Chapter 44

Preventive Approaches for Ruminant Coccidiosis; Probiotics, Prebiotics and Botanicals

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ABSTRACT

The use of synthetic drugs is banned in ruminants for growth and performance due to the development of resistance in many microbial agents. This situation led to the need of an alternative to these synthetic products. Plant based products are considered as the best alternative of synthetic drugs in ruminants. The growth and performance of ruminants have been affected by intestinal diseases, especially coccidiosis which cause severe damage to the ruminal microbiota. The plant based products such as flavonoids, tannins, saponins and many other botanical products are used in ruminants which help to fight against different *Eimeria* species to prevent Coccidiosis. Probiotics have also gained the focus of scientists and used various beneficial bacterial species as probiotics in ruminants. The use of probiotics was limited to bacterial and viral disease but recently they are used to treat various parasitic infections especially the intestinal infections and the outcomes were outstanding. The molecular mechanics of these natural products are still unknown and very limited knowledge is available about the process.

KEYWORDS
Eimeria, Ruminants, Probiotics, Plant product, Saponins, tannins, Flavonoids

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INTRODUCTION

Parasitic infections are known to occur in all vertebrate animals and generally termed as coccidiosis. A large number of species of coccidia are discovered to cause infections in all animals including herbivores, omnivores and carnivores. Some of these coccidian species are known to cause severe infections in their host but some are of less clinical importance. The major sign of coccidiosis is bloody diarrhea noticed by veterinarians and producers involved in the production and healthcare of ruminants. Pathogenic coccidial infections are the major reason for bloody diarrhea also called bloody scours and white scours. The pathogenic agents which cause coccidiosis are commonly single-cell protozoa which present in the intestinal cells of its host. These protozoa develop and multiply inside the intestinal cells so they cause the destruction of these cells. As a result of the destruction, they are called parasitic protozoa besides the fact that they cause an infection or not in their host. The coccidial species that cause infections in ruminants, exhibit no symptoms even though the diagnosis confirmed heavy parasitic infestation in the host. As a result of this situation it is important to differentiate between the major pathogenic species and other bacterial, viral and less important causes of intestinal diseases. The agent which causes coccidiosis belongs to genus *Eimeria* and family *Eimeriidae* so the term *eimeriiasis* or coccidiosis is generally used to represent the infections caused by these species. In ruminants, *Eimeria* species are host specific, they cause infections in the host and complete their development and reproduction in the intestinal tract of their host.

Pathology of Coccidiosis in Ruminants

The outcome related to the pathological and clinical situation may be influenced by many other factors. These factors include species of *Eimeria* which cause present infection, severity of infection, replication rate of related species, inflammatory conditions, immune status, managemental stress and any other infection present at that time. *Eimeria* localizes intracellularly in the intestine of its host, which causes potential damage to the mucosal lining of the intestine (Figure 1). The rate of infection and results of the infection depends on the species of the *Eimeria* which can be different in different hosts and the living conditions. The major destruction caused by the parasite is usually in the late reproduction stages such as during schizogony and gamogony (Friend and Stockdale, 1980). This is because of the multiplication of the parasite in its first schizogony stage which results in an increase in the number of intestinal cells in the further multiplication of the parasite. In the animals, infected with *Eimeria*, major damage happened just before the start of

excretion of the oocyst. In goat kids, early infection of *Eimeria* results in haemorrhagic enteritis (Taylor and Catchpole, 1994). Polyps formation in the small intestine is a result of *Eimeria* infection (Koudela and Boková, 1998), it also causes white nodule formation in the mucous visible from serosal surface (Kanyari, 1990).

