*Journal of Veterinary and Biomedical Sciences*
*Vol. 6 (2) 120–148, 2024*
*ISSN: 2659 – 0743*

DOI: 10.36108/jvbs/4202.60.0221



# Prevalence and Risk Factors of Gastrointestinal Helminth Infections in Turkeys (*Meleagris gallopavo*) in Borno State, Northeastern Nigeria

Jallailudeen Rabana Lawal, Halima Mshelia Pindar, Saraya Hyeladzira Mshelia, Umar Isa Ibrahim, Abdullahi Abubakar Biu, Adamu Maina Umar, Abubakar Abba Kaka.

1 Department of Veterinary Medicine, Faculty of Veterinary Medicine, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria
2 Department of Veterinary Parasitology and Entomology, Faculty of Veterinary Medicine, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria
3 Veterinary Teaching Hospital, Faculty of Veterinary Medicine, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria
*Corresponding author: Jallailudeen Rabana Lawal
Telephone No.: +234 803 2886 428; Email: rabana4real@unimaid.edu.ng

**Abstract**
This study investigated the prevalence and risk factors associated with gastrointestinal helminth infections in turkeys (*Meleagris gallopavo*) in Borno State, Northeastern Nigeria. A total of 650 turkeys were sampled from five Local Government Areas (LGAs) across the state, employing a purposive non-probability sampling technique over a 12-month period, spanning both rainy and dry seasons. The study population included turkeys of both sexes, of various age groups reared under free-range and intensive management systems, with faecal samples collected from farms, while gastrointestinal tracts after post-mortem from live poultry markets and veterinary hospitals. Gastrointestinal tracts and faecal samples were examined for adults and ova of nematodes and cestodes using standard parasitological methods. The overall prevalence of nematode infections was 41.2%, with *Ascaridia galli* being the most common (17.7%), followed by *Heterakis gallinarum* (13.1%), *Capillaria* spp. (6.8%), and *Strongyloides avium* (3.7%). Cestode infections were detected in 14.3% of turkeys, predominantly *Raillietina tetragona* (6.8%), *Choanotaenia infundibulum* (3.8%), and *Davainea proglottina* (2.8%). Mixed infections were found in 11.5% of turkeys. Free-range turkeys exhibited significantly higher prevalence of nematodes (56.3%) and mixed infections (20.6%) compared to intensively managed birds (25.2% and 2.5%, respectively) ($p < 0.0001$). Seasonal variation was significant, with a higher prevalence during the rainy season (61.8%) compared to the dry season (20.6%) ($p < 0.0001$). Age and sex were also significant factors, with adult and female turkeys having higher rates of helminth infections. This study highlights the substantial burden of gastrointestinal helminths in turkeys, with management systems, season, age, and sex identified as critical risk factors. The findings underscore the need for improved management practices and targeted control measures to mitigate the impact of helminthiasis on turkey health and productivity in the region.

**Keywords**: Gastrointestinal helminths, Infections, Turkeys, Prevalence, Risk factors, Northeastern Nigeria.

## Introduction

Turkey farming plays a vital role in the poultry industry and the broader livestock sector in Nigeria, contributing significantly to the nation's economy [1]. It offers a source of income, employment opportunities, and nutritional value, particularly in rural communities where agriculture remains the mainstay [2]. Turkeys, known for their robust size and meat quality, are increasingly becoming popular in various parts of Nigeria, especially in the northeastern region [3, 4]. This surge in popularity is attributed to the bird's adaptability to different environmental conditions and the growing demand for poultry meat as a high-quality protein source [5, 6, 7]. However, like other poultry species, turkey production faces several challenges, with gastrointestinal helminth infections being a significant concern [8, 9].

Gastrointestinal helminths, including nematodes, cestodes, and trematodes, are a major threat to turkey farming, particularly in regions where biosecurity measures are inadequate [10, 11]. These parasites thrive in environments where sanitary conditions are poor, leading to significant economic losses due to reduced productivity, increased mortality, and the cost of treatment [12, 13]. The burden of these parasites is particularly high in free-range systems where turkeys scavenge for food, exposing them to various intermediate hosts and contaminated environments [14]. In contrast, intensively managed systems, although generally better controlled, are not entirely free from the risk of helminth infections, as poor management practices and environmental contamination can still lead to outbreaks [10].

