Al-Muthanna J. For Agric Sci

Online ISSN:2572-5149

Print ISSN: 2226-4086

Vol. 12 , Issue 2. **2025**

https://muthjas.mu.edu.iq/

http://doi.org/10.52113/mjas04/12.2/21

Coccidiosis in Chickens: Diagnostic Methods and Control Strategies

A review

Abbas Najm Aldin Saleh [1*], Noor Faisal Noaman[2], Damat Fikrat Saber[3], Kasim Sakran Abass[4]

[1]Department of Pathology and Poultry Disease, College of Veterinary Medicine, University of Kirkuk, Kirkuk, Iraq https://orcid.org/0009-0006-5796-358X

[2]Department of Physiology, Biochemistry and Pharmacology, College of Veterinary Medicine, University of Kirkuk, Kirkuk, Iraq https://orcid.org/0009-0006-9386-3543

[3]Department of anatomy and histology, College of Veterinary Medicine, University of Kirkuk, Kirkuk, Iraq https://orcid.org/0009-0008-9580-7005

[4]Department of Physiology, Biochemistry and Pharmacology, College of Veterinary Medicine, University of Kirkuk, Kirkuk, Iraq https://orcid.org/0000-0002-4202-783X

***Corresponding author email**: abbasalbeaty@uokirkuk.edu.iq

Abstract

The most prevalent and significant illness affecting chicken that causes significant financial losses globally is coccidiosis. Thus, this review goal is to discuss the topic of poultry coccidiosis. It is brought on by Eimeria species' intracellular protozoa parasite, which belongs to the genus Eimeria. There are approximately nine different types of Eimeria known to exist in domesticated poultry, with the most infectious being Eimeria brunette, Eimeria maxima, Eimeria necatrix, and Eimeria tenella; the least pathogenic being Eimeria acervulina and Eimeria mivati, and the least pathogenic being Eimeria praecox and Eimeria hagani. The most effective method for diagnosing coccidiosis in chickens is postmortem examination of a representative number of birds, morphology of oocysts can be assessed by taking intestinal mucosal scrapings or by counting the droppings and molecular diagnosis. The fundamental principles of coccidiosis prevention and control include the use of immunizations, natural feed additives, preventive anticoccidial medications, and best practices for farm handling. Therefore, appropriate management and treatment should be implemented to reduce the effect of coccidiosis on emerging economies of different countries. The purpose of this review is to examine the basic knowledge of coccidiosis, including the several Eimerian species that infect poultry and the methods for identifying and treating the disease.

Keywords: Eimeria, poultry, infectious, prevalence, treatment .

1. Introduction

One of the most prominent and rapidly expanding active subsectors of the global agribusiness that supports protein nutrition is the broiler chicken industry (Petracci et al., 2019; Abdulqader Thulfiqar et al., 2020). According to Chang (2007), the production of broiler meat is more advantageous and efficient even in developing nations with limited agricultural resources because of the chicken superior feed efficiency and comparatively cheaper. The health of broilers has a significant impact on the poultry industry’s expansion, worldwide rivalry, current production costs, and strategic direction (Hafez and Attia, 2020; Ameen et al., 2021). However, infectious diseases can undermine food security and pose a risk to public health through zoonoses, as well as result in significant economic losses through decreased earnings, decreased meat quantity or quality, higher labor and pharmaceutical costs (Asfaw et al., 2021).

Moreover, parasitic infections have been shown to have more detrimental consequences than other bacterial or viral diseases, including increased mortality, stunted growth, decreased feed efficiency, and anemia in broiler (Kaufman et al., 2006). In poultry, coccidiosis is one of the most common and economically significant parasite infections (Shirley et al., 2005). An estimated $13 billion is lost annually due to this disease in the production of broilers worldwide (Blake et al., 2020).

