriculture, providing a significant source of protein and sustenance to millions of people worldwide [1]. The efficiency of poultry production, with its relatively short production cycles and high feed conversion rates, has made it an attractive choice for meeting the growing demand for animal protein [2]. However, the industry is not without its challenges. Among the many threats that poultry farmers face, one of the most persistent and economically damaging diseases is colibacillosis [3], caused by the bacterium *Escherichia coli* [4,5].

Colibacillosis is a broad term used to describe a spectrum of diseases in poultry caused by various pathogenic strains of *E. coli* [6]. These infections manifest as a complex interplay of factors, including the pathogen itself, the host's immune response, and environmental conditions [7]. The disease's manifestations range from mild respiratory or intestinal infections to severe systemic infections, leading to significant morbidity and mortality rates. The economic impact of colibacillosis on the poultry industry is substantial, with losses arising from decreased production, increased medication costs, and the culling of affected birds [8].

Understanding colibacillosis is a multifaceted challenge, as it involves the study of both the bacterium and the host [9]. The bacterium *E. coli* is a ubiquitous commensal microorganism found in the intestinal tracts of healthy poultry and many other animals, including humans [10]. However, some strains of *E. coli* have acquired virulence factors that enable them to cause disease under specific conditions [11]. These pathogenic strains of *E. coli* have evolved to breach the host's defenses, colonize various organs and tissues, and produce toxins that contribute to the clinical signs of disease [12].

The host response to *E. coli* infections in poultry is equally complex. The bird's immune system is essential in protecting it from infection, but the effectiveness of this response depends on various factors, such as the age and breed of the bird, its overall health status, and environmental stressors. The interplay between the immune system, the bacterium, and the environment shapes the outcome of colibacillosis in each case [13].

This paper aims to provide a comprehensive overview of colibacillosis in poultry, delving into the various aspects of this complex disease, from its etiology to its impact on the poultry industry. By examining the pathogen, the host, and the environmental factors that contribute to the disease's manifestation, we seek to shed light on the multifaceted nature of colibacillosis. This understanding is crucial for the development of effective prevention and control strategies, ultimately reducing the economic burden on the poultry industry and ensuring the welfare of these valuable birds.

