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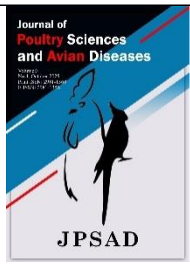

Emerging Histomoniasis in Poultry Farms: A Narrative Review

Sanaz Majidi[1], Mohammad Barari[2], Ali Tolooe*[3]

[1] Department of Viral Disease, SANA Institute for Avian Health and Diseases Research, Tehran, Iran
[2] Department of Fungal, Parasitic and Metabolic Diseases, SANA Institute for Avian Health and Diseases Research, Tehran, Iran
[3] Department of Pathobiology, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada

*** Corresponding author email address**: atolooez@uoguelph.ca

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ABSTRACT

This review explores histomoniasis in poultry, focusing on its epidemiology, pathogenesis, clinical manifestations, risk factors, diagnostic methods, and control strategies. We analyzed recent literature on histomoniasis published between 2014 and 2024 using a narrative review approach. Articles were selected based on their relevance to the disease's epidemiology, clinical signs, diagnosis, and control measures. Histomoniasis, caused by Histomonas meleagridis, primarily affects turkeys and chickens, showing significant geographic variations in prevalence. The disease is transmitted through contaminated earthworms, with environmental factors such as moisture and soil type playing a crucial role in its transmission dynamics. Clinical signs include lethargy, diarrhea, and liver lesions, which can lead to high mortality rates, especially among young birds. Pathological findings typically reveal necrosis in the cecum and liver, and if left untreated, the infection can cause severe tissue damage. Various risk factors, including farming practices and co-infections, contribute to the spread and severity of histomoniasis. Diagnosis often relies on clinical signs, histopathology, and molecular methods, such as PCR, although early detection can be challenging. Control measures include antimicrobial treatments, biosecurity practices, and ongoing research into vaccines. However, existing solutions face limitations in terms of resistance and efficacy. Histomoniasis remains a significant threat to poultry health, influenced by farming practices, environmental conditions, and the presence of intermediate hosts. While antimicrobial treatments and management practices provide some level of control, further research into diagnostic tools, alternative treatments, and vaccines is essential for effective long-term disease management. Comprehensive control strategies, including enhanced biosecurity and preventive measures, are vital for reducing the impact of histomoniasis on poultry farms.

Keywords: *Histomoniasis, poultry, Histomonas meleagridis, Blackhead disease, Turkey, Chicken.*

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1 Introduction

Histomoniasis, commonly referred to as blackhead disease, is a protozoan infection of significant concern in the poultry industry, primarily affecting turkeys and chickens. The causative agent, *Histomonas meleagridis*, is an anaerobic flagellated parasite that targets the cecum and liver, inducing necrotic lesions that may lead to substantial morbidity and mortality. Transmission is typically indirect, occurring through ingestion of embryonated eggs of the nematode *Heterakis gallinarum*, which serves as the principal vector (1). These eggs may also be ingested by earthworms, which act as paratenic hosts, thereby contributing to the persistence and spread of the parasite in the environment (2). Infected birds often exhibit clinical signs such as depression, sulfur-yellow diarrhea, emaciation, and cyanosis of the head, hence the term “blackhead” (3, 4). Despite the long-standing recognition of histomoniasis, its control remains challenging due to complex transmission dynamics, environmental resilience, and a lack of highly effective treatment options (5, 6).

The economic consequences of histomoniasis are profound, particularly in commercial turkey operations, where mortality rates can exceed 80% in severe outbreaks (7). Beyond direct losses from bird mortality, the disease compromises feed efficiency, weight gain, and overall flock productivity. In recent years, histomoniasis has increasingly been reported in chickens, particularly broiler breeders and layers, often resulting in subclinical infections that are difficult to detect yet still detrimental to performance (8). Factors contributing to this shift include intensified poultry production, high stocking densities, inadequate biosecurity measures, and the frequent movement of birds and equipment between farms (9, 10). Moreover, the presence of wild birds and earthworms in free-range systems increases the risk of environmental contamination and pathogen persistence (11).