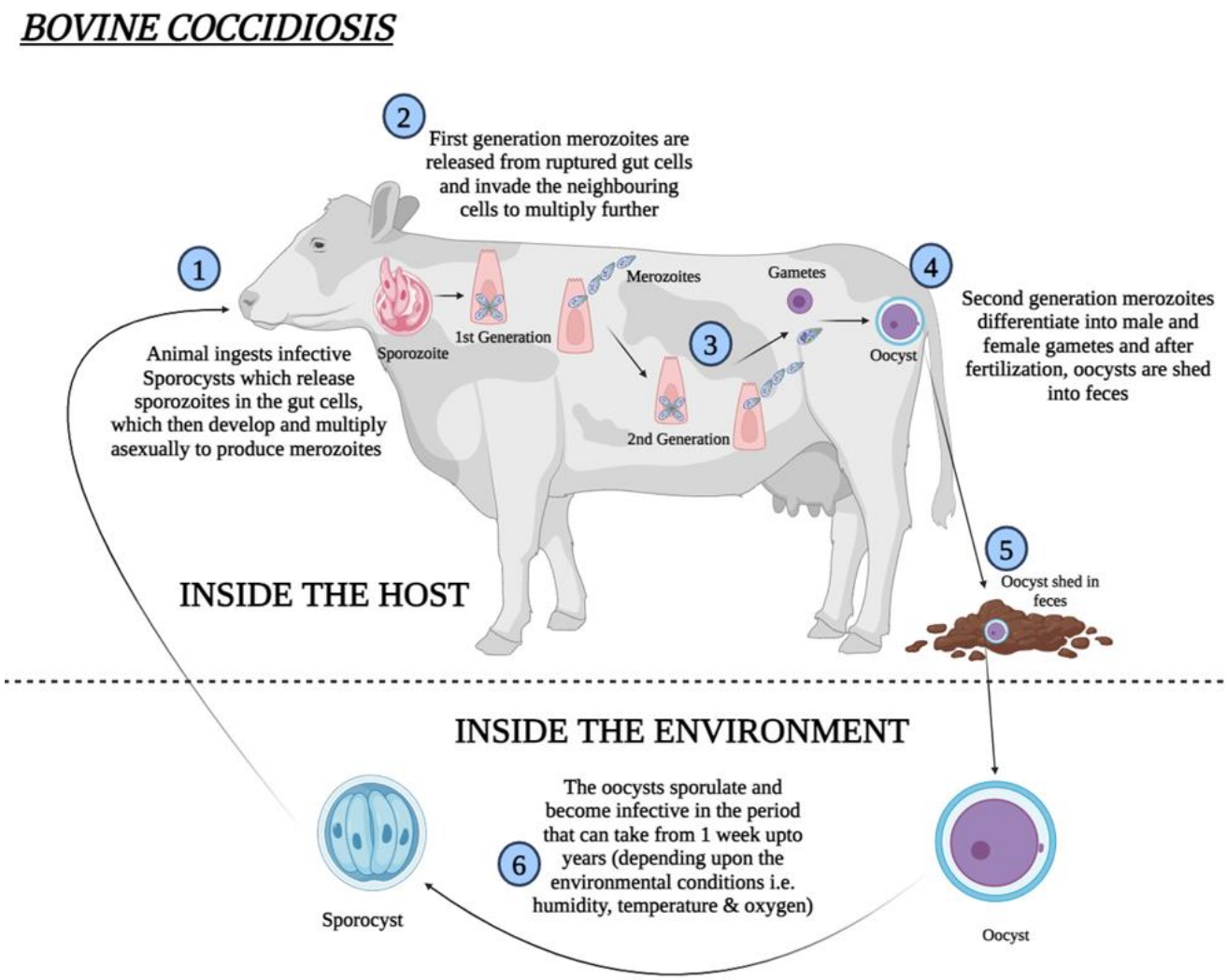

Fig. 1: Cycle of coccidiosis inside the ruminants and the envisronment.

Economic Impacts of Coccidiosis in Livestock Industry

Because of the clinical and subclinical cases of coccidiosis in tropical regions, there is no documented data about the economic losses caused by coccidiosis. The subclinical infection of coccidiosis is not of much importance so it is not usually compared to other diseases (Khodakaram-Tafti and Hashemnia, 2017). In small ruminants, a larger number of animals with high production rates can be a source of high economic loss if they get infected due to coccidiosis (Foreyt, 1990). In animals with mild coccidial infection, the economic losses can be characterized as low production rates and no clinical signs available. According to an estimation, loss of $140 million per annum has been faced due to sheep and goat production globally (Fitzgerald, 1981). The major contributors to the loss include mortality rate, high cost of treatment for diarrhea, increased sensitivity to secondary infection, decrease production rates. The long term effects of coccidiosis include less feed efficiency, decreased growth rate and reproductive performance (Lassen and Østergaard, 2012). It has been seen that subclinical infection of coccidiosis contributes more in economic losses as compared to clinical cases as the animals are affected for a long period of time (Daugschies and Najdrowski, 2005).

Treatment Options for Ruminant Coccidiosis

The best way to treat the animal having coccidial infection is to follow the instruction of the veterinarian that may include treatment with ionophores, use of amprolium or sulpha drugs and any other alternatives. In the past, the best way to treat coccidiosis was the use of antiparasitic drugs which not only gives brilliant results against a wide range of parasites but also are cost effective (Ali et al., 2022; Alvi et al., 2022). The prime way to treat coccidiosis is to use different chemicals and ionophores drugs (Adeyemi et al., 2023). Oral route is mainly used to give medications mixed in water or feed. The immense and irregular use of these drugs to treat infection has become the major reason for the

development of various new species which may or may not be sensitive to these drugs (Gray et al., 2021; Ahmad et al., 2023). The major constraints of high production from farm animals are development of resistance in parasites and the control of parasites. This situation alarms the need of some alternative ways which especially includes plant based medications, probiotics and prebiotics which is safer in terms of resistance development and also cost friendly (Saeed and Alkheraije, 2023).

Probiotics; an Emerging Preventive Measure

It has been proved through many in vitro studies that the feed supplemented probiotics reside in the intestine of the ruminants and exhibit characteristics antimicrobial activities against many pathogenic agents which cause enteric infections (Adeniyi et al., 2015; Lin et al., 2020). This ability of probiotics made them a potential factor to use as therapeutic agents to treat many intestinal diseases (Prabhurajeshwar and Chandrakanth, 2019). To support the intestinal epithelial barrier, probiotics helps to enhance the expression of the components of barrier function (Rokana et al., 2016; Bron et al., 2017) which helps in the prevention and control of many gastrointestinal diseases in its host (Lucey et al., 2021). Many probiotics are known for the production of metabolites such as bacteriocins which helps to control growth of the pathogens and assist in defense mechanisms to prevent infections (Osuntoki and Korie, 2010; Meale et al., 2017). Probiotics also compete with pathogenic agents for the attachment to the gut epithelium which also helps to prevent infections (Rokana et al., 2017). The mechanism of probiotics to work against different pathogens to prevent infections is also investigated recently. The rate of parasite-borne diseases is high in dairy animals as compared to bacterial diseases. The therapeutic effects of probiotics against parasites such as *Eimeria* have been proved through many studies using different animal models (Travers et al., 2011). Some studies stated that probiotics can be used to decrease the helminth infection in dairy animals. To find out the mode of action of probiotics against parasitic infections still requires more experimental data.