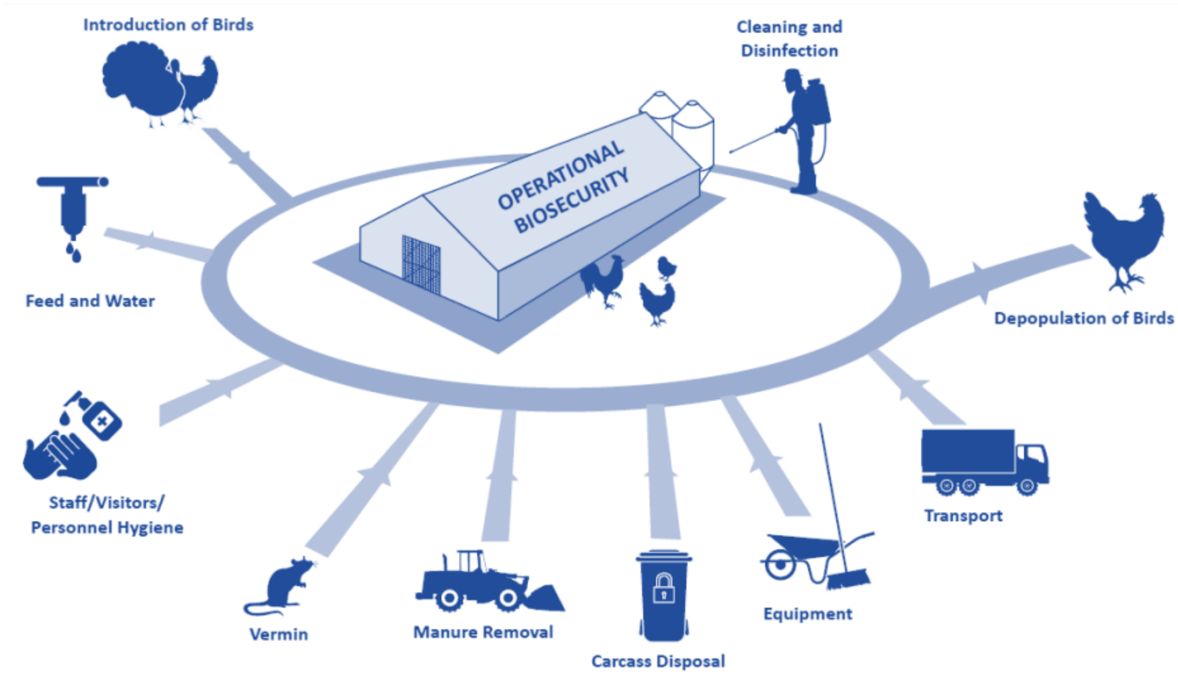
2. Etiology and pathogenesis

This topic is critical in understanding how *E. coli* infections occur in poultry and how they impact the industry. The following discussion will cover various aspects of the etiology and pathogenesis of colibacillosis, as well as the modern factors that have influenced its dynamics. Colibacillosis in poultry is a multifaceted disease caused by various pathogenic strains of the bacterium *E. coli*. Understanding the etiology and pathogenesis of colibacillosis is crucial for effective management and control of this economically significant disease in modern poultry production [5]. In recent years, the landscape of poultry farming has evolved with changes in production systems [14], genetic selection, and antimicrobial usage [15], all of which have influenced the dynamics of colibacillosis. This discussion delves into the etiological factors, pathogenic mechanisms, and modern influences that shape the occurrence and impact of colibacillosis in poultry.

Colibacillosis primarily results from infections with pathogenic strains of *E. coli*, a gram-negative, facultative anaerobic bacterium. While *E. coli* is a common commensal inhabitant of the avian intestinal tract, not all strains are pathogenic [16]. Pathogenic strains have acquired specific virulence factors that enable them to cause disease under appropriate conditions. The virulence of pathogenic *E. coli* strains is attributed to an array of virulence factors, including adhesins, toxins, and invasins [17]. These factors allow the bacterium to adhere to host tissues, colonize various organs, and evade the host's immune defenses. Common virulence factors include fimbriae (pili) and outer membrane proteins, as well as toxins like cytotoxins, hemolysins, and endotoxins [18]. Pathogenic *E. coli* strains are classified into different serogroups based on their surface antigens [19]. Serogroups that are frequently associated with colibacillosis in poultry include O1, O2, O8, and O78. These serogroups may differ in their virulence properties, including their ability to adhere to the gut epithelium and invade host tissues [20].

In poultry, colibacillosis can manifest as either an intestinal or extraintestinal infection [4]. The infection can begin through the oral-fecal route, with birds ingesting contaminated feed, water, or litter [10]. Once ingested, the pathogenic *E. coli* strains can adhere to the mucosal surfaces of the gut [21]. Some pathogenic strains of *E. coli* possess invasins that allow them to penetrate the intestinal epithelium and gain access to underlying tissues. These invasins facilitate the invasion of the lamina propria and submucosa, where *E. coli* can cause damage and initiate an inflammatory response. In addition to their adhesive and invasive properties, pathogenic *E. coli* strains produce various toxins that contribute to the clinical signs of colibacillosis [22]. For example, cytotoxins can cause damage to host cells, leading to ulceration of the intestinal mucosa. Hemolysins may disrupt red blood cells, and endotoxins can trigger an inflammatory response. In cases of extraintestinal colibacillosis, *E. coli* can disseminate systemically through the bloodstream, affecting various organs such as the liver, lungs, and pericardium [23]. This systemic spread can lead to septicemia, characterized by severe illness and high mortality rates.