Nematodes, such as *Ascaridia galli* and *Heterakis gallinarum*, are among the most common gastrointestinal parasites affecting turkeys [15]. These parasites have a direct life cycle, meaning they can infect birds through the ingestion of embryonated eggs from contaminated food, water, or the environment [11, 16]. The presence of *Heterakis gallinarum* is particularly concerning as it can harbor the protozoan *Histomonas meleagridis*, the causative agent of histomoniasis (blackhead disease), a severe condition that can decimate turkey flocks [17, 18]. Cestodes, including *Raillietina* and *Hymenolepis* species, also pose a significant threat, particularly in free-range systems where turkeys have access to intermediate hosts such as insects [10]. These tapeworms can cause a range of health issues in infected birds, including weight loss, decreased egg production, and, in severe cases, death [19, 20].

The impact of gastrointestinal helminths on turkey health is profound, with infections leading to clinical signs such as diarrhea, anemia, weight loss, and reduced growth rates [21]. Infected turkeys are also more susceptible to secondary infections, further complicating their health status and reducing their overall productivity [22]. The economic implications are substantial, as the cost of treatment, coupled with losses in meat production, can severely affect farmers' livelihoods, particularly those operating small-scale and backyard farms.

In Borno State, Northeastern Nigeria, the prevalence of gastrointestinal helminths in turkeys is exacerbated by the region's climatic conditions, which favor the survival and proliferation of these parasites. The hot and humid climate, combined with the seasonal rains, creates an ideal environment for the development of helminth eggs and larvae. Moreover, the widespread practice of free-range farming in this region exposes turkeys to a higher risk of infection, as they are more likely to come into contact with contaminated soil, water, and intermediate hosts.

Despite the importance of turkeys in the local economy and the significant threat posed by gastrointestinal helminths, there is a paucity of data on the prevalence and impact of these parasites in turkeys in Borno State. Most studies on gastrointestinal helminths in Nigeria have focused on chickens, with limited attention given to turkeys, despite their growing significance in the poultry sector. This gap in knowledge hampers the development of effective control and prevention strategies, which are crucial for improving turkey production and ensuring food security in the region.

The current study aims to address this gap by conducting a comparative analysis of gastrointestinal helminth burden in free-range and intensively managed turkeys in Borno State. The study seeks to identify the major helminth species affecting turkeys, assess the epidemiological risk factors associated with helminth infections. By providing baseline epidemiological data, this study will contribute to the development of targeted control strategies, ultimately improving the health and productivity of turkeys in Borno State and beyond.

## Materials and Methods

### Study Area

The research was conducted in Borno State, located in the northeastern region of Nigeria. Geographically, Borno State is positioned between latitudes 10°N and 14°N and longitudes 11°30′E and 14°45′E, covering a land area of approximately 61,435 square kilometers. The state shares borders with Adamawa State to the south, Gombe State to the southwest, and Yobe State to the west. Additionally, Borno State borders three countries: Cameroon to the east, the Republic of Niger to the north, and the Republic of Chad to the northeast, making it unique in Nigeria for its international boundaries with multiple nations [23]. The study area spans five Local Government Areas (LGAs) within Borno State: Maiduguri Metropolitan Council, Jere, Konduga, Bama, and Gwoza.

### Study Design, Population, and Target Population

The study employed a purposive non-probability sampling technique to select turkeys from the five aforementioned LGAs. Sampling was conducted over a 12-month period, from February 2023 to January 2024, covering both the rainy and dry seasons. The study population consisted of 650 turkeys, with approximately 130 turkeys sampled from each LGA. These turkeys were reared under two different management systems: free-range and intensive management.

The turkeys sampled represented both male and female birds and spanned different age groups, ensuring a comprehensive analysis across various demographic factors.

The target population comprised all turkeys within the selected LGAs of Borno State, and the primary focus was on evaluating the gastrointestinal helminth burden in these birds. Before commencing the study, poultry farmers were informed about its significance, especially regarding the implications for turkey health and productivity. Verbal consent was obtained from the farmers to collect samples from their turkeys, ensuring ethical compliance.

**Sample Collection**

Samples were collected from turkeys raised under free-range and intensive management systems across the study area. The gastrointestinal tracts of the turkeys were sampled after humane slaughter at live poultry markets and from necropsies conducted at veterinary hospitals. Fresh visceral organs, including the gastrointestinal tracts, were collected aseptically, placed in polythene bags, and immediately transported in ice-packed boxes to the laboratory for parasitological examination. Detailed records were maintained for each bird, including sex, age, management system, health status, season, and location of sampling.