Nowadays, there are two methods used to diagnose coccidiosis. Firstly, is initially diagnosed by a veterinarian using a scoring system based on macroscopic apparent lesions or by counting the quantity of Eimeria oocysts in the feces (Hodgson, 1970; Long et al., 1976). The entire diagnosis process requires a lot of work, and the veterinarian's knowledge and expertise determine how accurate the diagnosis is (De Gussem, 2007). Yang et al., (2015), described the oocysts were visible as early as four days following infection. Secondly, a method for diagnosing coccidiosis that has better sensitivity and specificity is the polymerase chain reaction (PCR) (Nolan et al., 2015; You, 2014).

This aims goal is to review the fundamentals of coccidiosis, including the several Eimerian species that affect poultry and the techniques for diagnosing and managing the illness.

2. Avian coccidiosis

Coccidiosis in chicken is an intestinal illness that inhibits growth and weakens the immune system, leading to a high death rate and financial losses for the livestock industry (Blake and Tomley 2014). The disease is caused by Eimeria species, which have been known to infect a variety of host animals, including domestic dogs and cats, cattle, sheep, ducks, chickens, and turkeys (Blake 2015). Avian coccidiosis is mostly caused by Eimeria oocysts, which infect chickens when they consume contaminated food, water, or litter (Shivaramaiah et al. 2014). The oocyst growing on the droppings of infected chicks can also be transferred to the poultry house by individual moving from one house to another (Belli et al. 2006). Chickens infected with Eimeria have decreased feed intake, bloody diarrhea, and trouble gaining weight because the parasite invades and destroys their intestinal epithelium (Gilbert et al., 2011). According to Morris et al. (2007), the degree of pathogenicity of these species is correlated with the extent of the lesions they induce in various gastrointestinal regions. The most dangerous species include Eimeria brunetti, E. maxima, E. necatrix, and E. tenella, while E. praecox and E. hagani are considered the least pathogenic, E. acervulina, E. mitis, and E. mivati are classified as slightly pathogenic species (Jadhav, 2011; Dalloul and Lillehoj, 2006).

3. Etiological Agent

Coccidia are a broad category of unicellular parasites that belong to the phylum Apicomplexa's protozoan subdivision. Infecting a single host species or a collection of closely related hosts, coccidia of the genus Eimeria (Eimeridae family) are species-specific (Müller and Hemphill, 2013). The obligatory internal parasites that make up the phylum Apicomplexa are distinguished by their particular specialized organelles, which together form the apical complex (Suarez et al., 2017). These consist of dense granules, rhoptries, micronemes, and conoid and polar rings that offer the structural stability needed for host cell penetration (Suarez et al., 2017).

4. Diagnosis of Eimeria parasite

The traditional method for diagnosing coccidiosis involves examining the intestine macroscopically using a technique outlined by Johnson and Reid (1970) and (Conway and McKenzie, 2007), this involves looking for particular lesions in the duodenum to jejunum, ileum, cecum, along with colon. In addition, the diagnosis and treatment of the condition depend on the precise identification of Eimeria species (Carvalho et al., 2011).

4.1 Score for intestinal lesions

The presence of coccidiosis can be confirmed by pathological and morphological analysis of lesion site, oocyst size, and shape, but the precise identification of Eimeria species is essential for disease control because it indicates the degree of drug or vaccine resistance (Lee et al. 2010). The score was determined by the size of the gross lesion, and the relevant Eimeria species can be identified by looking at the intestine's preference site (because species are site-specific; see Table 1) (Singla and Gupta, 2012). The total mean lesion score is often calculated by adding the individual lesion scores from a discrete bird for each species of Eimeria for a certain number of birds (De Gussem, 2007).

Table 1. The state of lesions brought on by Eimeria infections and the locations where they are most common, Adapted from Abebe and Gugsa (2018).

Eimeria species	Predilection site	Condition of the lesion
Eimeria brunetti	The lower half of the intestine	Intestinal distension, mucoid in necrotic discharge, and intestinal walls that are thin.
Eimeria necatrix	Middle intestine	Severe bleeding, accompanied by a red and white patch in the intestinal wall and mucoid secretion.
Eimeria tenella	Caeca	Severe bleeding with red, white patches on the intestinal wall.
Eimeria acervulina	Upper intestine	Mucoid enteritis, whitish lesions on the intestinal surface, and whitish patches on the wall of the serous surface hemorrhage streak.
Eimeria maxima	Middle intestine	Intestinal distention with mucoid secretion and hemorrhage patches.
Eimeria praecox	Duodenum	The duodenum's intestinal surface has a mild mucoid discharge and a somewhat hemorrhagic appearance, but there is no lesion.