The limited availability of approved therapeutic agents and vaccines has hindered efforts to manage histomoniasis. Anthelmintics such as fenbendazole, although effective against *Heterakis gallinarum*, have shown decreasing efficacy due to the emergence of resistant parasite strains (12). Additionally, commonly used anticoccidials do not confer protection against *Histomonas meleagridis* (13). Consequently, disease control currently relies heavily on management practices, including strict biosecurity, vector control, and strategic anthelmintic administration (14). However, these measures alone are often insufficient to prevent outbreaks, especially in endemic areas or under intensive farming conditions (15).

Diagnosis of histomoniasis is complicated by its nonspecific clinical presentation and overlap with other gastrointestinal diseases, such as coccidiosis and bacterial enteritis (16). Traditional diagnostic methods, including necropsy and microscopic examination of liver and cecal lesions, remain useful but are often confirmed through molecular techniques such as polymerase chain reaction (PCR) (17). PCR enables the detection of H. meleagridis DNA even in early or subclinical infections, thus supporting timely intervention and control measures (17). Nevertheless, access to advanced diagnostics may be limited in many field settings, emphasizing the need for practical, rapid, and affordable tools for routine surveillance and early detection (18).

This review synthesizes current knowledge on the epidemiology, transmission, clinical presentation, diagnosis, and control of histomoniasis in poultry. Emphasis is placed on recent findings between 2014 and 2024, including new data on drug resistance, novel diagnostic approaches, and ongoing vaccine development efforts (19). By consolidating these developments, this review aimed to support veterinarians, poultry producers, and researchers in implementing effective and sustainable strategies for managing histomoniasis, mitigating its economic impact, and improving overall flock health.

2 Methods and Materials

This narrative review was designed to provide a comprehensive and updated synthesis of recent findings on histomoniasis in poultry, with a particular focus on its emergence, diagnosis, and control measures. The methodological framework employed a descriptive, qualitative approach to analyze and interpret existing peer-reviewed literature published between 2014 and 2024. A systematic search strategy was implemented across major academic databases, including PubMed, Scopus, and Google Scholar, using combinations of keywords such as “Histomoniasis”, “*Histomonas meleagridis*”, “poultry”, “pathogenesis”, “diagnosis”, “control”, and “prevalence”. This strategy aimed to capture the most relevant and recent studies concerning histomoniasis in chickens, turkeys, and other avian hosts. Articles published in non-English languages or those unrelated to poultry species were excluded to maintain specificity. Out of 85 initially identified articles, 41 met the inclusion criteria after screening titles, abstracts, and full texts for scientific rigor and thematic relevance.

Data extraction focused on core aspects of each selected study, including geographic location, poultry species, diagnostic methods employed, and findings related to pathogenesis, clinical signs, and intervention strategies. Special attention was given to studies that explored the epidemiological dynamics of *Histomonas meleagridis*, including those addressing the parasite's interactions with its vector *Heterakis gallinarum*, environmental risk factors, and farm management practices. Studies describing the emergence of drug resistance, particularly to anthelmintics like fenbendazole, were prioritized for analysis due to their implications for treatment efficacy. The review also incorporated data from meta-analyses and national surveillance reports when available to provide a broader context on disease trends and intervention outcomes.

The descriptive analytical approach allowed for thematic comparison across studies, highlighting areas of consensus and identifying gaps in current knowledge. For example, while there is widespread agreement on the role of biosecurity in disease prevention, differences exist in reported vaccine efficacy and treatment protocols across geographic regions. No statistical meta-analysis was performed, as the review focused on qualitative synthesis rather than quantitative outcomes. However, efforts were made to cross-reference findings to ensure the reliability of reported conclusions and to triangulate evidence across multiple sources. When conflicting results were encountered, the methodological quality of each study and the strength of its evidence were considered.

To ensure scientific validity and relevance, only peer-reviewed journal articles, credible government or institutional reports, and publications with clearly defined methodologies were included. Studies that lacked experimental transparency or used small, unrepresentative sample sizes were excluded from critical analysis. This selective approach helped maintain the integrity of the review while emphasizing evidence-based findings that could be applied to practical field settings. The overarching objective was to equip veterinarians, poultry producers, and researchers with an evidence-based understanding of histomoniasis to inform better disease management, policy development, and future research directions.