Compound Probiotics

Compound probiotics consist of more than one beneficial bacterial species which mainly include ECL1.2 strain of Bacillus subtilis, different strains of other bacteria such as *Saccharomyces cerevisiae J, Lactobacillus plantarum R* and *Lactococcus lactis*. Different studies were established to find out the probiotics improvements on growth rate, immune function and gut microbial status of the weaned lambs which were infected with coccidial infection. The drastic impacts of coccidiosis include diarrhea, damage to intestinal epithelium, decrease growth rate and increase rate of mortality (Reeg et al., 2005). Studies show that the animals fed with probiotics supplements showed better performance as the probiotics safeguard the intestine from coccidial damage. It is done by competing with coccidia for the binding sites on the intestinal mucosa which hinder the proliferation and replication of the pathogens thus protecting the intestine up to some extent (Bozkurt et al., 2014). The use of compound probiotics as feed supplements improve the growth performance factors and the effects of probiotics were comparable with the drug diclazuril (Giannenas et al., 2014). Outcomes of another study shows that the supplementation of compound probiotics don't have major beneficial impacts on growth rate, performance level, immune responses and improvement of intestinal microbiota of the weaned lambs. To achieve these effects a long term use of these probiotics required but the supplementation of compound probiotics have produced significant improvements of daily weight gain, decreased fecal score and decreased oocysts of coccidia in the fecal sample of the infected weaned lambs with coccidia.

***L. plantarum* and *B. toyonensis* Probiotics**

After the birth, the first few days of the pre-weaned calves are very significant as they are at high risk of mortality and morbidity (Mee, 2013; Jiang et al., 2020; Hordofa et al., 2021). This is because neonatal calves have an immature immune system and antioxidant systems are also not fully functional so these neonates have a low resistance against infections and diseases. At that time of their life, calves are at high risk of getting respiratory and intestinal infections which affect their growth rate and overall health (Chester-Jones et al., 2017). *Lactobacillus plantarum* has a good reputation due to its characteristics ability to colonize the gastric cells and play the role of beneficial bacteria in the intestine (Le and Yang, 2018), it is known to be present in several fermented feed products including different types of silages (Busconi et al., 2008; Goel et al., 2020). The beneficial effects of *L. plantarum* are quoted as promote digestibility of nutrients, enhance immune responses, and act as a barrier to hinder the colonization of pathogenic agents in the intestine in different species of animal (Wang et al., 2018; Ding et al., 2019). The characteristics qualities of *L. plantarum* which made it a perfect probiotic supplement to be used in pre-weaned calves include robustness, ability to show resistance against bile and acids and its ability to produce antimicrobial compounds (Ahire et al., 2021). *Bacillus* species have been known to be used as probiotics because of their unique ability to produce endospores. These endospores have the potential to tolerate the adverse environmental conditions that made them able to stay in the gastrointestinal tract (Casula and Cutting, 2002). A strain of *Bacillus cereus* known as *Bacillus toyonensis* is naturally present and used as a probiotic due to its non-toxigenic and non-pathogenic characteristics. It is used as a safe feed additive as there are no adverse side effects of this probiotics have been reported on different animal species (EFSA, 2014). The probiotic properties of *B. toyonensis* include development of antimicrobial compounds, enhanced immunity responses and improved gut health (Abd El-Hack et al., 2020; Pechrkong et al., 2023).

Alternative Control Measures for Coccidiosis

Plant-based Products

Natural products usually extracted from plants are the most reliable agents to control and prevent infections. Currently, a lot of research studies reported that plant based products are best to use against coccidial infections. Several plant species are known to be used as an alternative of drugs, used for the production of many drugs such as ionophores and other synthetic compounds. Some phyto compounds are identified with antimicrobial property and used to prevent and control *Eimeria* infections in ruminants (Nahed et al., 2022). Natural products are relevant to use against many infections due to the low efficacy of many synthetic drugs. These products are also used as additives with other classic anticoccidial drugs to enhance the effect of drugs and to achieve long term control of coccidial infections. There is no relevant data about the emergence of parasitic resistance against these natural products however the risk may exist (Quiroz-Castañeda and Dantán-González, 2015). The efficacy of plant based products is considered to be no more than those of licensed anticoccidial drugs (Peek and Landman, 2011).

Herbs or Spices

Herbs and spices such as rosemary, thyme, garlic, oregano, turmeric, peppermint and basil belong to aromatic plants used to enhance flavor and aroma. These aromatic plants consist of phenolic compounds which exhibit antioxidants properties such as thymol (Franz et al., 2010). These compounds are known to protect their host for free radical induced oxidative stress (Madsen and Bertelsen, 1995; Couladis et al., 2003). Turmeric, an aromatic plant, contain curcumin which shows anti-*Eimeria* properties. The lambs infected with *Eimeria* give feed supplemented with turmeric shows decrease weight loss, low output score of oocysts, reduction in inflammation and oxidative stress (Cervantes-Valencia et al., 2016). The essential oils of rosemary are reported to prevent the sporulation of *Eimeria* oocysts in sheep (Figure 2) (Aouadi et al., 2021).