4.2 Methods for determining oocytes

The presence and morphology of oocysts can be assessed by taking intestinal mucosal scrapings (Barrios et al., 2017) or by counting the droppings (Hodgson, 1970). There are typically two ways to make a determination: quantitative and qualitative fecal investigation. The quantity of oocysts per gram of feces (OPG count) is determined using the quantitative method of fecal oocyst testing through the McMaster technique (Bortoluzzi et al., 2018). The McMaster chamber method is typically used to count the individual oocysts and ascertain the pattern of shedding of an infected chicken (Conway and McKenzie, 2007).

4.3 Molecular Diagnosis

It is challenging to diagnose Eimeria infections in the field because they are frequently caused by many species with comparable clinical traits (Carvalho et al., 2011). This indicates that more accurate diagnosis depends heavily on techniques that are less subjective and more sensitive (You, 2014). In many situations, molecular biology methods provide more accurate diagnosis. An example is the identification of Eimeria using the polymerase chain reaction (PCR); this technology is now widely accessible and involves amplifying specific portions of the ribosomal DNA's internal transcribed space 1 (ITS1) (Tang et al., 2018). Additional molecular methods for identifying Eimeria species are being documented, including quantitative PCR (Vrba et al., 2010), Loop-Mediated Isothermal Amplification (LAMP) (Barkway et al., 2011), Sequence Characterized Amplified Region (SCAR) markers (Shu-San et al., 2019), and Random Amplified Polymorphic DNA (RAPD) (Shirley and Bumstead, 1994).

5. Control of coccidiosis

While proper husbandry can help lower the likelihood of parasites that cause coccidiosis spreading, more steps are necessary to achieve full disease control (McDonald and Shirley, 2009). The use of vaccines, natural feed additives, preventive anticoccidial drugs, and best practices for farm handling are the mainstays of coccidiosis prevention and control (Broom, 2021). Likewise (Chapman et al., 2010), instead of focusing on the most contagious stage, the oocyst, several efforts have been made to produce anticoccidial drugs that target both the sexual and asexual phases of the infection (stages which happen inside the host).

5.1 Management

The goal of management, which has always been crucial to the control of coccidiosis, is to minimize infection until immunity is developed by lowering the quantity of coccidia (Fanatico, 2006). Particularly in areas with feeding troughs or water dispensers, litter must always be dry (Taylor et al., 2007). Consequently, stocking density, cleanliness, feeder and drinker cleaning, and litter are the primary factors in preventing disease on chicken farms (Ashenafi et al., 2004). In the case of a clinical epidemic, the clinically afflicted birds must be put down because they regularly excrete oocysts, which pose a risk to other birds (Roy, 2007). The transmission of infectious oocysts can be significantly reduced by the careful biocontrol procedures taken by the people who look after poultry houses (Allen and Fetterer 2002).

5.2 Treatment

The treatment and prevention of coccidiosis involves the use of a number of anticoccidial medications (chemoprophylaxis) in bird feed and drinking water (Quiroz-Castañeda and Dantán-González, 2015). In general, Coccidiocidal medications have often proven to be more successful than coccidiostatic ones. The reason for this is because when coccidiostatic drugs are stopped, parasites that have been arrested can still survive and release infectious oocysts into the environment (McDougald and Fitz-Coy, 2003). There are several subcategories of anticoccidial medications, including synthetic substances, polyether/ionophores, and a combination of both the two (Peek and Landman, 2011). However, most of these synthetic drugs lose their effectiveness due to drug resistance (Chapman, 1997). Sulphonamides, clopidol, nicarbazin, halofuginone, quinolones, and amprolium are a few examples of frequently used synthetic substances (Peek and Landman, 2011).