Modern poultry production is often characterized by high stocking densities, which can create stressful and overcrowded conditions [24]. These stressors can weaken the birds' immune responses, making them more susceptible to *E. coli* infections. Selective breeding for improved growth rates and production traits has led to changes in poultry genetics. While this has enhanced production efficiency, it may have inadvertently affected the birds' ability to resist disease, potentially increasing their susceptibility to colibacillosis. The use of antibiotics in poultry production has been a common practice to promote growth and prevent disease [25]. However, the overuse of antibiotics has led to the emergence of antimicrobial-resistant *E. coli* strains [26]. These resistant strains pose a significant challenge in the control of colibacillosis. The implementation of biosecurity measures on poultry farms (Picture 1) has become increasingly important in preventing the introduction and spread of *E. coli* and other pathogens [27]. Strict biosecurity protocols, such as controlling access to farms and maintaining clean environments, can help reduce the risk of colibacillosis outbreaks [28]. Advances in vaccine development have led to the creation of vaccines against specific pathogenic *E. coli* strains. These vaccines can be used to protect poultry from colibacillosis, especially in situations where the disease is endemic [29]. Proper nutrition is essential for maintaining the health and immunity of poultry [30]. Modern nutritional practices aim to support the gut health of birds, which can influence their resistance to *E. coli* infections.



Picture 1. Biosecurity measures on poultry farms [27].

3. Clinical manifestations

Understanding the clinical signs and symptoms is crucial for the timely diagnosis and effective management of this disease, which has economic implications for the poultry industry. This discussion will cover a range of clinical manifestations of colibacillosis and their impact on poultry health and production (Table 1). This bacterial disease is associated with a diverse range of clinical manifestations that can affect poultry health and productivity [31]. As the poultry industry has evolved with changing management practices, breeding, and environmental factors, it is essential to understand the clinical signs and symptoms of colibacillosis to facilitate early diagnosis and effective disease management [8].

Table 1. Clinical signs and symptoms of colibacillosis in poultry [5,8,31–33].

Clinical signs	Symptoms
Respiratory manifestations	• *Coughing and Sneezing:* Respiratory colibacillosis often presents with clinical signs resembling those of respiratory infections. Affected birds may exhibit coughing and sneezing, which can be more prevalent in broiler chickens, pullets, and young layers. • *Nasal Discharge:* Nasal discharge, ranging from clear to mucopurulent, can be observed in birds with respiratory colibacillosis. This discharge may contribute to a wet environment within the housing, predisposing other birds to infection.
Pericarditis and airsacculitis	• *Depression and Weakness:* In cases of pericarditis and airsacculitis, affected birds may appear lethargic and weak. They may spend more time resting and exhibit reluctance to move. • *Dyspnea (Labored Breathing):* Birds with pericarditis or airsacculitis may experience labored breathing, manifested as an increased respiratory rate, gasping, and open-mouth breathing. The accumulation of exudate and inflammation within the air sacs and pericardial sac can restrict respiratory function.
Colisepticemia	• *Depression and Huddling:* Colisepticemia, characterized by the systemic spread of E. coli, can result in a range of non-specific clinical signs. Affected birds may huddle together, appear lethargic, and show reduced activity. • *Diarrhea:* Diarrhea, often watery and greenish in color, can be observed in birds with colisepticemia. This condition can lead to dehydration and electrolyte imbalances.
Enteric manifestations	• *Diarrhea and Dehydration:* Colibacillosis can manifest as enteric infections, leading to diarrhea, dehydration, and electrolyte imbalances. Affected birds may pass watery feces with varying degrees of blood or mucus. • *Ruffled Feathers:* Sick birds may display ruffled feathers and a hunched posture, indicating discomfort and illness. • *Drop in Egg Production:* Layers affected by colibacillosis may experience a significant drop in egg production. The disease can negatively impact egg quality and shell integrity, resulting in economic losses.
Joints and osteomyelitis	• *Lameness and Swollen Joints:* In cases of colibacillosis affecting the joints, birds may exhibit lameness and swollen, painful joints. This condition is commonly referred to as septic arthritis. • *Reduced Mobility:* Due to joint pain and swelling, affected birds may have reduced mobility and difficulty walking.
Salpingitis and reproductive issues	• *Reduced Fertility:* Colibacillosis can lead to reduced fertility and poor hatchability in breeder flocks. The infection may affect the reproductive organs, particularly the oviduct, causing inflammation and damage. • *Egg Yolk Peritonitis:* In severe cases, infected hens may develop egg yolk peritonitis, characterized by the accumulation of egg yolk within the abdominal cavity. This condition can lead to severe peritonitis and a drop in egg production.