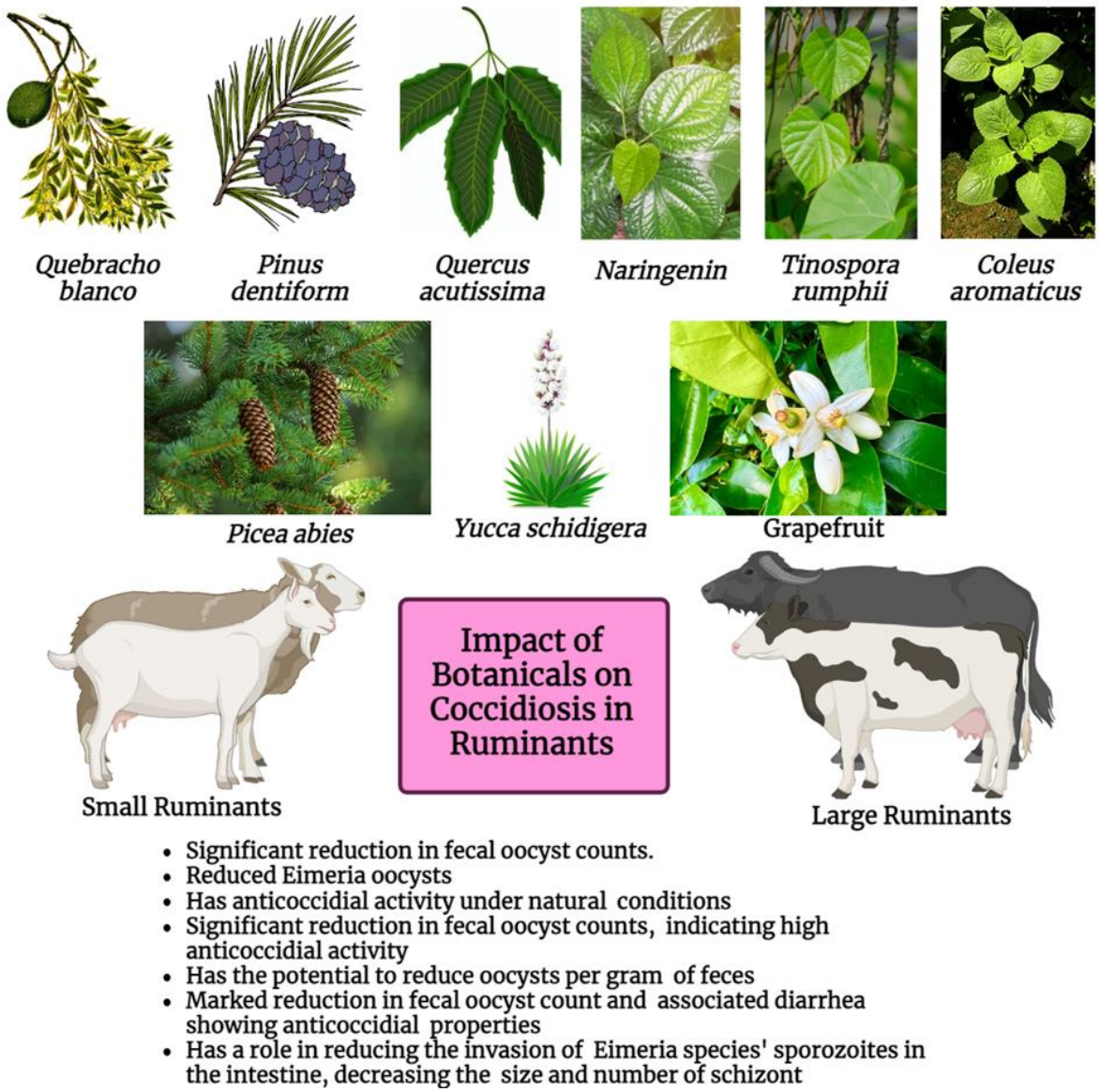

Fig. 2: Impact of different plants on ruminant coccidiosis.

Trace Elements

Trace elements for example zinc, copper, and selenium play vital roles in maintaining the immune system, energy production levels and other physiological functions of animals. Trace elements act as dietary antioxidants and safeguard the ruminants from parasitic infections (A Puertollano et al., 2011). It has been reported in a study that a mineral mixture of zinc, copper, selenium and manganese decrease the excretion of *Eimeria* oocysts in sheep but have no effect on the occurrence of diarrhea (Cazarotto et al., 2018).

Essential Oils and Vitamins

Essential oils are extracted from different parts of plants through different methods. These essential oils and vitamins are known to exhibit several potential properties including immunomodulation, antifungal properties and antioxidant activities (Iordache et al., 2023). Due to these properties These oils and vitamins are used against coccidiosis (Youssefi et al., 2023). Several studies show that essential oils and vitamins are very effective in preventing coccidiosis (Saeed et al., 2023).

Saponins

Saponins are naturally occurring compounds present in several parts of the plants including seeds, roots, fruit, bark, tube, and leaves (Subiono and Tavip, 2023). Attributed to their foam-forming property, they are called saponins just like soap in aqueous solution (Rai et al., 2021). There are several groups of saponins such as glycosylated steroids and triterpenoids (Li et al., 2023). The mode of action of saponins is polarization of cell membrane and vacuolization, through these mechanisms saponins fight against *Eimeria* (Saladino et al., 2022). *Eimeria* are double membrane structures, almost impossible to destroy by the saponins but through the micropyle cap, saponins entering the oocyst wall of *Eimeria* cause serious destruction of sporocyst (Rizwan et al., 2021). Saponins directly bind with the ruminal protozoa and destroy them. Another major function of saponins is the vacuolization in the endoplasmic reticulum of protozoa during all the developmental stages. They cause the disruption of the cell division process of protozoa and mitochondrial activities (Peng et al., 2021). Several plants containing saponins are known to have anticoccidial properties (Trotta et al., 2023).