5.3 Vaccines

When Eimeria spp. infect a host, the immune system goes through a number of processes that produce a strong, enduring, but dependent on species immunity (Yun et al., 2000). Most importantly, it takes a lot of inoculating oocysts to produce an immune response to Eimeria; however, E. maxima is thought to be extremely immunogenic and only needs a minimal number of oocysts to produce robust immunity (Yun et al., 2000). Furthermore, it is thought that the initial endogenous phases of the parasite life cycle become more immune stimulating than the later sexual phases (Rose and Hesketh, 1976)

One of the most important components of coccidiosis control measures is vaccination. It boosts the immune system, which protects against upcoming Eimeria disorders (Lee et al., 2022). The development of lymphoid cells and B and T lymphocytes can rapidly initiate this reaction (Broom, 2021). The ability of vaccines to stimulate adaptive immune reactions within 3–4 weeks, contingent on host genotype, infection length and frequency, and parasite concentration, makes them a crucial part of preventing coccidiosis (Martins et al., 2022). Vaccines can be applied topically (sprayed into the eye), directly (given as gels or mixed with water), or in the hatchery where the chickens are hatched. Likewise, the high costs and inexperienced labor they require may make it difficult for them to be implemented successfully (Blake et al., 2021). Three types of vaccines;

recombinant, attenuated, and non-attenuated—are currently often utilized in field settings. There is a diverse range of attenuated and non-attenuated parasites in each of them (Arczewska-Włosek et al., 2022). Hence, rotation techniques that employ both medications and vaccinations in subsequent flocks can gradually prevent coccidiosis in poultry (Chapman and Rathinam, 2022)

5.4 Natural Replacements

Currently, there is interest in using so-called natural substances, such as probiotics, plant extracts, and fungal extracts, to decrease coccidiosis-related issues (Chapman et al., 2013). Numerous natural substances with a range of effects, such as cytoplasmic damage, antioxidant and anti-inflammatory properties, and immunological activation, are used as dietary supplements (Abbas et al., 2012).

6. Conclusions

The main source of animal protein is poultry, which also makes a substantial contribution to the production of meat and eggs. Globally, the need for this kind of protein is growing quickly. The seven Eimeria species cause poultry diseases that range from asymptomatic enteritis to subacute mortality, and they all reside in distinct parts of the gastrointestinal tract. Indeed, host genetic composition, flock density, environmental and stress factors, concurrent infections, Eimeria species, strain, and infectious dose all affect the level of severity coccidiosis is. Although chicken coccidiosis has a high mortality rate and costs farmer's money, the birds can be saved from it with early diagnosis, appropriate treatment, and managerial care. Additional applied and fundamental investigations based on field tests and molecular approaches that assist the characterization and identification of various Eimerias is necessary to attain more precise identification of the various Eimerias. Thus, it is necessary to establish alternative management measures that are centered on global production patterns without the usage of antibiotics.

7. References

Abbas, R.Z., Colwell, D.D. and Gilleard, J., 2012. Botanicals: an alternative approach for the control of avian coccidiosis. World's Poultry Science Journal, 68(2), pp.203-215.

Abdulqader Thulfiqar, A.A., Celik, Y. and Talb Altalb, A.A., 2020. Chicken Meat Consumption Status of Households in Iraq. Example of Mosul Province. Journal of Kirkuk University for Agricultural Sciences, 11(1).

Abebe, E. and Gugsa, G., 2018. A review on poultry coccidiosis. Abyssinia Journal of Science and Technology, 3(1), pp.1-12.

Allen, P.C. and Fetterer, R., 2002. Recent advances in biology and immunobiology of Eimeria species and in diagnosis and control of infection with these coccidian parasites of poultry. Clinical microbiology reviews, 15(1), pp.58-65.

Ameen, Q., Mohammed, M., Ameen, S. and Alsaadi, S., 2023. The requirements of chickens for nutritional compounds for growth, an advanced nutritional outlook. Kirkuk University Journal For Agricultural Sciences, 14(3), pp.17-33.

