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Review article

An updated insight into the gastrointestinal helminthoses of poultry: a review

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ABSTRACT. This review article provides more information about the incidence of helminths affect the gastrointestinal tracts of poultry in different countries, life cycle, clinical picture, diagnosis, and prevention and control measures of such infections. Backyard and deep litter production systems show higher helminth infections than cage system. Moreover, the incidence of helminth infection is more common in tropical countries of Africa and Asia than of European ones due to the suitability of environment and management conditions. Nematodes and cestodes are the most common gastrointestinal helminths of avian species, followed by trematodes. The life cycles of helminths may be direct or indirect, but the infection is usually through faecal-oral route. Affected birds show general signs, low production performance parameters, and even death due to intestinal obstruction and rupture. Lesions of the infected birds reveal catarrhal to haemorrhagic enteritis according to the severity of infection. Diagnosis of affection is mainly based on *post mortem* examination or microscopic detection of eggs or parasites. As internal parasites adversely affect the host causing poor feed utilization and low performance, thus intervention control strategies are urgent. Prevention and control strategies are relied on application of strict biosecurity measures, eradication of intermediate hosts, early routine diagnosis, and continuous application of specific anthelmintic drugs. Deworming using herbal medicine is recent and successful and may be good alternative to chemicals. In conclusion, helminth infections of poultry remain a major hurdle against the profitable production in poultry producing countries and necessary preventive and control measures should be strictly applied by poultry producers.

Keywords: poultry, cestodes, diagnosis, nematodes, trematodes

Introduction

As a result of global growth of poultry production and the recent shift toward application of extensive free range housing to achieve animal welfare, the incidence of parasitic infections has been increased either in poultry [1,2] or other animals [3]. Helminth infections are common around the globe especially in chicken with a significant variation among localities and production systems.

Presence of the gastrointestinal helminths has a negative impact on poultry production [4]. Helminths, especially nematodes showed economic losses associated with health, intestinal damage, and reduced the production performance. These direct losses including reduced feed conversion rate, loss of body weight, drop in egg production, changes in egg quality, and death in severe infection [5]. In addition to indirect loss of the intestinal barriers, immune suppression, and consequently increasing the susceptibility to other infections [6]. Gastrointestinal helminths can transmit other protozoon parasites such as *Histomonas meleagridis* (*H. meleagridis*) which causes high morbidity and up to 20% mortality in the affected flocks [7].

Helminths of the gastrointestinal tract of poultry can be classified into nematodes, cestodes, and trematodes [8]. Nematodes are regarded as an important group of helminths that infect poultry in terms of the number of species and the produced intestinal damage [9]. Nematodes belong to the phylum Nemathelminths, class Nematoda. More than 50 species of nematodes have been described in poultry. Out of the 25 nematodes families, 14 infect birds: Ascarididae, Heterakidae, Capillaridae, Syngamidae, Strongyloididae, Trichostrongylidae, Trichuridae, Spiruridae, Subuluridae, Gnathostomatidae, Thelaziidae, Physalopteridea, Acuariidae, and Dipetalonematidae [10,11]. However, about 1400

species of cestodes were detected in the domestic and wild birds. The pathogenicity of cestodes varies from mild to severe [10]. Three families (Davainidae, Dilepididae, and Hymenolepidae) and 10 genera (*Raillietina*, *Davainea*, *Choanotaenia*, *Amoebotaenia*, *Diorchis*, *Drepanidotaenia*, *Imparmargo*, *Metroliasthes*, *Hymenolepis*, *and Fimbriaria*) were previously identified in poultry [12]. The identified trematodes in avian species were classified into 27 families, 125 genera, and almost 500 species. Trematodes are less host-specific than nematodes and tapeworms, thus wild birds are frequently introducing infection in areas where domestic poultry are reared [12].

Thus, the objectives of this review article were to provide more data on the incidence of helminths affect the gastrointestinal tracts of poultry in different countries, especially in the Middle East region as well as the life cycle, clinical picture, diagnosis, and the prevention and control of helminth infections.