Flavonoids

Flavonoids are naturally occurring phenolic compounds extracted from plants (Chen et al., 2021). Flavonoids are widely used for their antioxidant properties present in various plant parts including fruit, vegetables and flowers or in whole plants such as *Mangifera indica* (Shen et al., 2022). There are many beneficial effects of these compounds due to which they are widely used in the pharmaceutical and nutraceutical industry (Ayala-Fuentes and Chavez-Santoscoy, 2021). The antioxidant properties of flavonoids (Ashfaq et al., 2021) and there work to prevent damage due to oxygen reactive species (Thenmozhi et al., 2023) made them of great importance to be used against *Eimeria* species (Mounir et al., 2022). Due to these benefits, plants containing flavonoids are widely used against coccidiosis in ruminants (El-Ghareeb et al., 2023).

Tannins

Tannins belong to phenolic compounds and are generally found in seed coat and foliage of plants such as sorghum (Galgano et al., 2021). They are widely used against *Eimeria* in ruminants due to their antiparasitic activities (Choi et al., 2022; Kumar et al., 2022). The mode of action of tannins is that they enter the inner wall of oocysts of *Eimeria* and disrupt the cellular functions (Saladino et al., 2022). They also interfere with the cell components causing thickening of walls of oocysts (Hur et al., 2005).

Conclusion

The use of botanicals, herbs, spices and probiotics has become the need of the livestock industry. Various parts of plant or whole plant, probiotics, herbs and spices have been used for the treatment of coccidiosis in ruminants. These alternatives not only present best treatment options but also are very economical so used widely in the livestock industry. These herbal products have many beneficial properties such as antimicrobial activities, antioxidant properties, immunomodulation, anti-inflammatory and anti-parasitic activities. The basic mechanics of action of these botanical products are still in debate and research is required to find out the exact mode of action of herbal products. The use of the therapeutic nature of probiotics helps to control the infestation of parasites in ruminants and by further understanding of the mode of action of these probiotics led to the development of new ways to fight against these pathogenic agents. In future, herbal products, probiotics and prebiotics would become a powerful tool to treat and control many pathogenic infections including Coccidiosis in ruminants.

REFERENCES

A Puertollano, M., Puertollano, E., Alvarez de Cienfuegos, G., and A de Pablo, M. (2011). Dietary antioxidants: immunity and host defense. *Current Topics in Medicinal Chemistry*, *11*(14), 1752-1766.

Abd El-Hack, M. E., El-Saadony, M. T., Shafi, M. E., Qattan, S. Y., Batiha, G. E., Khafaga, A. F., and Alagawany, M. (2020).

Probiotics in poultry feed: A comprehensive review. *Journal of Animal Physiology and Animal Nutrition*, *104*(6), 1835-1850.

Adeniyi, B. A., Adetoye, A., and Ayeni, F. A. (2015). Antibacterial activities of lactic acid bacteria isolated from cow faeces against potential enteric pathogens. *African Health Sciences*, *15*(3), 888-895.

Adeyemi, O., Idowu, E., Akinsanya, B., and Jatau, I. (2023). Knowledge, Attitude, and Practices of Poultry Farmers Regarding the Control of Chicken Coccidiosis in Lagos State, Nigeria. *Pan African Journal of Life Sciences*, *7*(1), 561-571.

Ahire, J., Jakkamsetty, C., Kashikar, M., Lakshmi, S., and Madempudi, R. (2021). In vitro evaluation of probiotic properties of Lactobacillus plantarum UBLP40 isolated from traditional indigenous fermented food. *Probiotics and Antimicrobial Proteins*, *13*(5), 1413-1424.

Ahmad, B., Samad, A., and Hamza, M. (2023). Antibiotic Resistance in Poultry and farm Animals and its Solution. *Biological Times*, *2*(3), 3-4.

Ali, A., Bahmani, M., Pirhadi, M., Kaviar, V., Karimi, E., and Abbasi, N. (2022). Phytochemical analysis and antimicrobial effect of essential oil and extract of Loranthus europaeus Jacq. on Acinetobacter baumannii, Staphylococcus aureus, and Pseudomonas aeruginosa. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, *28*(2).

Alvi, M. A., Khan, S., Ali, R. M. A., Qamar, W., Saqib, M., Faridi, N. Y., and Jia, W.-Z. (2022). Herbal medicines against hydatid disease: A systematic review (2000–2021). *Life*, *12*(5), 676.

Aouadi, M., Sebai, E., Saratsis, A., Kantzoura, V., Saratsi, K., Msaada, K., and Akkari, H. (2021). Essential oil of Rosmarinus officinalis induces in vitro anthelmintic and anticoccidial effects against Haemonchus contortus and Eimeria spp. in small ruminants. *Veterinarni Medicina*, *66*(4).

Ashfaq, M. H., Siddique, A., and Shahid, S. (2021). Antioxidant activity of Cinnamon zeylanicum:(A review). *Asian Journal of Pharmaceutical Research*, *11*(2), 106-116.