Arczewska-Włosek, A., Świątkiewicz, S., Ognik, K. and Józefiak, D., 2022. Effects of a dietary multi-strain probiotic and vaccination with a live anticoccidial vaccine on growth performance and haematological, biochemical and redox status indicators of broiler chickens. Animals, 12(24), p.3489.

Asfaw, Y.T., Ameni, G., Medhin, G., Gumi, B., Hagos, Y. and Wieland, B., 2021. Poultry disease occurrences and their impacts in Ethiopia. Tropical Animal Health and Production, 53(1), p.54.

Ashenafi, H., Tadesse, S., Medhin, G. and Tibbo, M., 2004. Study on coccidiosis of scavenging indigenous chickens in central Ethiopia. Tropical Animal Health and Production, 36(7), pp.693-701.

Barkway, C.P., Pocock, R.L., Vrba, V. and Blake, D.P., 2011. Loop-mediated isothermal amplification (LAMP) assays for the species-specific detection of Eimeria that infect chickens. BMC Veterinary Research, 7(1), p.67.

Barrios, M.A., Da Costa, M., Kimminau, E., Fuller, L., Clark, S., Pesti, G. and Beckstead, R., 2017. Relationship between broiler body weights, Eimeria maxima gross lesion scores, and microscores in three anticoccidial sensitivity tests. Avian diseases, 61(2), pp.237-241.

Belli, S.I., Smith, N.C. and Ferguson, D.J., 2006. The coccidian oocyst: a tough nut to crack!. Trends in parasitology, 22(9), pp.416-423.

Blake, D.P. and Tomley, F.M., 2014. Securing poultry production from the ever-present Eimeria challenge. Trends in parasitology, 30(1), pp.12-19.

Blake, D.P., 2015. Eimeria genomics: where are we now and where are we going?. Veterinary Parasitology, 212(1-2), pp.68-74.

Blake, D.P., Knox, J., Dehaeck, B., Huntington, B., Rathinam, T., Ravipati, V., Ayoade, S., Gilbert, W., Adebambo, A.O., Jatau, I.D. and Raman, M., 2020. Re-calculating the cost of coccidiosis in chickens. Veterinary research, 51(1), p.115.

Blake, D.P., Marugan-Hernandez, V. and Tomley, F.M., 2021. Spotlight on avian pathology: Eimeria and the disease coccidiosis. Avian Pathology, 50(3), pp.209-213.

Bortoluzzi, C., Paras, K.L., Applegate, T.J. and Verocai, G.G., 2018. Comparison between McMaster and Mini-FLOTAC methods for the enumeration of Eimeria maxima oocysts in poultry excreta. Veterinary Parasitology, 254, pp.21-25.

Broom, L.J., 2021. Evidence-based consideration of dietary 'alternatives' to anticoccidial drugs to help control poultry coccidial infections. World's Poultry Science Journal, 77(1), pp.43-54.

Carvalho, F.S., Wenceslau, A.A., Teixeira, M., Carneiro, J.A.M., Melo, A.D.B. and Albuquerque, G.R., 2011. Diagnosis of Eimeria species using traditional and molecular methods in field studies. Veterinary parasitology, 176(2-3), pp.95-100.

Chang, H.S., 2007. Overview of the world broiler industry: implications for the Philippines. Asian Journal of Agriculture and Development, 4(2), pp.67-82.

Chapman, H.D. and Rathinam, T., 2022. Focused review: the role of drug combinations for the control of coccidiosis in commercially reared chickens. International Journal for Parasitology: Drugs and Drug Resistance, 18, pp.32-42.

Chapman, H.D., Barta, J.R., Blake, D., Gruber, A., Jenkins, M., Smith, N.C., Suo, X. and Tomley, F.M., 2013. A selective review of advances in coccidiosis research. Advances in parasitology, 83, pp.93-171.

Chapman, H.D., Jeffers, T.K. and Williams, R.B., 2010. Forty years of monensin for the control of coccidiosis in poultry. Poultry science, 89(9), pp.1788-1801.