To prevent cross-contamination of parasites between different sections of the gastrointestinal tract, the tracts were tied off using nylon ligatures at specific anatomical points, as described by previous studies [24]. The gastrointestinal tracts were then dissected longitudinally with sterile scissors, with each section of the tract being carefully separated and stored in physiological saline solution within petri dishes. The sections included the oesophagus, crop, proventriculus, gizzard, duodenum, small intestines, caeca, and rectum.

**Helminth Collection, Processing, and Coproscopical Examination**

In the laboratory, the dissected gastrointestinal tracts were thoroughly examined for the presence of adult helminths and ova. The visible worms were carefully extracted using sterile thumb forceps and preserved accordingly. Nematodes were stored in 70% ethanol, while cestodes were fixed in acetic formalin alcohol, stained with haematoxylin, and mounted in Canada balsam, following standard parasitological techniques [25]. The identification of the recovered helminths was carried out using taxonomic keys and identification guides, as detailed by Bowman [25] and Soulsby [26].

For the detection of helminth ova, faecal samples and intestinal scrapings were subjected to flotation techniques using a saturated salt solution. Microscopic examination was conducted to identify and quantify the helminth ova present in the samples. All the parasitological analyses were performed at the Teaching and Research Laboratory of the Department of Veterinary Medicine, University of Maiduguri, Borno State, Nigeria.

## Statistical Analysis

Data collected during the study were initially entered into Microsoft Excel 2010 for preliminary analysis. The frequency and percentages of the recovered helminths were calculated, providing an overview of the parasitic burden in the sampled turkeys. Further statistical analyses were conducted using GraphPad InStat software to assess the relationships between helminthiasis prevalence and various independent variables, including sex, age, management system, season, and location. The Chi-square test was employed to determine the statistical significance of these associations, with the level of significance set at $p \leq 0.05$. Additionally, the observed prevalence rates were calculated along with their 95% confidence intervals, ensuring robust statistical interpretations of the findings.

## Results

Out of a total of 650 turkeys examined for gastrointestinal helminth infections in Borno State, Nigeria, 436 were found to be infected, resulting in an overall prevalence of 67.1% (95% CI: 63.4–70.6). Nematode infections were detected in 268 birds (41.2%; 95% CI: 37.5–45.1), with *Ascaridia galli* being the most prevalent species (17.7%; 95% CI: 15.0–20.8), followed by *Heterakis gallinarum* (13.1%; 95% CI: 10.7–15.9). Lower prevalences were noted for *Capillaria* spp. (6.8%; 95% CI: 5.1–9.0) and *Strongyloides avium* (3.7%; 95% CI: 2.5–5.4). Cestode infections were present in 93 turkeys (14.3%; 95% CI: 11.8–17.2), with *Raillietina tetragona* (6.8%; 95% CI: 5.1–9.0) being the most frequent, followed by *Choanotaenia infundibulum* (3.8%; 95% CI: 2.6–5.6) and *Davainea proglottina* (2.8%; 95% CI: 1.8–4.3). Mixed infections were detected in 75 turkeys, accounting for 11.5% (95% CI: 9.3–14.2) of the total sample. The most prevalent co-infections involved two different helminth species. The combination of *Heterakis gallinarum* and *Capillaria* species was the most common, occurring in 42 turkeys (6.5%; 95% CI: 4.8–8.6). In contrast, co-infections of *Capillaria* species and *Raillietina tetragona* were observed in 26 turkeys (4.0%; 95% CI: 2.7–5.8). The least frequent mixed infection, involving *Ascaridia galli* and *Capillaria* species, was found in 7 turkeys (1.1%; 95% CI: 0.5–2.2) (Table 1).