Ayala-Fuentes, J. C., and Chavez-Santoscoy, R. A. (2021). Nanotechnology as a Key to Enhance the Benefits and Improve the Bioavailability of Flavonoids in the Food Industry. *Foods*, *10*(11), 2701.

Bozkurt, M., Aysul, N., Küçükyilmaz, K., Aypak, S., Ege, G., Catli, A., and Çınar, M. (2014). Efficacy of in-feed preparations of an anticoccidial, multienzyme, prebiotic, probiotic, and herbal essential oil mixture in healthy and Eimeria spp.-infected broilers. *Poultry Science*, *93*(2), 389-399.

Bron, P. A., Kleerebezem, M., Brummer, R.-J., Cani, P. D., Mercenier, A., MacDonald, T. T., and Wells, J. M. (2017). Can probiotics modulate human disease by impacting intestinal barrier function? *British Journal of Nutrition*, *117*(1), 93-107.

Busconi, M., Reggi, S., and Fogher, C. (2008). Evaluation of biodiversity of lactic acid bacteria microbiota in the calf intestinal tracts. *Antonie van Leeuwenhoek*, *94*, 145-155.

Casula, G., and Cutting, S. M. (2002). Bacillus probiotics: spore germination in the gastrointestinal tract. *Applied and Environmental Microbiology*, *68*(5), 2344-2352.

Cazarotto, C. J., Boito, J. P., Gebert, R. R., Reis, J. H., Machado, G., Bottari, N. B., and Leal, M. L. (2018). Metaphylactic effect of minerals on immunological and antioxidant responses, weight gain and minimization of coccidiosis of newborn lambs. *Research in Veterinary Science*, *121*, 46-52.

Cervantes-Valencia, M. E., Alcalá-Canto, Y., Sumano-Lopez, H., Ducoing-Watty, A. M., and Gutierrez-Olvera, L. (2016). Effects of Curcuma longa dietary inclusion against Eimeria spp. in naturally-infected lambs. *Small Ruminant Research*, *136*, 27-35.

Chen, Q., Wang, X., Yuan, X., Shi, J., Zhang, C., Yan, N., and Jing, C. (2021). Comparison of phenolic and flavonoid compound profiles and antioxidant and α-glucosidase inhibition properties of cultivated soybean (Glycine max) and wild soybean (Glycine soja). *Plants*, *10*(4), 813.

Chester-Jones, H., Heins, B., Ziegler, D., Schimek, D., Schuling, S., Ziegler, B., and Broadwater, N. (2017). Relationships between early-life growth, intake, and birth season with first-lactation performance of Holstein dairy cows. *Journal of Dairy Science*, *100*(5), 3697-3704.

Choi, J., Tompkins, Y. H., Teng, P.-Y., Gogal Jr, R. M., and Kim, W. K. (2022). Effects of tannic acid supplementation on growth performance, oocyst shedding, and gut health of in broilers infected with eimeria maxima. *Animals*, *12*(11), 1378.

Couladis, M., Tzakou, O., Verykokidou, E., and Harvala, C. (2003). Screening of some Greek aromatic plants for antioxidant activity. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, *17*(2), 194-195.

Daugschies, A., and Najdrowski, M. (2005). Eimeriosis in cattle: current understanding. *Journal of Veterinary Medicine, Series B*, *52*(10), 417-427.

Ding, S., Wang, Y., Yan, W., Li, A., Jiang, H., and Fang, J. (2019). Effects of Lactobacillus plantarum 15-1 and fructooligosaccharides on the response of broilers to pathogenic Escherichia coli O78 challenge. *PLOS one*, *14*(6), e0212079.

EFSA, F. (2014). Scientific Opinion on the safety and efficacy of Toyocerin® (Bacillus toyonensis) as a feed additive for chickens for fattening, weaned piglets, pigs for fattening, sows for reproduction, cattle for fattening and calves for rearing and for rabbits for fattening. *EFSA Journal*, *12*(7), 3766.

El-Ghareeb, W. R., Kishawy, A. T., Anter, R. G., Aboelabbas Gouda, A., Abdelaziz, W. S., Alhawas, B., and Ibrahim, D. (2023).

Novel antioxidant insights of myricetin on the performance of broiler chickens and alleviating experimental infection with Eimeria spp.: Crosstalk between oxidative stress and inflammation. *Antioxidants*, *12*(5), 1026.

Fitzgerald, P. R. (1981). The economic impact of coccidiosis in domestic animals. *Advances in Veterinary Science and Comparative Medicine*, *24*, 121-143.

Foreyt, W. J. (1990). Coccidiosis and cryptosporidiosis in sheep and goats. *Veterinary Clinics of North America: Food Animal Practice*, *6*(3), 655-670.

Franz, C., Baser, K., and Windisch, W. (2010). Essential oils and aromatic plants in animal feeding–a European perspective. A review. *Flavour and Fragrance Journal*, *25*(5), 327-340.

Friend, S., and Stockdale, P. (1980). Experimental Eimeria bovis infection in calves: a histopathological study. *Canadian Journal of Comparative Medicine*, *44*(2), 129-140.

Galgano, F., Tolve, R., Scarpa, T., Caruso, M. C., Lucini, L., Senizza, B., and Condelli, N. (2021). Extraction kinetics of total polyphenols, flavonoids, and condensed tannins of lentil seed coat: Comparison of solvent and extraction methods. *Foods*, *10*(8), 1810.