3 Epidemiology of Histomoniasis

Histomoniasis is becoming more common in poultry worldwide, especially in North America, Europe, and parts of Asia. Recently, it has been reported in regions where it was previously rare, largely due to changing climate patterns and evolving farming practices. As poultry operations expand and birds are housed in increasingly dense conditions, outbreaks have become more frequent, leading to considerable economic losses for producers (4, 6, 16, 18, 20, 21). The disease is most prevalent in areas characterized by intensive poultry farming, where inadequate biosecurity and close contact between birds facilitate the spread of *Histomonas meleagridis*. In regions such as North America and Europe, where the poultry industry is highly developed, histomoniasis is especially common in turkey production systems. Both conventional and organic farms have reported outbreaks, with organic operations often facing greater risk due to reduced access to medications and weaker biosecurity protocols (14). Global trade and frequent bird movement have further introduced the pathogen into emerging poultry industries, notably in countries such as China and India (22-24).

Historically, turkeys have shown the highest susceptibility to *Histomonas meleagridis*, frequently experiencing severe disease and high mortality. However, the parasite now affects other avian species, including chickens, pheasants, quails, and wild birds such as peafowl. In commercial broiler systems, chickens raised in high-density environments have demonstrated vulnerability to the infection, albeit with milder clinical signs compared to turkeys. Nonetheless, the disease in chickens can result in production losses due to reduced growth, inefficient feed conversion, and a higher risk of secondary infections (6, 21, 25-28).

The transmission dynamics of histomoniasis are complex and involve multiple hosts, primarily through indirect means. The cecal worm *Heterakis gallinarum* serves as the main vector for *Histomonas meleagridis*. The parasite's life cycle begins when poultry ingests the eggs of *Heterakis gallinarum*, which contain the infective form of *Histomonas meleagridis*. Once the eggs hatch in the host's ceca, the worm larvae ingest the parasite, allowing Histomonas to develop within the worm. Infected worms subsequently shed the parasite in their eggs, which can remain viable in the environment for extended periods, facilitating transmission to other poultry that consume contaminated earthworms or cecal worm eggs (29). Earthworms themselves can serve as paratenic hosts by ingesting *Heterakis gallinarum* eggs containing *Histomonas meleagridis*. Poultry consuming these earthworms may become infected. While this route is still under investigation, it is widely accepted as part of the parasite's transmission cycle. Moreover, the infection may also spread through contaminated water, feed, or equipment, especially under poor hygienic conditions. *Histomonas meleagridis* is environmentally resilient and can survive for prolonged periods, making its control especially difficult in farms lacking strict biosecurity (9, 10, 30).

Environmental and managerial factors significantly influence the prevalence of histomoniasis. The disease thrives in moderate temperatures and high humidity, which favor the survival of both *Heterakis gallinarum* and the protozoan itself (31). Intensive farming systems with high bird density, frequent inter-farm movement, and inadequate sanitation are particularly vulnerable. Conversely, smaller or free-range systems may appear safer, but they remain exposed through contact with wild birds and environmental vectors. Notably, the absence of strict biosecurity on organic farms may facilitate outbreaks despite lower bird densities (4, 32).

Recent studies have revealed an alarming increase in histomoniasis incidence in poultry populations, particularly in regions with concentrated commercial turkey production. For example, reports from parts of North America indicate a sharp rise in histomoniasis cases over the past decade, coinciding with increased poultry movement between farms and the spread of Heterakis worms. Furthermore, farms using shared equipment, such as feed and water systems, are at increased risk for disease transmission, as *Histomonas meleagridis* can be spread through contaminated surfaces (6, 33-35). Although incidence rates vary by region and system, histomoniasis is recognized as a significant threat to poultry health and profitability. In some countries, estimated annual economic losses attributed to this disease reach millions of dollars (3). The global spread of Histomonas meleagridis has been documented in various poultry-producing regions (Figure 1).

The prevalence of histomoniasis is also affected by the parasite's resistance to treatment and the availability of effective therapeutic agents. The development of drug resistance, particularly to anthelmintics used against *Heterakis gallinarum*, has complicated the control of histomoniasis. Reports of resistance to drugs like fenbendazole have emerged, and the limited availability of vaccines or other preventative measures exacerbates the situation (7, 36). Consequently, the incidence of histomoniasis continues to rise in areas lacking effective treatments. In some instances, the use of broad-spectrum antibiotics and other antimicrobial agents has inadvertently supported the growth of the parasite or its vectors (9).