**Table 1. Burden of Gastrointestinal Helminths of Turkeys (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths | Number (n = 650) of Turkeys Infected | Prevalence (%) (95% CI) |
|---|---|---|
| Nematodes | 268 | 41.2 (37.5 – 45.1) |
| *Ascaridia galli* | 115 | 17.7 (15.0 – 20.8) |
| *Heterakis gallinarum* | 85 | 13.1 (10.7 – 15.9) |
| *Capillaria* species | 44 | 6.8 (5.1 – 9.0) |
| *Strongyloides avium* | 24 | 3.7 (2.5 – 5.4) |
| Cestodes | 93 | 14.3 (11.8 – 17.2) |
| *Raillietina tetragona* | 44 | 6.8 (5.1 – 9.0) |
| *Choanotaenia infundibulum* | 25 | 3.8 (2.6 – 5.6) |
| *Davainea proglottina* | 18 | 2.8 (1.8 – 4.3) |
| *Subulura brumpti* | 6 | 0.9 (0.4 – 2.0) |
| Mixed infections | 75 | 11.5 (9.3 – 14.2) |
| *Heterakis gallinarum* and *Capillaria* species | 42 | 6.5 (4.8 – 8.6) |
| *Capillaria* species and *Raillietina tetragona* | 26 | 4.0 (2.7 – 5.8) |
| *Ascaridia galli* and *Capillaria* species | 7 | 1.1 (0.5 – 2.2) |
| Overall | 436 | 67.1 (63.4 – 70.6) |

n = number of examined; CI = Confidence interval

Table 2 summarizes the prevalence of gastrointestinal helminth infections in turkeys based on management systems (free-range vs. intensive) in Borno State, Nigeria. Helminth categories include nematodes, cestodes, and mixed infections. In the free-range group (n = 325), 186 turkeys (56.3%) were infected with nematodes (prevalence: 28.6%, 95% CI: 25.3–32.2), significantly higher than the intensive group (n = 325), where 82 turkeys (25.2%) were infected (prevalence: 12.6%, 95% CI: 10.3–15.4). Overall, nematode prevalence was 41.2% (95% CI: 37.5–45.1), with a significant difference between systems ($p < 0.0001$, $\chi 2 = 68.67$). Free-range turkeys had a 1.9 times higher risk of infection, with an odds ratio of 3.97. For cestodes, 61 free-range turkeys (18.8%) were infected (prevalence: 9.4%, 95% CI: 7.4–11.9) compared to 32 (9.8%) in the intensive group (prevalence: 4.9%, 95% CI: 3.5–6.9). The overall prevalence was 14.3% (95% CI: 11.8–17.2), with a significant difference ($p = 0.0012$, $\chi 2 = 10.55$). The relative risk in free-range turkeys was 1.38, with an odds ratio of 2.12. Mixed infections occurred in 67 free-range turkeys (20.6%) with a prevalence of 10.3% (95% CI: 8.2–12.9), compared to 8 (2.5%) in the intensive group (prevalence: 1.2%, 95% CI: 0.6–2.4). The overall prevalence was 11.5% (95% CI: 9.3–14.2), and the difference was statistically significant ($p < 0.0001$, $\chi 2 = 52.47$). Free-range turkeys had nearly 10 times the odds of mixed infections (OR = 10.29).

**Table 2: Prevalence of Gastrointestinal Helminths According to Management System of Turkeys (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths infection | Management System | Number Examined | Number (%) Infected | Prevalence (%; 95% CI) | p - value | χ2 | Relative risk | Odd ratio |
|---|---|---|---|---|---|---|---|---|
| Nematodes | Free range | 325 | 186 (56.3) | 28.6[a] (25.3 – 32.2) | < 0.0001 | 68.67 | 1.907 | 3.965 |
| | Intensive | 325 | 82 (25.2) | 12.6[b] (10.3 – 15.4) | | | | |
| Overall (%; 95% CI) | | | 268 (41.2) | 41.2 (37.5 – 45.1) | | | | |
| Cestodes | Free range | 325 | 61 (18.8) | 9.4[a] (7.4 – 11.9) | 0.0012 | 10.55 | 1.384 | 2.116 |
| | Intensive | 325 | 32 (9.8) | 4.9[b] (3.5 – 6.9) | | | | |
| Overall (%; 95% CI) | | | 93 (14.3) | 14.3 (11.8 – 17.2) | | | | |
| Mixed | Free range | 325 | 67 (20.6) | 10.3[a] (8.2 – 12.9) | <0.0001 | 52.47 | 1.991 | 10.29 |
| | Intensive | 325 | 8 (2.5) | 1.2[b] (0.6 – 2.4) | | | | |
| Overall (%; 95% CI) | | | 75 (11.5) | 11.5 (9.3 – 14.2) | | | | |

[a,b] Different superscripts indicate significant ($p < 0.05$) difference in prevalence; χ2 = Chi-square; CI = Confidence Interval