The age of the birds significantly influences the clinical manifestations of colibacillosis [34]. Young birds, especially broilers and pullets, may exhibit respiratory signs, while layers are more prone to enteric manifestations and reproductive issues [35]. The quality of the poultry housing environment plays a vital role in disease expression. Crowded and poorly ventilated conditions can exacerbate the spread of *E. coli*, leading to more severe clinical signs. Wet and litter-caked conditions can contribute to the development of pericarditis and airsacculitis [36]. The immune status of the flock is a critical determinant of clinical manifestations. Birds with compromised immune systems, such as those stressed by management practices or co-infections, may exhibit more severe signs of colibacillosis [37]. The virulence factors of the infecting *E. coli* strain influence the severity of clinical manifestations. Strains with a high virulence potential may cause more severe disease. The route of infection can affect the primary target organ. Birds infected through the respiratory route are more likely to exhibit respiratory signs, while those infected through the digestive tract are prone to enteric manifestations [5]. The use of vaccines targeting specific pathogenic *E. coli* strains can reduce the severity of clinical signs. However, the effectiveness of vaccination may vary depending on the strain's virulence and the overall health of the flock.

4. Host immune response

Understanding how the avian immune system reacts to *E. coli* infections is crucial for developing effective control and management strategies [38]. The host immune response plays a critical role in determining the outcome of *E. coli* infections in birds (Table 2). Understanding how the avian immune system reacts to colibacillosis is essential for developing effective control and management strategies [39]. The age of the birds significantly influences the maturity of their immune system. Young chicks have an immature immune system, making them more susceptible to *E. coli* infections. Maturation of the immune system occurs gradually during the first few weeks of life [40]. Modern poultry production often involves crowded and stressful environments, which can weaken the immune response. Stressors, such as high stocking densities, poor ventilation, and exposure to environmental pollutants, can compromise the bird's ability to combat *E. coli* infections. Proper nutrition is crucial for maintaining a robust immune response [41]. Deficiencies in essential nutrients, such as vitamins and minerals, can impair the immune system's ability to respond to infections. Selective breeding for production traits may inadvertently affect the immune response. Birds bred for rapid growth and high production may have genetic traits that make them more susceptible to *E. coli* infections. Concurrent infections with other pathogens can influence the host immune response. Birds facing co-infections may exhibit a weakened immune response to *E. coli*, making them more susceptible to severe disease [42]. The use of vaccines targeting specific pathogenic *E. coli* strains can enhance the immune response and reduce the severity of clinical signs. However, the effectiveness of vaccination may vary based on the strain's virulence and the bird's immune status.

The host immune response to colibacillosis in modern poultry production involves various components of the avian immune system, including innate immunity, cell-mediated immunity, and humoral immunity [38]. The immune response begins with the recognition of *E. coli* by pattern recognition receptors and includes phagocytosis, the inflammatory response, T cell activation, antibody production, and the action of natural killer cells [4].

The effectiveness of the immune response can be influenced by factors such as the age of birds, stress, environmental conditions, nutrition, genetic selection, co-infections, and vaccination. As the poultry industry continues to evolve, a comprehensive approach to disease prevention and management should consider these factors and aim to bolster the host's immune response to combat colibacillosis effectively. Understanding the intricacies of the immune response is crucial for reducing the economic losses associated with this disease and ensuring the health and welfare of poultry in modern production systems [43,44].

Table 2. Immune response to colibacillosis, and components of the avian immune system [39,45,46].