Giannenas, I., Tsalie, E., Triantafillou, E., Hessenberger, S., Teichmann, K., Mohnl, M., and Tontis, D. (2014). Assessment of probiotics supplementation via feed or water on the growth performance, intestinal morphology and microflora of chickens after experimental infection with Eimeria acervulina, Eimeria maxima and Eimeria tenella. *Avian Pathology*, *43*(3), 209-216.

Goel, A., Halami, P. M., and Tamang, J. P. (2020). Genome analysis of Lactobacillus plantarum isolated from some Indian fermented foods for bacteriocin production and probiotic marker genes. *Frontiers in Microbiology*, *11*, 40.

Gray, P., Jenner, R., Norris, J., Page, S., and Browning, G. (2021). Antimicrobial prescribing guidelines for poultry. *Australian Veterinary Journal*, *99*(6), 181.

Hordofa, D., Abunna, F., Megersa, B., and Abebe, R. (2021). Incidence of morbidity and mortality in calves from birth to six months of age and associated risk factors on dairy farms in Hawassa city, southern Ethiopia. *Heliyon*, *7*(12).

Hur, S. N., Molan, A. L., and Cha, J. O. (2005). Effects of feeding condensed tannin-containing plants on natural coccidian infection in goats. *Asian-Australasian Journal of Animal Sciences*, *18*(9), 1262-1266.

Iordache, A. M., Nechita, C., Podea, P., Șuvar, N. S., Mesaroș, C., Voica, C., and Culea, M. (2023). Comparative amino acid profile and antioxidant activity in sixteen plant extracts from Transylvania, Romania. *Plants*, *12*(11), 2183.

Jiang, X., Ma, G., Cui, Z., Li, Y., and Zhang, Y. (2020). Effects of fermented corn gluten meal on growth performance, plasma metabolites, rumen fermentation and bacterial community of Holstein calves during the pre-weaning period. *Livestock Science*, *231*, 103866.

Kanyari, P. (1990). Eimeria apsheronica in the goat: endogenous development and host cellular response. *International Journal for Parasitology*, *20*(5), 625-630.

Khodakaram-Tafti, A., and Hashemnia, M. (2017). An overview of intestinal coccidiosis in sheep and goats. *Revue de Médecine Vétérinaire*, *168*(1/3), 9-20.

Koudela, B., and Boková, A. (1998). Coccidiosis in goats in the Czech Republic. *Veterinary Parasitology*, *76*(4), 261-267.

Kumar, K., Sinha, R. K., Kumar, S., Nirala, R., Kumari, S., and Sahu, S. (2022). Significance of tannins as an alternative to antibiotic growth promoters in poultry production. *Pharmacology Innovations*, *14*, 257.

Lassen, B., and Østergaard, S. (2012). Estimation of the Economical effects of Eimeria infections in Estonian dairy herds using a stochastic model. *Preventive Veterinary Medicine*, *106*(3-4), 258-265.

Le, B., and Yang, S. H. (2018). Efficacy of Lactobacillus plantarum in prevention of inflammatory bowel disease. *Toxicology Reports*, *5*, 314-317.

Li, Y., Yang, H., Li, Z., Li, S., and Li, J. (2023). Advances in the biosynthesis and molecular evolution of steroidal saponins in plants. *International Journal of Molecular Sciences*, *24*(3), 2620.

Lin, W.-C., Ptak, C. P., Chang, C.-Y., Ian, M.-K., Chia, M.-Y., Chen, T.-H., and Kuo, C.-J. (2020). Autochthonous lactic acid bacteria isolated from dairy cow feces exhibiting promising probiotic properties and in vitro antibacterial activity against foodborne pathogens in cattle. *Frontiers in Veterinary Science*, *7*, 239.

Lucey, P., Lean, I., Aly, S., Golder, H., Block, E., Thompson, J., and Rossow, H. (2021). Effects of mannan-oligosaccharide and Bacillus subtilis supplementation to preweaning Holstein dairy heifers on body weight gain, diarrhea, and shedding of fecal pathogens. *Journal of Dairy Science*, *104*(4), 4290-4302.

Madsen, H. L., and Bertelsen, G. (1995). Spices as antioxidants. *Trends in Food Science and Technology*, *6*(8), 271-277.

Meale, S. J., Chaucheyras-Durand, F., Berends, H., and Steele, M. A. (2017). From pre-to postweaning: Transformation of the young calf's gastrointestinal tract. *Journal of Dairy Science*, *100*(7), 5984-5995.

Mee, J. F. (2013). Why do so many calves die on modern dairy farms and what can we do about calf welfare in the future? *Animals*, *3*(4), 1036-1057.

Mounir, M., Ibijbijen, A., Farih, K., Rabetafika, H. N., and Razafindralambo, H. L. (2022). Synbiotics and their antioxidant properties, mechanisms, and benefits on human and animal health: a narrative review. *Biomolecules*, *12*(10), 1443.

Nahed, A., Abd El-Hack, M. E., Albaqami, N. M., Khafaga, A. F., Taha, A. E., Swelum, A. A., and AbuQamar, S. F. (2022). Phytochemical control of poultry coccidiosis: a review. *Poultry Science*, *101*(1), 101542.

Osuntoki, A., and Korie, I. (2010). Antioxidant activity of whey from milk fermented with Lactobacillus species isolated from Nigerian fermented foods. *Food Technology and Biotechnology*, *48*(4), 505-512.