Overall, the epidemiology of histomoniasis is shaped by a complex interplay of environmental, ecological, and management factors. The increasing prevalence of the disease, coupled with the growing recognition of its impact on poultry health, underscores the need for comprehensive strategies to manage its spread. Enhanced biosecurity measures, improved management practices, and the development of novel therapeutic agents will be essential for mitigating the risk of histomoniasis outbreaks and reducing the economic burden on poultry farmers. As our understanding of the disease's transmission dynamics and risk factors evolves, targeted interventions addressing both environmental and biological aspects will be critical to controlling its spread.

4 Pathogenesis and Clinical Manifestation

The pathogenesis of histomoniasis, caused by *Histomonas meleagridis*, begins with ingestion of infective stages, typically via eggs of *Heterakis gallinarum*, the cecal worm that serves as its biological vector. After ingestion, the eggs hatch in the ceca, releasing larvae that harbor *Histomonas meleagridis*, which then migrate to and colonize the mucosal lining. Utilizing its flagella, the parasite adheres to and invades epithelial cells, triggering a cascade of inflammatory responses. These reactions disrupt the intestinal structure and nutrient absorption, leading to necrosis and ulcer formation in the cecal walls (6, 11, 37-42). Once established in the ceca, *Histomonas meleagridis* may enter the bloodstream and disseminate to secondary organs, particularly the liver. In hepatic tissue, it induces localized necrotic lesions, often described as concentric "target-like" foci, a hallmark of histomoniasis pathology. Severe hepatic invasion can impair hepatocyte function and lead to liver failure. These lesions may coalesce and result in extensive hepatic necrosis, reducing the organ's metabolic and detoxifying capacity (6, 7, 43-45).

Clinical manifestations of histomoniasis differ across bird species and depend on age and immune status. In turkeys, which are highly susceptible, signs include depression, anorexia, stunted growth, poor feathering, and yellowish, mucous-laden diarrhea. Blood in feces indicates severe ulceration of the ceca. In contrast, chickens often exhibit milder or subclinical signs, such as lethargy and reduced feed intake, but still suffer from impaired growth and economic losses (6). A distinguishing clinical feature in turkeys is the so-called "blackhead," a darkening of the skin on the head and neck due to liver dysfunction and impaired blood flow. In advanced infections, neurological symptoms such as head tilting or incoordination may occur, presumably from systemic inflammation or toxemia. Though less common in chickens, similar signs can still be present (14, 25).

In addition to overt clinical symptoms, histomoniasis can also lead to subclinical infections, particularly in chickens, where clinical signs are less pronounced. In these cases, birds may show only mild lethargy or reduced feed intake, yet still suffer from poor growth and overall productivity. These subclinical infections are often more challenging to detect, but they can result in economic losses due to decreased performance, particularly in commercial broiler flocks (4, 6). *Histomonas meleagridis* infection also predisposes birds to secondary bacterial infections due to immunosuppression and mucosal barrier disruption. Opportunistic pathogens such as *Escherichia coli* and *Salmonella* may exacerbate clinical outcomes and increase mortality. These co-infections further complicate treatment and management, especially in large flocks (9, 46, 47).

Pathological findings associated with histomoniasis typically include distinctive lesions in the ceca and liver. In the cecum, the initial signs of infection include hyperemia (increased blood flow), swelling, and inflammation of the mucosal lining. As the infection progresses, necrosis develops, and the cecal walls may become severely ulcerated. Lesions can range from small, shallow ulcers to extensive areas of tissue destruction. In severe cases, the cecum may completely become necrotic, leading to perforation and peritonitis. The liver, often the next site of infection, exhibits round, pale, necrotic lesions characterized by concentric rings of necrosis surrounded by zones of inflammation. These lesions may be encased in a thick fibrous capsule that forms as part of the inflammatory response. In severe infections, lesions can merge into larger areas of necrosis, impairing the liver's ability to detoxify blood and regulate metabolic processes (6, 37). A comprehensive overview of the transmission route, affected organs, and pathological lesions is depicted in Figure 2.