The prevalence of gastrointestinal helminth infections in turkeys across seasons in Borno State is summarized in Table 3. During the dry season, 67 out of 325 turkeys (20.6%, 95% CI: 10.3–12.9) were infected with nematodes, compared to 201 out of 325 (61.8%, 95% CI: 30.9–34.6) in the rainy season. Overall, the prevalence of nematode infections across both seasons was 41.2% (95% CI: 37.5–45.1). Chi-square analysis ($\chi^2 = 114.0$, $p < 0.0001$) indicates a significant seasonal variation, with a higher prevalence during the rainy season (30.9%) than in the dry season (10.3%). Relative risk (2.310) and odds ratio (6.242) suggest a strong association between seasonality and nematode infection, with increased risk during the rainy season. Cestode infections were also more prevalent in the rainy season (23.4%, 95% CI: 9.4–14.4) than in the dry season (5.2%, 95% CI: 1.6–4.2), with an overall prevalence of 14.3% (95% CI: 11.8–17.2). Chi-square analysis ($\chi^2 = 43.68$, $p < 0.0001$) and a relative risk (1.828) and odds ratio (5.530). Mixed infections showed a similar trend, with 7.1% of turkeys infected in the dry season and 16.0% in the rainy season. The overall prevalence was 11.5% (95% CI: 9.3–14.2), and the seasonal difference was significant ($\chi^2 = 12.68$, $p = 0.0004$), with a relative risk (1.460) and odds ratio (2.501) indicating a higher risk in the rainy season.

**Table 3: Prevalence of Gastrointestinal Helminths According to Season of Turkeys (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths infection | Season | Number Examined | Number (%) Infected | Prevalence (%; 95% CI) | p - value | χ2 | Relative risk | Odd ratio |
|---|---|---|---|---|---|---|---|---|
| Nematodes | Dry | 325 | 67 (20.6) | 10.3[a] (8.2 – 12.9) | <0.0001 | 114.0 | 2.310 | 6.242 |
| | Rainy | 325 | 201 (61.8) | 30.9[b] (27.5 – 34.6) | | | | |
| Overall (%; 95% CI) | | | 268 (41.2) | 41.2 (37.5 – 45.1) | | | | |
| Cestodes | Dry | 325 | 17 (5.2) | 2.6[a] (1.6 – 4.2) | <0.0001 | 43.68 | 1.828 | 5.530 |
| | Rainy | 325 | 76 (23.4) | 11.7[b] (9.4 – 14.4) | | | | |
| Overall (%; 95% CI) | | | 93 (14.3) | 14.3 (11.8 – 17.2) | | | | |
| Mixed | Dry | 325 | 23 (7.1) | 3.5[a] (2.4 – 5.3) | 0.0004 | 12.68 | 1.460 | 2.501 |
| | Rainy | 325 | 52 (16.0) | 8.0[b] (6.2 – 10.3) | | | | |
| Overall (%; 95% CI) | | | 75 (11.5) | 11.5 (9.3 – 14.2) | | | | |

[a,b] Different superscripts indicate significant ($p < 0.05$) difference in prevalence; χ2 = Chi-square; CI = Confidence Interval

Table 4 presents the prevalence of gastrointestinal helminths according to the sex of turkeys in Borno State, Northeastern Nigeria. Nematode infections were observed in 42.1% of female turkeys (141/335; 95% CI: 18.7–25.0) and 40.3% of males (127/315; 95% CI: 16.8–22.8). There was no significant difference in infection rates between sexes ($p = 0.6465$, $\chi^2 = 0.2104$), with a relative risk of 1.036 and an odds ratio of 1.076. Cestode infections were significantly higher in females (17.3%, 58/335; 95% CI: 7.0–11.4) compared to males (11.1%, 35/315; 95% CI: 3.9–7.4), with a significant difference ($p = 0.0240$, $\chi^2 = 5.094$), a relative risk of 1.254, and an odds ratio of 1.675. Mixed infections were also significantly more common in females (14.9%, 50/335; 95% CI: 5.9–10.0) than in males (7.9%, 25/315; 95% CI: 2.6–5.6), with a significant difference ($p = 0.0053$, $\chi^2 = 7.769$), a relative risk of 1.345, and an odds ratio of 2.035. The overall prevalence of nematodes, cestodes, and mixed infections across both sexes were 41.2% (95% CI: 37.5–45.1), 14.3% (95% CI: 11.8–17.2), and 11.5% (95% CI: 9.3–14.2), respectively.