Pechrkong, T., Incharoen, T., Hwanhlem, N., Kaewkong, W., Subsoontorn, P., Tartrakoon, W., and Charoensook, R. (2023). Effect of Bacillus toyonensis BCT-7112T supplementation on growth performance, intestinal morphology, immune-related gene expression, and gut microbiome in Barbary ducks. *Poultry Science*, *102*(10), 102991.

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

Peng, P., Jia, D., Cao, L., Lu, W., Liu, X., Liang, C., and Fang, Z. (2021). Akebia saponin E, as a novel PIKfyve inhibitor, induces lysosome-associated cytoplasmic vacuolation to inhibit proliferation of hepatocellular carcinoma cells. *Journal of Ethnopharmacology*, *266*, 113446.

Prabhurajeshwar, C., and Chandrakanth, K. (2019). Evaluation of antimicrobial properties and their substances against pathogenic bacteria in-vitro by probiotic Lactobacilli strains isolated from commercial yoghurt. *Clinical Nutrition Experimental*, *23*, 97-115.

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

Rai, S., Acharya-Siwakoti, E., Kafle, A., Devkota, H. P., and Bhattarai, A. (2021). Plant-derived saponins: a review of their surfactant properties and applications. *Science*, *3*(4), 44.

Reeg, K. J., Gauly, M., Bauer, C., Mertens, C., Erhardt, G., and Zahner, H. (2005). Coccidial infections in housed lambs: oocyst excretion, antibody levels and genetic influences on the infection. *Veterinary Parasitology*, *127*(3-4), 209-219.

Rizwan, H., Sajid, M., Shamim, A., Abbas, H., Qudoos, A., Maqbool, M., and Amin, Z. (2021). Sheep parasitism and its control by medicinal plants: A review. *Parasitologists United Journal*, *14*(2), 112-121.

Rokana, N., Mallappa, R. H., Batish, V. K., and Grover, S. (2017). Interaction between putative probiotic Lactobacillus strains of Indian gut origin and Salmonella: impact on intestinal barrier function. *LWT*, *84*, 851-860.

Rokana, N., Singh, R., Mallappa, R. H., Batish, V. K., and Grover, S. (2016). Modulation of intestinal barrier function to ameliorate Salmonella infection in mice by oral administration of fermented milks produced with Lactobacillus plantarum MTCC 5690–a probiotic strain of Indian gut origin. *Journal of Medical Microbiology*, *65*(12), 1482-1493.

Saeed, Z., Abbas, R. Z., Khan, M. K., and Saleemi, M. K. (2023). Anticoccidial activities of essential oil of Amomum subulatum in broiler chicks. *Pakistan Journal of Agricultural Sciences*, *60*(2).

Saeed, Z., and Alkheraije, K. A. (2023). Botanicals: A promising approach for controlling cecal coccidiosis in poultry. *Frontiers in Veterinary Science*, *10*, 1157633.

Saladino, P. M., Gonzaga, E. A., and Gonzaga, L. J. A. (2022). Anticoccidial effects of Tinospora rumphii extract in naturally infected goats. *Journal of Advanced Veterinary and Animal Research*, *9*(1), 8.

Shen, N., Wang, T., Gan, Q., Liu, S., Wang, L., and Jin, B. (2022). Plant flavonoids: Classification, distribution, biosynthesis, and antioxidant activity. *Food Chemistry*, *383*, 132531.

Subiono, T., and Tavip, M. A. (2023). Qualitative and quantitative phytochemicals of leaves, bark and roots of Antiaris toxicaria Lesch., a promising natural medicinal plant and source of pesticides. *Plant Science Today*, *10*(1), 5-10.

Taylor, M., and Catchpole, J. (1994). Coccidiosis of domestic ruminants. *Applied Parasitology*, *35*(2), 73-86.

Thenmozhi, M., Arunthathi, K., Abhinav, J., Sharika, K., and Dhasarathan, P. (2023). Extraction of Phytochemical Constituents from the Leaves of Vitex trifolia in the Inhibition of Lipoxygenase, Cyclooxygenase, Tyrosinase and Xanthine Oxidase. *Indian Journal of Agricultural Research*, *1*(5).

Travers, M.-A., Florent, I., Kohl, L., and Grellier, P. (2011). Probiotics for the control of parasites: an overview. *Journal of Parasitology Research*, *2011*(1), 610769.

Trotta, R. J., Kreikemeier, K. K., Foote, S., McLeod, K. R., and Harmon, D. L. (2023). Influence of Anti-Coccidial Compounds and Phytogenic Saponin Extracts on In Vitro and In Vivo Ruminal Fermentation and Methane Production of Cattle. *Animals*, *13*(14), 2308.

Wang, J., Ji, H., Wang, S., Liu, H., Zhang, W., Zhang, D., and Wang, Y. (2018). Probiotic Lactobacillus plantarum promotes intestinal barrier function by strengthening the epithelium and modulating gut microbiota. *Frontiers in Microbiology*, *9*, 1953.

Youssefi, M. R., Alipour, R., Fakouri, Z., Shahavi, M. H., Nasrabadi, N. T., Tabari, M. A., and Centoducati, G. (2023). Dietary supplementation with eugenol nanoemulsion alleviates the negative effects of experimental coccidiosis on broiler chicken's health and growth performance. *Molecules*, *28*(5), 2200