Incidence and distribution in different countries

Factors influence on helminth infections may be environmental conditions (temperature and humidity), management system, host susceptibility and resistance, presence of intermediate host, the load of infective stages as eggs or larvae, and the application of anthelminthic drugs [13–15]. The incidences of helminth infections are more in birds reared in backyard free range system and deep litter system than birds reared in cages [16]. Birds in open or semi-closed systems are in direct contact with their droppings and litter which contain the infective stages [17]. The incidence rate of helminth infection in these systems may reach to 100% [18]. Free range system is the main source for shedding of helminths infective stages to the surrounding [19]. However, some reports showed presence of intestinal helminths in cages production system. This observation may be possibly correlated to poor hygienic conditions around the birds with accumulation of droppings beneath them [20]. In addition, layer and breeder pullets can be infected during rearing on the litter before their later transmission to cages. Another possible reason of helminth infections of caged birds is the longer period of rearing of these types of birds that extends to several months [21].

The high incidences of parasitic infections of birds in Africa and Asia may be related to the system of poultry housing in these continents coupled with the worm and humid climatic conditions that favor the development of infective stages [22–27]. However, the re-emerge of helminthosis across the European countries has been increased as a result of shifting production systems into free-range and organic systems [28], along with prohibited application of anthelmintic drugs in the European organic production system [29].

The incidence of gastrointestinal helminthoses in some countries of the Middle East region (Egypt, Iraq, Iran, Turkey, Jordan, and Saudi Arabia) is shown in table 1 [30–58].

Infection and life cycles

The life cycle of most nematodes in birds is direct and the main route of infection is the faecal-oral route. Regarding *A. galli*, the infective eggs (egg contains the 3rd larva stage) are ingested by the host, the eggs hatched by the effect of enzymes in the gastric juice. The larvae burrow through lining intestinal epithelium and form two moults. Then, they develop into adults and produce large quantities of eggs that excreted in the droppings of birds and continue their life cycle. Though, the life cycle of *Capillaria* species may be direct or indirect. For intense, *C. obsignata*, *C. contorta*, and *C. anatis* exhibit direct life cycle. Their infective stage is egg contains the 1st larva stage which hatches at its site in the host and develops into worms without migration. However, eggs of *C. annulata*, *C. caudinflata*, and *C. bursata* are ingested by the earthworms and develop into infective stages in 2–3 weeks. Birds may be infected when ingest the earthworms. Similarly, the life cycle of *Subulura brumpti* requires an intermediate host such as beetles and cockroaches. The embryonated eggs are ingested by the intermediate host and the larva undergoes development to the 3rd larva stage (infective stage). When the final host ingests the intermediate host, the adult worms develop in the proventriculus of the host.

The life cycle of all cestodes is indirect. Cestodes require an intermediate host such as earthworms, ants, beetles, grasshoppers, houseflies, snails, or slugs for their transmission [26]. The eggs are present in the droppings of the infected host and they may be ingested by the intermediate host. By the effect of the gastric juice, the embryophore is removed to expose oncosphere which is developed

Table 1. The incidence of gastrointestinal helminthoses in some countries of the Middle East region