**Table 4: Prevalence of Gastrointestinal Helminths According to Sex of Turkeys (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths infection | Season | Number Examined | Number (%) Infected | Prevalence (%; 95% CI) | p - value | χ2 | Relative risk | Odd ratio |
|---|---|---|---|---|---|---|---|---|
| Nematodes | Female | 335 | 141 (42.1) | 21.7[a] (18.7 – 25.0) | 0.6465 | 0.2104 | 1.036 | 1.076 |
| | Male | 315 | 127 (40.3) | 19.5[a] (16.8 – 22.8) | | | | |
| Overall (%; 95% CI) | | | 268 (41.2) | 41.2 (37.5 – 45.1) | | | | |
| Cestodes | Female | 335 | 58 (17.3) | 8.9[a] (7.0 – 11.4) | 0.0240 | 5.094 | 1.254 | 1.675 |
| | Male | 315 | 35 (11.1) | 5.4[b] (3.9 – 7.4) | | | | |
| Overall (%; 95% CI) | | | 93 (14.3) | 14.3 (11.8 – 17.2) | | | | |
| Mixed | Female | 335 | 50 (14.9) | 7.7[a] (5.9 – 10.0) | 0.0053 | 7.769 | 1.345 | 2.035 |
| | Male | 315 | 25 (7.9) | 3.8[b] (2.6 – 5.6) | | | | |
| Overall (%; 95% CI) | | | 75 (11.5) | 11.5 (9.3 – 14.2) | | | | |

[a,b] Different superscripts indicate significant ($p < 0.05$) difference in prevalence; $\chi^2$ = Chi-square; CI = Confidence Interval

The prevalence of gastrointestinal helminths in turkeys based on age is presented in Table 5. Among 335 juvenile turkeys, 95 (28.4%) were infected with nematodes, with a prevalence of 14.6% (95% CI: 12.1–17.5). In 315 adult turkeys, 173 (54.9%) were infected, showing a significantly higher prevalence of 26.6% (95% CI: 23.4–30.2). The overall nematode prevalence was 41.2% (95% CI: 37.5–45.1). A statistically significant difference was observed between juveniles and adults ($p < 0.0001$, $\chi^2 = 42.27$), with juveniles having a lower risk of infection (RR = 0.5642; OR = 0.3249). Cestode infections were observed in 21 juveniles (6.3%), with a prevalence of 3.2% (95% CI: 2.1–4.9), and in 72 adults (22.9%), with a prevalence of 11.1% (95% CI: 8.9–13.7). The overall prevalence was 14.3% (95% CI: 11.8–17.2). A significant difference was found between the age groups ($p < 0.0001$, $\chi^2 = 36.44$), with juveniles again showing a lower risk (RR = 0.4056; OR = 0.2257). For mixed infections, 24 juveniles (7.2%) had a prevalence of 3.7% (95% CI: 2.5–5.4), while 51 adults (16.2%) had a prevalence of 7.8% (95% CI: 6.0–10.2). The overall prevalence of mixed infections was 11.5% (95% CI: 9.3–14.2), with a significant difference between age groups ($p = 0.0003$, $\chi^2 = 12.96$), indicating juveniles were at lower risk (RR = 0.5916; OR = 0.3995).

**Table 5: Prevalence of Gastrointestinal Helminths According to Age of Turkeys (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths infection | Age | Number Examined | Number (%) Infected | Prevalence (%; 95% CI) | p - value | χ2 | Relative risk | Odd ratio |
|---|---|---|---|---|---|---|---|---|
| Nematodes | Juvenile | 335 | 95 (28.4) | 14.6[a] (12.1 – 17.5) | <0.0001 | 42.27 | 0.5642 | 0.3249 |
| | Adult | 315 | 173 (54.9) | 26.6[b] (23.4 – 30.2) | | | | |
| Overall (%; 95% CI) | | | 268 (41.2) | 41.2 (37.5 – 45.1) | | | | |
| Cestodes | Juvenile | 335 | 21 (6.3) | 3.2[a] (2.1 – 4.9) | <0.0001 | 36.44 | 0.4056 | 0.2257 |
| | Adult | 315 | 72 (22.9) | 11.1[b] (8.9 – 13.7) | | | | |
| Overall (%; 95% CI) | | | 93 (14.3) | 14.3 (11.8 – 17.2) | | | | |
| Mixed | Juvenile | 335 | 24 (7.2) | 3.7[a] (2.5 – 5.4) | 0.0003 | 12.96 | 0.5916 | 0.3995 |
| | Adult | 315 | 51 (16.2) | 7.8[b] (6.0 – 10.2) | | | | |
| Overall (%; 95% CI) | | | 75 (11.5) | 11.5 (9.3 – 14.2) | | | | |