The progression of histomoniasis can vary significantly, with outcomes ranging from mild, self-limiting infections to severe, fatal cases. The disease tends to progress more rapidly in younger birds, particularly turkeys, which are highly susceptible. Infected birds that cannot mount an effective immune response may succumb to the disease within a few days to weeks. Mortality rates can be particularly high in young turkeys, with some outbreaks resulting in mortality rates of up to 90% if left untreated. In older birds or cases of subclinical infection, the progression may be slower, with birds showing signs of weight loss, reduced feed conversion, and poor overall growth (4).

In conclusion, histomoniasis pathogenesis reflects the invasive and inflammatory nature of *Histomonas meleagridis*, affecting primarily the ceca and liver. Key clinical features include lethargy, yellow diarrhea, blackhead, and high mortality in turkeys. Diagnostic lesions in the liver and ceca, along with secondary infections, underscore the importance of early detection, strict biosecurity, and improved therapeutic options to control this economically significant poultry disease (9).

5 Diagnosis of Histomoniasis

The diagnosis of histomoniasis, caused by *Histomonas meleagridis*, begins with clinical observation of nonspecific signs such as lethargy, reduced feed intake, poor weight gain, and diarrhea, often yellow or green, suggesting liver involvement. In severe cases, birds may also exhibit dehydration, abdominal swelling, and an unkempt appearance. While these signs can raise suspicion, they are not pathognomonic and often overlap with diseases such as coccidiosis, salmonellosis, or colibacillosis, necessitating further diagnostic confirmation (9, 17, 48-50). Evaluating flock history is crucial in raising clinical suspicion. The presence of turkeys, highly susceptible hosts, especially in mixed-species systems, or previous outbreaks of histomoniasis in the farm, increases the likelihood of infection. Management factors, such as free-range rearing or exposure to soil potentially contaminated with *Heterakis gallinarum* eggs, also elevate risk. However, these factors alone are not sufficient to confirm the disease, making laboratory-based diagnostics essential (6, 51).

Laboratory diagnosis is essential to confirm histomoniasis and differentiate it from other conditions with similar clinical presentations. The most commonly employed method for diagnosing histomoniasis is the microscopic examination of tissue samples, such as cecal or liver tissues. This approach allows for the direct observation of *Histomonas meleagridis* trophozoites, typically found within the cecal mucosa and liver lesions (37). Trophozoites appear as pear-shaped, flagellated organisms and are often located in clusters within the tissue. Detecting these trophozoites under a microscope can strongly indicate the disease, although it requires the expertise of a trained pathologist to distinguish *Histomonas* from other protozoan organisms that may be present in similar tissues (6, 52). In addition to microscopic examination, histopathological analysis of affected tissues can provide further confirmation. Histopathology reveals characteristic lesions, such as necrosis and inflammation in the cecum and liver, which are hallmarks of histomoniasis. In severe cases, these lesions may progress to extensive liver damage, including necrotic foci and perihepatitis (12, 29, 53).

Polymerase chain reaction (PCR) is another powerful diagnostic tool that offers higher sensitivity and specificity than traditional microscopic methods. PCR enables the detection of *Histomonas meleagridis* DNA in various sample types, including feces, liver, and cecal swabs, allowing for the identification of the parasite even before clinical signs become apparent (8, 54, 55). PCR is particularly useful in detecting subclinical cases of histomoniasis, where typical clinical symptoms may not yet be visible. By amplifying specific genetic markers of *Histomonas meleagridis*, PCR can confirm the presence of the parasite in cases where microscopic examination might fail to identify trophozoites. The high sensitivity of PCR also makes it an ideal method for screening poultry flocks, especially in regions where histomoniasis is endemic or emerging (9, 17, 56, 57). However, while PCR is a highly reliable method, it requires specialized equipment and trained personnel, which may limit its accessibility in some veterinary practices, particularly in resource-limited settings.