Country	Findings	Reference
Egypt	A total of 110 ducks were examined in El-Behera governorate, Egypt in 2001–2003. The prevalence rate of nematode, cestode, and trematode was 2.72%, 3.63%, and 1.81%, respectively, with a total rate of 4.54%. Both *A. galli* (0.9%) and *H. gallinarum* (1.81%) were the recovered species of nematodes. However, *Echinoparyphium recurvatum* (0.9%) and *Echinoparyphium paraulum* (1.81%) were the recovered trematodes. *Cladogynia phoeniconaiadis* (3.63%), *Echinolepis carioca* (3.63%), and *Baerfainia anoplocephaloides* (3.63%) were the recorded new species of cestodes.	[30]
	Eight hundred and sixty chickens were collected from Zagazig governorate, Egypt during the period from March 2005 till July 2007. Thirty-seven birds showed infection with cestodes (4.3%). Cestodes species were *R. tetragona* (97.2%), *R. echinobothrida* (91.9%), *R. cesticillus* (59.4%), *Choanotaenia infundibulum* (40.5%), and *R. ransomi* (18.9%).	[31]
	The genomic DNA of *A. galli* worm that detected in chickens from Egypt was extracted and the polymerase chain reaction was applied. Two primers were used and screened. Only the second primer gave total amplified fragment markers 818 bp. The gene sequence was compared with another one and it was to some extent similar to *Heterorhabditis* spp.	[32]
	The intestinal tracts of 705 fowls, 265 pigeons, 84 turkey, 353 ducks, and 58 geese were subjected for parasitological examination for helminths infection during the period from January 2012 to 2013 in Gharbia governorate, Egypt. It was found that 642 (43.8%) out of 1465 examined birds were infected with intestinal worms and the incidence rates were 46.4% in fowls, 51.7% in pigeons, 42.9% in turkeys, 38% in ducks, and 13.8% in geese. Trematode (*Echinostoma revolutum*) was found ducks (1.7%). Cestodes infection rate in ducks was 14.7 % and the highest incidence rate was in pigeons (30.9%). Nematodes were found in 19.7% of birds and the highest incidence was in turkey (26.2%). *R. tetragona* was found in all birds (7.4%), while *R. echinobothrida* was found in 6.6% of fowl, pigeon, ducks, and geese which were 5.4%, 17.7%, 2.8%, and 1.7% respectively. *R. georgiensis* was detected in pigeon and turkey in rates of 5.3% and 9.5% respectively. *Ascaridia galli* was present in all examined birds (16.3%) which were 28.7%, 3.5%, 8.8% and 5.2% in fowl, turkey, duck, and geese, respectively. *A. columbae* was detected in pigeon (12%). *H. gallinae* was found in turkey (7.1%) and ducks (3.4%), but *H. dispar* was detected in fowl (4%), turkey (8.3%), ducks (5.4%), and geese (3.4%). *C. obsignata* was present (3.1%) in all birds with incidences of 0.9%, 7.2%, 17.9%, 3.1% and 1.7% for fowl, pigeons, turkey, ducks, and geese respectively.	[33]
	A total of 740 intestinal samples from pigeons and 100 from turkeys were investigated during the period from June 2015 to May 2016 in Beni-Suef province, Egypt. The recovered species were identified as 4 nematodes, 5 cestodes, and 2 trematodes. The overall prevalence of recovered helminths was 11.76% in pigeons. Digeneans were *Brachylaima cribbi* (0.14%) and unidentified *Brachylaima* species (0.14%). Cestodes species were characterized as *R. echinobothrida* (4.46%), *R. cesticillus* (0.95%), *R. tetragona* (0.95%), *Cotugnia digonopora* (0.68%), and *Hymenolepis carioca* (0.27%). Nematode species were *A. columbae* (3%), *Subulura brumpti* (0.81%), *H. gallinarum* (0.41%), and *Capillaria* species (0.27%). The only helminth species detected in turkeys was *A. dissimilis* (6%).	[34]
	A total of 156 intestinal tracts of chickens were collected from Aswan governorate, Egypt during the period from April 2016 to March 2017. Out of 156, 76 (50.6%) of birds showed intestinal helminths. Seven species of helminths were detected. The recovered helminths were cestodes (34.6%) and nematodes (23.7%). Mixed infection were estimated in 7%. *R. tetragona* was the most common species (16%), followed by *R. echinobothrida* (10.9%), *Cotugnia digonopora* (6.4%), and *R. cesticillus* (1.3%). Nematodes were detected in 23.7% of chickens. *H. gallinae*, *A. galli*, and *Subulura brumpti* were identified in percentages of 15.4%, 9%, and 1.3%, respectively.	[35]

Table 1. The incidence of gastrointestinal helminthoses in some countries of the Middle East region