Host Immune Response to Colibacillosis	
Recognition of *E. coli*	• *Pattern Recognition Receptors (PRRs):* The avian immune system relies on pattern recognition receptors (PRRs) to detect pathogenic invaders like *E. coli*. PRRs, such as Toll-like receptors (TLRs), recognize specific molecular patterns on the surface of *E. coli*, triggering an immune response.
Innate immune response	• *Phagocytosis:* Upon recognition of E. coli, phagocytic cells, particularly heterophils, are recruited to the site of infection. They engulf and digest the bacteria. • *Inflammatory Response:* The complement system is activated, leading to inflammation at the site of infection. Inflammation enhances the recruitment of immune cells and promotes tissue repair.
Cell-mediated immunity	• *T Cell Activation:* T cells play a role in orchestrating the immune response. When activated, cytotoxic T cells can directly target and destroy infected host cells, while helper T cells help regulate the immune response. • *Natural Killer Cells:* NK cells are responsible for detecting and eliminating host cells that have been infected with *E. coli*.
Humoral immunity	• *Antibody Production:* B cells produce antibodies specific to *E. coli* antigens. These antibodies can neutralize the bacteria and enhance their clearance by phagocytic cells. • *Secretory IgA:* In mucosal surfaces of the gut and respiratory tract, secretory immunoglobulin A (IgA) antibodies play a crucial role in defending against *E. coli* infections.
Components of the Avian Immune System	
Innate immunity	• *Physical and Chemical Barriers:* The avian immune system's first line of defense includes physical and chemical barriers. These include the skin, mucus, and acidic environments that help prevent pathogen entry. • *Phagocytic Cells:* Innate immunity involves phagocytic cells such as heterophils and monocytes. These cells are responsible for engulfing and digesting invading bacteria like *E. coli*. • *Complement System:* The complement system, a group of blood proteins, plays a role in enhancing phagocytosis and triggering inflammation in response to infection.
Humoral immunity	• *B Lymphocytes (B cells):* B cells produce antibodies (immunoglobulins) in response to infection. Antibodies can neutralize bacteria, including E. coli, and enhance phagocytosis. • *Antibody Production:* Upon exposure to E. coli, B cells generate antibodies specific to the pathogen's antigens. These antibodies are released into the bloodstream and mucosal secretions to combat the infection.

5. Epidemiology

The epidemiology of colibacillosis encompasses the study of the patterns of disease occurrence, distribution, and the factors that influence its prevalence within poultry populations [3]. Understanding the epidemiology of colibacillosis is essential for implementing effective prevention and control measures in contemporary poultry farming.

Prevalence and distribution

Colibacillosis is a widespread bacterial infection affecting poultry globally [39]. Its prevalence can vary geographically, with certain regions experiencing higher incidence rates due to differences in management practices, climate, and biosecurity measures. Colibacillosis affects various poultry species, including broilers [6], layers [47], breeders [48], as well as other species such pigs [49,50], and rabbits [51], including pet animals followed with coccidiosis [52]. The disease can manifest differently in different age groups, with young chicks often exhibiting respiratory signs and older birds showing enteric manifestations or reproductive issues. The prevalence of colibacillosis may exhibit seasonal patterns, influenced by environmental factors such as temperature and humidity [53]. Cold and wet conditions may favor the survival and spread of *E. coli*, contributing to increased disease occurrence during specific times of the year [10]. Within individual poultry farms, the dynamics of colibacillosis can be influenced by factors such as farm size, biosecurity practices, and the presence of stressors [28]. Large-scale commercial farms with high stocking densities may be more susceptible to disease outbreaks. The transmission of *E. coli* within poultry populations can occur through various routes. The oral-fecal route is a common mode of transmission, with birds ingesting contaminated feed, water, or litter [54]. Vertical transmission from infected breeder hens to their progeny is another significant route [55].