Conway, D.P. and McKenzie, M.E., 2007. Poultry coccidiosis: diagnostic and testing procedures. John Wiley & Sons.

Dalloul, R.A. and Lillehoj, H.S., 2006. Poultry coccidiosis: recent advancements in control measures and vaccine development. Expert review of vaccines, 5(1), pp.143-163.

De Gussem, M., 2007, August. Coccidiosis in poultry: review on diagnosis, control, prevention and interaction with overall gut health. In Proceedings of the 16th European Symposium on Poultry Nutrition (pp. 253-261).

Fanatico, A., 2006. Parasite management for natural and organic poultry: coccidiosis. NCAT Agriculture Specialist, ATTRA Publication# IP, 245.

Gilbert, E.R., Cox, C.M., Williams, P.M., McElroy, A.P., Dalloul, R.A., Ray, W.K., Barri, A., Emmerson, D.A., Wong, E.A. and Webb Jr, K.E., 2011. Eimeria species and genetic background influence the serum protein profile of broilers with coccidiosis. PloS one, 6(1), p.e14636.

Hafez, H.M. and Attia, Y.A., 2020. Challenges to the poultry industry: current perspectives and strategic future after the COVID-19 outbreak. Frontiers in veterinary science, 7, p.516.

Hodgson, J.N., 1970. Coccidiosis: oocyst counting technique for coccidiostat evaluation. Experimental Parasitology, 28(1), pp.99-102.

Jadhav, B.N., Nikam, S.V., Bhamre, S.N. and Jaid, E.L., 2011. Study of Eimeria necatrix in broiler chicken from Aurangabad District of Maharashtra state India. International

Multidisciplinary Research Journal, 1(11).

Johnson, J. and Reid, W.M., 1970. Anticoccidial drugs: lesion scoring techniques in battery and floor-pen experiments with chickens. Experimental parasitology, 28(1), pp.30-36.

Kaufman, P.E., Koehler, P.G. and Butler, J.F., 2006. External parasites of poultry. Published by Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida:1-13.

Lee, B.H., Kim, W.H., Jeong, J., Yoo, J., Kwon, Y.K., Jung, B.Y., Kwon, J.H., Lillehoj, H.S. and Min, W., 2010. Prevalence and cross-immunity of Eimeria species on Korean chicken farms. Journal of Veterinary Medical Science, 72(8), pp.985-989.

Lee, Y., Lu, M. and Lillehoj, H.S., 2022. Coccidiosis: recent progress in host immunity and alternatives to antibiotic strategies. Vaccines, 10(2), p.215.

Long, P.L., Millard, B.J., Joyner, L.P. and Norton, C.C., 1976. A guide to laboratory techniques used in the study and diagnosis of avian coccidiosis. Folia veterinaria latina, 6(3), pp.201-217.

Martins, R.R., Silva, L.J., Pereira, A.M., Esteves, A., Duarte, S.C. and Pena, A., 2022. Coccidiostats and poultry: A comprehensive review and current legislation. Foods, 11(18), p.2738.

McDonald, V. and Shirley, M.W., 2009. Past and future: vaccination against Eimeria. Parasitology, 136(12), pp.1477-1489.

McDougald, L.R. and Reid, W.M., 2003. Coccidiosis. Diseases of poultry. Chapter, 28, pp.1076-1085.

Morris, G.M., Woods, W.G., Richards, D.G. and Gasser, R.B., 2007. Investigating a persistent coccidiosis problem on a commercial broiler–breeder farm utilising PCR-coupled capillary electrophoresis. Parasitology Research, 101(3), pp.583-589.

Müller, J. and Hemphill, A., 2013. In vitro culture systems for the study of apicomplexan parasites in farm animals. International journal for parasitology, 43(2), pp.115-124.

Nolan, M.J., Tomley, F.M., Kaiser, P. and Blake, D.P., 2015. Quantitative real-time PCR (qPCR) for Eimeria tenella replication—implications for experimental refinement and animal welfare. Parasitology international, 64(5), pp.464-470.