Country	Findings	Reference
Egypt	A total of 276 poultry representing 156 chickens and 120 were collected from Aswan province, Egypt during the period from April 2016 to March 2017. The overall prevalence of intestinal helminths was 55.79%. Moreover, 59.09% of chickens showed mixed infections with 4 cestodes and 3 nematodes. Regarding cestodes species, *R. tetragona* (16.02%) followed by *R. echinobothrida* (10.98%), *Cotugnia digonopora* (6.41%), and *R. cesticillus* (1.28%) were the recorded species. Nematodes species were *H. gallinarum* (15.38%), *A. galli* (8.97%), and *Subulura brumpti* (1.28%). In pigeons, 52.5% were found to be infected by 4 cestodes including *R. echinobothrida* (22.5%), *Cotugnia digonopora* (13.33%), *R. tetragona* (9.16%), and *R. cesticillus* (3.33%), and one species of nematodes, *A. columbae* (9.16%).	[36]
	A total of 510 ducks were collected during the period from October 2018 to November 2019 in Beni-Suef, Egypt. The results showed that the overall prevalence was 13.92% and 2.16% of ducks had mixed infections. The recovered nematodes and cestodes species were 5 and 8, respectively. The most predominate species was *A. galli* (5.10%), *H. gallinarum* (1.76%), *Subulura brumpti* (0.59%), *Trichostrongylus tenuis* (0.2%), and *Epomidiostomum uncinatum* (0.2%). The most prevalent cestodes were *R. tetragona* (1.96%), followed by *R. cesticillus* (1.57%), *Amoebotaenia cuneata* (1.18%), *Cotugnia digonopora* (0.98%), *R. echinobothrida* (0.78%), *Hymenolepis apodemi*-like (0.78%), *Choanotaenia infundibulum* (0.59%), and *Hymenolepis carioca* (0.39%).	[37]
Iraq	In Al-Diwaniya province, southern Iraq, the infection rate of nematode in ducks was 82.71%, while it was 96.29% for cestodes.	[38]
	In Babylon province, Iraq, 250 intestinal tracts of chickens were collected for parasitological examination. The prevalence rates for nematodes and cestodes were 10.4% and 1.2%, respectively.	[39]
	Examination of 80 dropping samples for each of ducks and geese in province, Iraq was carried out from December 2008 to July 2009. Mixed infection being 44.92% and 22.66% in ducks and geese respectively was the most common. Parasitic investigation showed presence of 17 and 12 species or genera of internal helminth in ducks and geese, respectively. The most predominant nematode of ducks and geese was *Capillaria* species which represented 38.75% in ducks and 42.5% in geese, while the common trematode species were *Noticotylus attenuatus* which represented 10% in ducks and 17.5% in geese. *Raillietina* species in ducks and geese were represented as 22.5% and 50% respectively.	[40]
	The presence of nematodes in 45 intestinal tract of chickens was detected in Babylon province, Iraq. The prevalence rates of the identified nematode species were 8.9%, 8.28%, 17.7%, and 15.5%.	[41]
	The intestines of 95 pigeon in Al-Dewniya city, Iraq were examined. The results showed 66.31% were parasitized with tape worms, 20% were belonged to *Cotugnia* species, while 46.31% were belonged to *Raillietina* species. Additionally, 38.94% of pigeons were infested by nematodes (*Ascaridia* species).	[42]
	Twenty two ducks were collected in Baghdad, Iraq during the period from September to November, 2012. *Amidostomoides acutum*, *Epomidiostomum uncinatum*, and *Tetrameres* species were the prevalent isolated nematode species in the provenrticulus and gizzard.	[43]
	A number of 107 chickens were examined in Diyala province, Iraq in the period from December 2012 to March of the 2013. The total infection rate was 41.18%. The rate of internal parasites infection is 17.75%. The recorded rate of tapeworms was 13.08%, while the filamentous nematodes reached 4.67%. The study revealed presence of *Cotugina* species and *H. gallinarum* at rates of 12.14% and 4.67 %, respectively.	[44]
	This study conducted to identify helminth in 74 pigeons in Sharqat city, Salah Al- Deen province, Iraq. The results showed presence of *R. tetragona* 12 (16.2%), *R. echinobothrida* 10 (13.5%), *A. columbae* 9 (12.1%), and *Capillaria* species 9 (12. 2%).	[45]

Table 1. The incidence of gastrointestinal helminthoses in some countries of the Middle East region