Serological tests are also employed to detect *Histomonas meleagridis* infections. These tests primarily identify antibodies produced by the host in response to infection. However, serological tests are less commonly used than PCR and microscopic examination, as they are less specific for detecting the parasite itself. Antibody-based tests can be useful in confirming exposure to the parasite, but they may not be as reliable for diagnosing active infections, especially in cases where the immune response has not yet fully developed (37). Furthermore, the presence of antibodies does not necessarily indicate that the bird is currently infected or experiencing clinical disease, as antibodies can remain detectable long after the parasite has been cleared from the host's system. Despite these limitations, serological testing can be a useful adjunct to other diagnostic methods, particularly in surveillance programs aimed at assessing the prevalence of histomoniasis in poultry populations.

Tissue culture, although less frequently employed, is another diagnostic method that can isolate *Histomonas meleagridis* from infected tissue samples. This method involves culturing tissue samples from the cecum or liver in specific growth media, allowing the parasite to proliferate and making identification easier. However, tissue culture is technically challenging, time-consuming, and requires highly specialized laboratory conditions, making it less practical for routine diagnosis (17, 58). Additionally, tissue culture may not be sensitive enough to detect low-level infections, particularly in the early stages of disease when the parasite burden is still minimal.

The main challenge in histomoniasis diagnosis is differentiating it from other gastrointestinal diseases with similar presentations. Concurrent infections with *Escherichia coli*, *Salmonella*, or *Eimeria* species may obscure the clinical picture and delay diagnosis. Additionally, in some cases, birds may die before developing characteristic cecal or liver lesions, complicating necropsy interpretation. Even when lesions are present, identifying *Histomonas meleagridis* trophozoites requires expertise to avoid misidentification with other protozoa (6, 17). Additionally, the microscopic identification of *Histomonas meleagridis* trophozoites requires experience and expertise, as the organism can resemble other flagellates or protozoans that may be present in the gastrointestinal tract. This can lead to misidentification or false-negative results if the parasites are not adequately distinguished from other organisms. The main diagnostic tools, along with their advantages and limitations, are summarized in Table 1.

In other words, while clinical signs and flock history provide important preliminary clues, definitive diagnosis of histomoniasis relies on laboratory confirmation through microscopy, histopathology, PCR, or, in some cases, serology or culture. Given the limitations of each technique, a combined diagnostic approach enhances accuracy. Early and accurate diagnosis is vital for effective management, especially considering the potential for high mortality and economic loss associated with this disease (1).

6 Control and Prevention Strategies

Controlling histomoniasis in poultry requires an integrated approach combining effective management, biosecurity, treatment, education, and continued research into vaccines. The foundation of control lies in proper sanitation to reduce environmental contamination with *Histomonas meleagridis* and its vector, *Heterakis* *gallinarum*. Regular cleaning and disinfection of facilities, feeders, drinkers, and equipment are essential to limit pathogen load (3, 6). In addition, preventing contact between birds and contaminated soil or earthworms can significantly reduce infection risk. In free-range or pasture systems, rotational grazing is recommended to interrupt the life cycle of *Heterakis gallinarum* by minimizing repeated exposure to infected environments (37). For confined housing systems, strict hygiene protocols must be enforced to compensate for the lack of pasture rotation.

Pharmacological treatment plays a role in disease management, particularly during active outbreaks. Compounds such as dimetridazole and ronidazole have shown efficacy against *Histomonas meleagridis*, limiting its replication and reducing clinical severity (31, 37, 59, 60). However, concerns over drug residues and resistance, especially with dimetridazole, have led to regulatory restrictions, particularly in the European Union (5). These drugs are administered through feed or water, requiring careful dosing and veterinary oversight to avoid subtherapeutic exposure and potential resistance development (54). While antimicrobial therapy remains useful in some settings, it is not a standalone solution and must be part of a broader control program.

Given the limitations of treatment, vaccine development has become a research priority. Experimental vaccines using inactivated, attenuated, or recombinant forms of *Histomonas meleagridis* are under investigation, aiming to elicit protective immunity against infection. Challenges remain, particularly regarding early immune evasion by the parasite and the difficulty of inducing robust mucosal immunity in the ceca and liver (17, 61). Nevertheless, promising studies have identified surface antigens as potential vaccine targets, and progress toward commercial vaccine availability is ongoing, albeit still in experimental stages (4).