Risk factors influencing colibacillosis dynamics

The intensification of poultry production, characterized by high stocking densities and rapid production cycles, can contribute to stress among birds. Stress weakens the immune response, making poultry more susceptible to *E. coli* infections [56]. The implementation of effective biosecurity measures is crucial in preventing and controlling the spread of colibacillosis. Farms with strict biosecurity protocols, including controlled access, proper sanitation, and disease surveillance, are better equipped to minimize disease transmission. The indiscriminate use of antibiotics in poultry production, while aimed at preventing bacterial infections, can contribute to the emergence of antimicrobial-resistant *E. coli* strains. Antimicrobial resistance poses a challenge in the effective treatment of colibacillosis [57]. Selective breeding for production traits may inadvertently influence the susceptibility of birds to colibacillosis. Birds bred for rapid growth and high productivity may have genetic traits that compromise their immune response, increasing the risk of infection. The quality of the poultry environment, including ventilation, litter management, and overall cleanliness, can influence the prevalence of colibacillosis [58]. Poor environmental conditions create favorable settings for the survival and transmission of *E. coli*. The use of vaccines targeting specific pathogenic *E. coli* strains can be an essential tool in preventing colibacillosis [59]. However, the effectiveness of vaccination depends on factors such as the virulence of circulating strains and the timing of vaccine administration. Concurrent infections with other pathogens, such as viruses or other bacteria, can influence the dynamics of colibacillosis. Co-infections may exacerbate the severity of clinical signs and increase the economic impact of the disease.

Diagnostic challenges

The clinical signs of colibacillosis can vary, making it challenging to diagnose based solely on observed symptoms [5]. Respiratory signs, enteric manifestations, and reproductive issues may all be present within the same flock. Coinfections with other pathogens can lead to overlapping clinical symptoms, further complicating the diagnostic process. Accurate diagnosis often requires laboratory testing to identify the presence of *E. coli* and determine its virulence factors [60,61]. Collecting representative samples for laboratory analysis can be challenging due to the intermittent shedding of *E. coli* and the need for specific diagnostic techniques. Fecal samples, organ samples, or environmental samples may be required for a comprehensive diagnosis.

Control and Prevention Strategies

Implementing stringent biosecurity measures is crucial in preventing the introduction and spread of *E. coli* on poultry farms [62]. This includes controlling access, maintaining cleanliness, and monitoring the health status of incoming birds. Vaccination against specific pathogenic *E. coli* strains can be an effective preventive measure. Vaccines stimulate the immune system to produce antibodies and enhance the birds' resistance to infection [63]. Responsible use of antimicrobials is essential in mitigating the development of antimicrobial resistance. Veterinarians should prescribe antibiotics judiciously, and alternative strategies such as probiotics may be considered for disease prevention [64]. Breeding programs can focus on selecting birds with enhanced resistance to colibacillosis. This approach involves identifying genetic markers associated with improved immune response and overall health. Maintaining optimal environmental conditions, including proper ventilation, litter management, and sanitation, helps reduce the risk of *E. coli* contamination and transmission within the flock. Regular monitoring of flock health and implementing surveillance programs can aid in early detection and prompt response to potential outbreaks. This includes routine testing for the presence of *E. coli* and other pathogens [65].

As already mentioned, the epidemiology of colibacillosis in modern poultry production is influenced by a complex interplay of factors, including the prevalence and distribution of the disease, risk factors within poultry farms, and challenges in diagnosis. Understanding these dynamics is essential for implementing effective control and prevention strategies. Biosecurity measures, vaccination programs, responsible antimicrobial usage, genetic selection for resistance, environmental management, and vigilant monitoring are all critical components of a holistic approach to managing colibacillosis and maintaining the health and productivity of poultry in contemporary farming systems [66,67].

6. Conclusions

Colibacillosis remains a significant challenge in modern poultry production, with economic implications for the industry. The etiology of the disease is intricately linked to pathogenic strains of *E. coli*, possessing various virulence factors that enable them to colonize and invade the host's tissues. The pathogenesis involves the initial infection, attachment and colonization, tissue invasion, toxin production, and potential systemic spread. Modern factors such as intensive farming practices, genetic selection, antimicrobial usage, biosecurity measures, vaccination, and nutritional management all play a role in shaping the dynamics of colibacillosis in poultry.

Efforts to control and manage colibacillosis in poultry production should take into consideration these multifaceted factors and focus on prevention, early detection, and responsible antimicrobial use. As the poultry industry continues to evolve, a holistic approach to disease management is essential to reduce the economic burden of colibacillosis and ensure the health and welfare of poultry in modern production systems.

Conflicts of Interest: The authors declare no conflict of interest.

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