Country	Findings	Reference
Iraq	The parasitological findings of 64 ducks and 70 geese that collected from April 2017 to December 2018, in Nineveh province, Iraq were investigated. The total infection rate of nematodes and cestodes in ducks was 50% and 28.1%, respectively, while in geese, it was 54.2% and 31.4%, respectively. In ducks, the dominant types of nematodes were *A. galli*, *H. gallinarum*, *H. isolonche*, and *Subulura brompti*, and the same types were also found in geese except *H. isolonche*. The identified species of cestodes in ducks and geese were *R. tetragona*, *R. echinobothrida*, *R. cesticillus*, and *Coantaenia infundibulum*.	[46]
Iran	This study was done from October 1999 to September 2000 on 105 chickens in Urmia, Iran. Chickens showed infection with one or more helminth species as the following; *A. galli* (32.38%), *H. gallinarum* (61.9%), *Subulura brumpti* (32.38%), *Choanotaenia infundibulum* (18.1%), *R. cesticillus* (17.14%), *R. echinobothrida* (36.2%), *R. tetragona* (7.62%), *Echinoparyphium recurvatum* (0.95%), and *Postharmostomum commutatus* (4.76%).	[47]
	During 2007, organs of 26 and 24 adult female chickens collected from humid parts and dry regions of Golestan Province, Iran respectively were examined for parasites infections. Parasites that were found in the intestinal tract were *A. galli* (56%), *H. gallinarum* (24%), *C. anatis* (4%), *Cheilospirura hamulosa* (4%), *R. tetragona* (58%), *R. echinobothrida* (6%), and *Choanotaenia infundibulum* (8%); while that found in the lungs was *Syngamus trachea* (16%).	[48]
	This study examined 102 pigeons in Birjand, Iran from October 2008 to September 2009. Five species of nematodes and cestodes were investigated as the followings; *A. colombae* (16.66%), *Hadjelia truncata* (1.96%), *Cotugnia digonopora* (13.79%), *R. magninumida* (18.62%), and *R. echinobothrida* (32.35%).	[49]
	This study was conducted from May to September 2011 on 250 faecal samples of pigeons in Ilam city, Iran. The data indicated prevalence rate of *R. echinobothrida* (10.4%), *Syngamus trachea* (8.4%), *C. colombae* (6%), and *A. colombae* (8.4%). Multiple infections observed with internal parasites were 19/4%.	[50]
	Intestinal samples were collected from 102 pigeons in Khorasan province from 2008 to September 2009. Five species of nematodes and cestodes were identified as 2 nematodes; *A. colombae* (16.66%) and *Hadjelia truncata* (1.96%), and 3 cestodes; *Cotugnia digonopora* (13.79%), *R. magninumida* (18.62%), and *R. echinobothrida* (32.35%).	[51]
	A total of 138 pigeons were examined from May 2011 to March 2012 in Urmia, Iran. The overall parasite prevalence in pigeons was 23.18%, with specific prevalence for *A. columbae* being 13.04% followed by species of *R. echinobothrida* (10.14%), *R. tetragona* (2.89%), *R. magninomida* (1.44%), and *Capillaria* species (0.72%).	[52]
	In this study, the gastrointestinal tracts of 60 turkeys were collected during February and March, 2014 in Amol, Iran. It was shown that 75% of samples were infected with nematode, cestode, and trematode. The prevalence of helminth species was 20% (*Capillaria*), 51% (*A. galli*), 8% (*R. tetragona*), 8% (*R. echinobothrida*), and 11% (*Echinostoma*).	[53]
	One hundred 100 gastrointestinal samples were taken from chickens in Tabriz city, Iran during 2016 for identification of intestinal helminthic. Out of 100 chicken, 37 (37%) were infected. Nematodes showed the highest prevalence 25 (68%), then the cestodes with a prevalence rate 12 (32%). Nematodes species including *A. galli* 9 (16 %) and *H. galinarum* 16 (64 %) were most predominant species. The highest species prevalence of cestodes was *R. tetragona* 12 (100%). The average parasite burden/bird was found to be 5.7 and 14 (38 %) of cases were mixed infections.	[54]

Table 1. The incidence of gastrointestinal helminthoses in some countries of the Middle East region