Regulatory frameworks also shape disease control efforts. Several countries have implemented strict policies limiting the use of antimicrobials critical to human medicine, such as dimetridazole, in food-producing animals. These regulations aim to curb antimicrobial resistance while encouraging sustainable poultry farming (17, 62). Veterinary oversight is critical in applying treatment responsibly and selecting alternatives when specific drugs are banned or restricted.

Training is vital for implementing effective control measures. Farmers and farm workers must understand the risks of histomoniasis, the importance of biosecurity, and the proper use of antimicrobial treatments. Training programs that provide information on identifying clinical signs, applying treatments correctly, and implementing preventive measures can significantly reduce histomoniasis incidence on farms. Additionally, collaboration with veterinary professionals is encouraged to monitor flock health and receive tailored advice on control strategies (6). Table 2 outlines various strategies currently used to control and prevent histomoniasis in poultry flocks.

Ultimately, a holistic strategy combining biosecurity, therapeutic options, vaccination research, and informed regulatory policy offers the most effective means of controlling histomoniasis. Continued investment in diagnostics, monitoring, and novel interventions will be essential to manage this re-emerging disease in commercial poultry. The integration of scientific advances with practical management will empower producers to maintain flock health, reduce economic losses, and prevent the further spread of *Histomonas meleagridis* in both intensive and extensive poultry systems.

7 Conclusion

Histomoniasis, caused by the protozoan *Histomonas meleagridis*, has emerged as a significant concern within the poultry industry. Commonly known as blackhead disease, it primarily affects turkeys, chickens, and other avian species, with its impact felt globally, particularly in regions with intensive poultry production. The disease presents a complex challenge due to its varied clinical manifestations, transmission dynamics, and environmental risk factors. Understanding its epidemiology, pathogenesis, diagnosis, and management is critical for mitigating its effects on poultry health and production (2, 15, 63, 64).

Effective management strategies for histomoniasis are rooted in a robust understanding of its epidemiology. The disease's prevalence is closely linked to farming practices, environmental conditions, and the presence of intermediate hosts, such as earthworms, which facilitate the transmission of *Histomonas meleagridis*. The increasing prevalence of histomoniasis can be attributed to factors such as enhanced poultry movement, intensified farming systems, and climate change, which influence the survival and spread of the parasite. Moreover, inadequate surveillance and biosecurity measures in many poultry operations have created environments conducive to outbreaks (2, 29, 65, 66).

A clear understanding of pathogenesis is essential, as *Histomonas meleagridis* invades the ceca and liver, causing necrosis, inflammation, and eventual organ dysfunction.

However, subtle early clinical signs such as lethargy, diarrhea, and poor growth are often confused with other avian diseases, which underscores the importance of laboratory confirmation (2, 4, 29, 67). Diagnostic methods such as PCR, microscopy, and histopathology remain critical tools, but their effectiveness is influenced by access, timing, and technical expertise. PCR, although highly sensitive, may be unavailable in low-resource settings, while histopathology requires post-mortem analysis. Thus, future research must prioritize the development of more accessible, rapid, and accurate diagnostic platforms (4, 12, 29, 63, 68).

Biosecurity remains the cornerstone of control strategies. Measures such as limiting bird access to contaminated areas, managing exposure to earthworms, regular cleaning of facilities, and controlling bird traffic can substantially reduce the risk of infection. While rotational grazing may reduce exposure in outdoor systems, it is often impractical in commercial intensive settings (29). When outbreaks occur, therapeutic agents like dimetridazole and ronidazole may provide temporary relief, but concerns regarding antimicrobial resistance and food safety have curtailed their use (4, 29, 69). Consequently, attention has shifted toward alternative therapeutics and natural compounds with antiparasitic properties, though evidence of their efficacy remains limited.

The absence of an effective commercial vaccine remains a significant gap in the long-term control of histomoniasis. Research into inactivated, attenuated, and recombinant vaccines continues, with promising but as-yet-unrealized results. Advances in immunology and molecular biology offer hope for a breakthrough, particularly with the identification of immunogenic parasite proteins that may confer protection. A successful vaccine would not only reduce mortality but also minimize reliance on chemical interventions and improve the sustainability of poultry health programs (4).