Peek, H.W. and Landman, W.J.M., 2011. Coccidiosis in poultry: anticoccidial products, vaccines and other prevention strategies. Veterinary quarterly, 31(3), pp.143-161.

Petracci, M., Soglia, F., Madruga, M., Carvalho, L., Ida, E. and Estévez, M., 2019. Wooden-breast, white striping, and spaghetti meat: causes, consequences and consumer perception of emerging broiler meat abnormalities. Comprehensive Reviews in Food Science and Food Safety, 18(2), pp.565-583.

Quiroz-Castañeda, R.E. and Dantán-González, E., 2015. Control of avian coccidiosis: future and present natural alternatives. BioMed research international, 2015(1), p.430610.

Rose, M.E. and Hesketh, P., 1976. Immunity to coccidiosis: stages of the life-cycle of Eimeria maxima which induce, and are affected by, the response of the host. Parasitology, 73(1), pp.25-37.

Roy, H.V., (2007). Poultry diseases, diagnosis and treatment (3rd ed.) New Delhi: New Age International Publisher Pp: 152-157.

Shirley, M.W. and Bumstead, N., 1994. Intra-specific variation within Eimeria tenella detected by the random amplification of polymorphic DNA. Parasitology Research, 80(4), pp.346-351.

Shirley, M.W., Smith, A.L. and Tomley, F.M., 2005. The biology of avian Eimeria with an emphasis on their control by vaccination. Advances in parasitology, 60, pp.285-330.

Shivaramaiah, C., Barta, J.R., Hernandez-Velasco, X., Téllez, G. and Hargis, B.M., 2014. Coccidiosis: recent advancements in the immunobiology of Eimeria species, preventive measures, and the importance of vaccination as a control tool against these Apicomplexan parasites. Veterinary Medicine: Research and Reports, pp.23-34.

Shu-San Loo, L.I.K.S.I.N.L.I., EFENDI, N.A., BLAKE, D.P., KAWAZU, S.I. and WAN, K.L., 2019. Comparison of molecular methods for the detection of Eimeria in domestic chickens in Malaysia. Sains Malaysiana, 48(7), pp.1425-1432.

Singla, L.D. and Gupta, S.K., 2012. Advances in diagnosis of coccidiosis in poultry. Veterinary Diagnostics: Current Trends, Gupta RP, Garg SR, Nehra V and Lather D (Eds), Satish Serial Publishing House, Delhi, pp.615-628.

Suarez, C.E., Bishop, R.P., Alzan, H.F., Poole, W.A. and Cooke, B.M., 2017. Advances in the application of genetic manipulation methods to apicomplexan parasites. International journal for parasitology, 47(12), pp.701-710.

Tang, X., Huang, G., Liu, X., El-Ashram, S., Tao, G., Lu, C., Suo, J. and Suo, X., 2018. An optimized DNA extraction method for molecular identification of coccidian species. Parasitology research, 117(3), pp.655-664.

Taylor, M., Coop, R. and Wall, R., 2007. Veterinary Parasitology (3rd Edn). Oxford, UK, Blackwell Publishing 475-483.

Vrba, V., Blake, D.P. and Poplstein, M., 2010. Quantitative real-time PCR assays for detection and quantification of all seven Eimeria species that infect the chicken. Veterinary parasitology, 174(3-4), pp.183-190.

Yang, W.C., Tien, Y.J., Chung, C.Y., Chen, Y.C., Chiou, W.H., Hsu, S.Y., Liu, H.Y., Liang, C.L. and Chang, C.L.T., 2015.

Effect of Bidens pilosa on infection and drug resistance of Eimeria in chickens. Research in veterinary science, 98, pp.74-81.

You, M.J., 2014. Detection of four important Eimeria species by multiplex PCR in a single assay. Parasitology International, 63(3), pp.527-532.

Yun, C.H., Lillehoj, H.S. and Lillehoj, E.P., 2000. Intestinal immune responses to coccidiosis. Developmental & Comparative Immunology, 24(2-3), pp.303-324.