Country	Findings	Reference
Jordan	The prevalence of gastrointestinal and tracheal helminths among 208 chickens in northern Jordan from December 2004 to February 2005 and from June 2005 to August 2005 was determined. Three nematode and 8 cestode species were detected. One hundred and fifty-two birds (73.1%) (95%) were infected. The prevalence of different species was *A. galli* (female 28% and male 43%), *C. obsignata* 0.5%, *H. gallinarum* 33%, *Amoebotaenia cuneata* 4.3%, *Choanotaenia infundibulum* (female 23% and male 13%), *Davainea proglottina* 1.4%, *Hymenolepis cantaniana* 11%, *Hymenolepis carioca* (female 35% and male 24%), *R. cesticillius* (female 5%, and male 11%), *R. echinobothrida* 16%, and *R. tetragona* 18%.	[23]
	The occurrence and distribution of helminth parasites in the intestinal tract of 60 chickens in different regions around Amman, Jordan were investigated. The infection rate was 91.6%. Nematodes were higher than cestodes by about 20% in duodenum, ileum and colon respectively.	[55]
Turkey	Dropping samples were taken from 251 pigeons in Nigade, Turkey in 2007. Helminth eggs were found in droppings of 32 (23.5%) domestic pigeons and in five (4.3%) wild pigeons. *Capillaria* species (19.9%), *A. columbae* (5.1%), and *Heterakis* species (3.7%) were characterized in domestic pigeons, while *Capillaria* species (4.3%) and *Syngamus* species (1.7%) in wild pigeons.	[56]
	This study was carried out on 200 broiler chickens, 200 layer hens, and 100 free ranging backyard chickens that collected from Afyonkarahisar, Turkey, No helminths was detected in broiler chickens. *Choanotaenia infundibulum* was found in 23 (11.5%) layer chickens. A total of 58 (58%) of free-range backyard chickens were infected with *H. gallinarum* (38%), *A. galli* (19%), *C. obsignata* (15%), *C. caudinflata* (13%), *Trichostrongylus tenuis* (3%), *Subulura differens* (2%), *Choanotaenia infundibulum* (14%), *R. echinobothrida* (6%), and *R. cesticillus* (3%). Totally, 9 species of helminths were detected, 6 of them were nematodes and 3 of them were cestodes. A total 81 out of 500 (16.2%) were infected with different helminth species.	[57]
Saudi Arabia	The prevalence of ectoparasites and intestinal helminths of different pigeon taxa in Medina, Saudi Arabia, with special emphasis on the feral pigeon, *Columba livia domestica* (Columbiformes: Columbidae), was evaluated. Twenty eight feral pigeons were examined for helminths in Medina, Saudi Arabia. The recovered cestodes were of *Raillietina* species (Cyclophyllidea: Davaineidae) with prevalence rate of 10.71%, while nematodes were of *Ascaridia* species (Ascaridida: Ascaridiidae) with prevalence rate of 3.57%.	[58]

to the larva or metacestode. Once the final host ingest the intermediate host containing the metacestode, the scolex attaches to the intestinal mucosa and then a chain of proglottids begins to grow from the base of the scolex. Mature worm of cestodes shows continuous re-growing of body segments. The gravid proglottids are passed with the droppings and the eggs can be survived for long time in the environment.

Trematodes need two to four intermediate hosts to complete their life cycles, and the eggs hatch only in water [21,59].

Clinical picture

The clinical signs and post-mortem lesions of the most important species of nematodes and cestodes in poultry is presented in table 2 [60–63].

Ascaridia galli (*A. galli*) is the most prevalent and pathogenic species of nematodes, especially in chickens, and it causes ascaridiosis disease. The adult worms inhabit the small intestine of birds. The worms infect all ages of almost all avian species, however, the severity of the clinical picture is increased in birds younger than 12 weeks of age [62]. Death is usually found after the intestinal obstruction and rapture especially in birds suffering from immune suppression or debilitating conditions [61]. *Capillaria* species are present domestic and wild birds including *Capillaria annulata* (*C. annulata*), *C. obsignata* (*C. columbae*), *C. contorta*, *C. caudinflata*, *C. bursata*, and *C. anatis*. The worms are located throughout the digestive tract of birds. Both *C. annulata* and *C. contorta* parasitize the crop and esophagus. Other species such as *C. obsignata*, *C. caudinflata*, and *C. bursata* are found

Table 2. Clinical signs and *post mortem* lesions of the most important species of nematodes and cestodes in poultry