Effective regulatory oversight is crucial for controlling histomoniasis. National and international policies must enforce antimicrobial stewardship, require timely disease reporting, and support surveillance and outbreak response systems, especially given the risks associated with global poultry trade (1, 4). A successful response to histomoniasis demands an integrated strategy combining biosecurity, diagnostics, therapeutics, education, and research. Educating farmers and veterinarians on disease detection and control, alongside collaboration between researchers, policymakers, and the poultry industry, will accelerate the development of sustainable solutions such as improved surveillance and vaccines, ultimately preserving flock health and industry productivity (29).

Histomoniasis represents a significant challenge to poultry health and productivity, with implications for animal welfare, farm profitability, and public health. The emergence and spread of the disease highlight the need for improved surveillance, early detection, and targeted interventions. While current control measures remain effective, developing sustainable, long-term solutions, including vaccines and alternative treatments, will be critical in combating this disease. By adopting a proactive and integrated approach, the poultry industry can mitigate the impact of histomoniasis and safeguard the health of poultry populations worldwide.

Table 1. Diagnostic Methods for Histomoniasis

Diagnostic Method	Description	References
Clinical Assessment	Initial evaluation based on clinical signs such as lethargy, poor weight gain, diarrhea, dehydration, and abdominal distension.	(10, 17)
Flock History	Consideration of previous outbreaks and management practices (e.g., confinement vs. free-range) to assess risk of exposure to *Heterakis gallinarum.*	(6)
Microscopic Examination	Direct observation of *Histomonas meleagridis* trophozoites in cecal or liver tissues. Requires expertise to distinguish it from other protozoa.	(6, 37)
Histopathological Analysis	Examination of tissue samples reveals characteristic lesions like necrosis and inflammation in the cecum and liver.	(17)
Polymerase Chain Reaction (PCR)	Highly sensitive method for detecting *Histomonas meleagridis* DNA in various samples (feces, liver, cecal swabs). Useful for identifying subclinical cases.	(9, 54, 70)
Serological Testing	Detection of antibodies produced by the host in response to infection. Less specific for active infections and may indicate past exposure.	(37)
Tissue Culture	Isolation of *Histomonas meleagridis* from infected tissues by culturing in specific media. Technically challenging and less practical for routine diagnosis.	(17)

Table 2. The various strategies for controlling and preventing histomoniasis

Control & Prevention Strategy	Description	References
Sanitation Practices	Regular cleaning and disinfection of facilities, equipment, feeders, and water sources to reduce pathogen load and limit exposure to *Histomonas meleagridis*.	(6)
Rotational Grazing	Rotating poultry across different pastures to minimize contact with contaminated soil and earthworms, thereby limiting the parasite's lifecycle and transmission potential.	(37)
Antimicrobial Treatment	Use of drugs like dimetridazole and ronidazole to control infections. These drugs inhibit the growth and proliferation of the parasite but require careful monitoring for effectiveness and resistance.	(37, 54)
Vaccine Research	Ongoing investigations into vaccine candidates aimed at providing long-lasting immunity against *Histomonas meleagridis*, including inactivated, attenuated, and recombinant vaccines.	(4, 17)
Regulatory Measures	Implementation of guidelines and regulations to manage disease spread, including restrictions on certain antimicrobials to prevent resistance and promote sustainable practices.	(17)
Education and Training	Programs designed to educate farmers and farm workers about histomoniasis risks, biosecurity importance, and proper antimicrobial usage to reduce disease incidence.	(6)
Collaboration with Veterinarians	Encouragement for farmers to work closely with veterinary professionals to monitor flock health and develop tailored control strategies.	(6)

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Conflict of Interest

The authors declare no competing interests.

Author Contributions

SM, MB, and AT: Wrote & reviewed the initial draft and revised the final version.

Data Availability Statement

Data are available for research purposes upon reasonable request to the corresponding author.

AI Usage Declaration

We hereby declare that we used an AI language model (ChatGPT) to assist in improving the language of this work. The final content has been reviewed, edited, and verified by me to ensure it reflects our understanding and effort.

Ethical Considerations

As a review of existing literature, this study did not involve direct interaction with human participants or the collection of primary data. Ethical approval was therefore not required. However, care was taken to appropriately credit all sources and adhere to principles of academic integrity. The review also prioritized the inclusion of studies that had undergone ethical scrutiny, ensuring that the findings presented are based on ethically conducted research.

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