Nematodes	Clinical picture	References
Ascaridia galli	Clinical signs is usually appear in heavy infection in the form of general depression, unthriftiness, drooping of the wings, bleaching of the shank, loss of body weight, emaciation, and reduced egg production. Death is usually occur in case of severe infection as a result of blockage of the intestinal lumen with helminths and intestinal rupture. In *post mortem* examination of dead birds, the adult worms could be seen in the intestinal lumen and sometimes found wondering in the abdominal cavity after rapture of the intestine. Moreover, the adult worms may found in the oviduct and on the hens' eggs after surface contamination with the droppings containing the helminths. Dead birds may also show anemia due to loss of blood and atrophy of the thymus glands.	[60,61]
Capillaria species	Infected birds show general signs, weakness, diarrhea, and anemia. Nevertheless, in heavy infection, the birds reveal severe emaciation and bloody diarrhea. In the crop and esophagus, light infection induces mild thickening and inflammation, while heavy infection produces severe thickening with mucoid exudate. Haemorrhagic enteritis is also seen in heavy infection.	[62]
Cestodes		
Raillietina species	Chronic stage of infection is characterized by retardation of growth and severe emaciation. Severe cases are exacerbated by malnutrition or immunosuppression. Severe enteritis with development of nodules at the attachment site of the helminth are also seen „Nodular tapeworm disease".	[61]
Davainea species	Light infections of the helminths show growth retardation and weakness. Signs of severe infections include severe depression, ruffled feathers, severe loss of weight and emaciation, bloody droppings, anaemia, paralysis, and death of birds. Heavy infections cause thickened intestinal mucosa, mucoid or haemorrhagic enteritis, and necrosis.	[18,63]

in the small intestine, while *C. anatis* is present in the caeca. These worm species may be highly pathogenic in birds reared in the deep litter system and in free-range system. The pathogenicity of the helminths depends on the numbers of infective eggs in the litter or soil. It was found that *C. obsignata* (*C. columbae*) is very pathogenic for pigeons and causes high mortalities. *Heterakis gallinarum* (*H. gallinarum*) is a small caecal worm of birds. It is incriminated in the transmission of protozoon parasite *H. meleagridis* of turkeys via eggs shedding [18]. *Subulura brumpti* is very common in domestic avian species in North and South America, Africa, and Asia [64]. It inhabits the caecum and it is quite similar to *Heterakis* species [10]. Clinical manifestations due to the worm are rarely seen.

The most important species of cestodes that show clinical manifestations in birds are *Raillietina* and *Davainea*. *Raillietina echinobothrida* (*R. echinobothrida*) is the most pathogenic for avian species. *Davainea proglottina* (*D. proglottina*) is also regarded as one of the most pathogenic species of cestodes in poultry as the scolex is embedded among the intestinal villi of the host. A small size *D. proglottina* shows severe infection of young birds particularly if it occurs in large numbers. *Choanotaenia infundibulum* worms are of moderate pathogenicity and they may be associated with weight loss.

Routine diagnosis

Diagnosis of helminth infections is based mainly on *post mortem* examination of the intestinal tract of dead birds and using of laboratory parasitological techniques. *Post mortem* examination is considered as rapid, accurate, and reliable widely used diagnostic approach [65]. However, this approach requires dead or sacrificed birds, so it is considered as non-economic for routine diagnosis [66]. Samples could be taken from the droppings or litter over multiple days for laboratory diagnosis of helminths. Flotation techniques are used for detection of eggs microscopically [67]. McMaster technique is a common and cheap method for microscopic examination. However, new FLOTAC method is more accurate and sensitive approach for laboratory examination [68].

Prevention and control

The scientific poultry managemental practices

are responsible for the reduction in the incidence of parasitic infections. There is a great need for more rigorous and early interventions for controlling of parasitic diseases either in free-range backyard system or in deep litter system [69,70]. These approaches include the basic biosecurity measures, continuous treatment along with early routine diagnosis of infection [66]. If possible, young birds should be segregated and reared on clean and previously unused environment. Feeding and watering systems should be thoroughly and regularly cleaned without faecal contamination. Moreover, control over infection simply relies upon breaking the reproductive cycle of the tapeworm, by eradicating the intermediary hosts. Eradication of insects and prevent birds to access water surfaces might be sufficient to prevent and control the transmission of helminths [71]. Slug and snail bait containing metaldehyde should be applied around the houses.

Chemical deworming requires 24 hours starvation of birds before application of drug which may disrupts egg production in mature birds. Treatment of nematodes with anthelmintic such as piperazine, hygromycin B, and tetramisole is common. Infected birds are given treatment in water or feed against mature worms. However, albendazole, fenbendazole, and levamisole are also very effective against immature and adult worms [72]. Most of medicaments can not completely eliminate all worms and the eggs still be infective. The worms after deworming are paralyzed, lost their intestinal attachment, and passed out with the droppings. Accordingly, deworming should be repeated as 2 or 3 times with 7–10 days interval [71]. Treatment of cestodes with nematodes anthelmintic is usually non effective. However, cestodes require repeated specific medicaments such as praziquantel, niclosamide, and butynorate to ensure complete detachment of scolex from the intestinal mucosa [61,71].

As a result of rising in anthelmintic resistance, insufficient accessibility, and the high price of anthelmintic, there is a growing demand for detecting the anthelmintic activities of herbal medicine in veterinary practices [73]. Initiating the search for alternative approaches to control helminths using novel ingredients from plants [74]. There is an increasing awareness of the antiparasitic potential of herbal medicines. Medicinal plants are involved in combating parasitic diseases by decreasing stress, alleviating oxidative stress leading to better nutrients, improved health, and enhanced production. Furthermore, commercial broiler and layers have been received the mixture of medicinal plants as a feed additive showed enhanced efficacy of feed and health [75]. The use of herbal medicine against parasitism has been around for a long time, and such they are still used world-wide to control parasitic infestations. Seeds, leaves, flowers, and oil of some medicinal plants are used to control gastrointestinal parasitic infections [76].

Several plants have been detected as having antiparasitic properties [77–79]. Some plants such as *Psorelia corylifolia*, *Anacardium occidentale*, *Allium sativa*, *Pilostigma thonningi*, *Caesalpinia crista*, *Ocimum gratissimum*, *Anacardium occidentale*, *Tribulus terrestris*, *Bassia latifolia*, *Piper betle*, *Morinda citrifolia*, *Cassia occidentalis*, and *Aloe secundiflora* have *in vitro* and *in vivo* anthelmintic action against *Ascaridia galli* [80]. For instance, Brito et al. [81] demonstrated that the aqueous extract of *Morinda citrifolia* fruit (noni) showed 27.08% elimination of *A. galli* worms in chickens when compared with control group. In addition, treatment of *H. gallinarum* infection in turkey pullets using crude aqueous extracts of *Artemisia herba-alba* (0.4 g/kg body weight) in comparison with albendazole was evaluated in an Egyptian study [82]. The results indicated that *Artemisia herba-alba* was more effective than albendazole in terms of reduction of helminths eggs output and worm burden, improvement of the bird's performance, and reduction of the histopathological alterations in the tissues. The authors also concluded that this herb is effective, safe, available, and cheap. In another study, Abdelqader et al. [83] demonstrated that citrus peels extracts have potential anthelmintic properties against *A. galli* in chickens when compared with fenbendazole treatment. Chickens treated with 100 mg of ginger extract or with 100 mg of curcumin extract against *A. galli* revealed lower mortality rates in comparison with birds treated with 7.5 mg albendazole [84].

Neem, *Azadirachta indica* tree is has medicinal properties that used for the treatment of gastrointestinal nematodes [85,86]. Moreover, a high anthelmintic efficiency of *Nigella sativa* extract has been detected in poultry [87]. The activity of *N. sativa* against parasites is related to the presence of thymoquinone, which is an important phytochemical anthelmintic, along with other bioactive components which improve nutritional status and host immunity [88].

Consequently, plants have great anthelmintic

actions in poultry and may be a substitute for commonly used synthetic drugs, and their use may reduce drug resistance and drug residues in chicken's meat. However, the synergetic effects of recently used and safe anthelmintic drugs and herbal medicines representing broad anthelmintic properties are of high significance.

In conclusion, poultry infection with gastro-intestinal helminths represents as an important production problem. Accordingly, eradication strategies including hygienic measures, routine and continuous diagnosis, and deworming are the must. Public awareness is crucial and research work should focused on this aspect.

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