[a,b] Different superscripts indicate significant ($p < 0.05$) difference in prevalence; χ2 = Chi-square; CI = Confidence Interval

Table 6 presents the prevalence of gastrointestinal helminths based on the health status of turkeys in Borno State, Northeastern Nigeria. Among the 285 clinically sick turkeys examined, 152 (53.3%) were infected with nematodes, with a prevalence of 23.4% (95% CI: 20.3–26.8). In contrast, 116 (31.8%) of 365 apparently healthy turkeys were infected, with a lower prevalence of 17.8% (95% CI: 15.1–21.0). Overall, nematode infections were detected in 268 (41.2%) of the 650 turkeys, with an overall prevalence of 41.2% (95% CI: 37.5–45.1). The difference between clinically sick and healthy turkeys was statistically significant ($p < 0.0001$), with a Chi-square value of 30.68. The relative risk for nematode infection in clinically sick birds was 1.629, with an odds ratio of 2.453. For cestode infections, 63 (22.1%) of the clinically sick turkeys were infected, with a prevalence of 9.7% (95% CI: 7.7–12.2), while 30 (8.2%) of the healthy group had a prevalence of 4.6% (95% CI: 3.3–6.5). Overall prevalence was 14.3% (95% CI: 11.8–17.2), affecting 93 of 650 turkeys. The difference between health groups was significant ($p < 0.0001$, $\chi^2 = 25.17$), with clinically sick birds having a 1.700 relative risk and an odds ratio of 3.169. Mixed helminth infections affected 56 (19.6%) of the clinically sick turkeys, with a prevalence of 8.6% (95% CI: 6.7–11.0), compared to 19 (5.2%) of the healthy group, with a prevalence of 2.9% (95% CI: 1.9–4.5). Overall, mixed infections had a prevalence of 11.5% (95% CI: 9.3–14.2), affecting 75 turkeys. The significant difference ($p < 0.0001$) had a $\chi^2$ value of 32.71. Clinically sick turkeys had a 1.875 relative risk and an odds ratio of 4.453 for mixed infections.

**Table 6: Prevalence of Gastrointestinal Helminths According to Health Status of Turkeys (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths infection | Health status | Number Examined | Number (%) Infected | Prevalence (%; 95% CI) | p - value | χ2 | Relative risk | Odd ratio |
|---|---|---|---|---|---|---|---|---|
| Nematodes | Clinically Sick | 285 | 152 (53.3) | 23.4[a] (20.3 – 26.8) | <0.0001 | 30.68 | 1.629 | 2.453 |
| | Apparently Healthy | 365 | 116 (31.8) | 17.8[b] (15.1 – 21.0) | | | | |
| Overall (%; 95% CI) | | | 268 (41.2) | 41.2 (37.5 – 45.1) | | | | |
| Cestodes | Clinically Sick | 285 | 63 (22.1) | 9.7[a] (7.7 – 12.2) | <0.0001 | 25.17 | 1.700 | 3.169 |
| | Apparently Healthy | 365 | 30 (8.2) | 4.6[b] (3.3 – 6.5) | | | | |
| Overall (%; 95% CI) | | | 93 (14.3) | 14.3 (11.8 – 17.2) | | | | |
| Mixed | Clinically Sick | 285 | 56 (19.6) | 8.6[a] (6.7 – 11.0) | <0.0001 | 32.71 | 1.875 | 4.453 |
| | Apparently Healthy | 365 | 19 (5.2) | 2.9[b] (1.9 – 4.5) | | | | |
| Overall (%; 95% CI) | | | 75 (11.5) | 11.5 (9.3 – 14.2) | | | | |

[a,b] Different superscripts indicate significant ($p < 0.05$) difference in prevalence; χ2 = Chi-square; CI = Confidence Interval

Table 7 presents the prevalence of gastrointestinal helminths in turkeys from urban and rural areas of Borno State, Nigeria. In urban areas, 36% (117/325) of turkeys were infected with nematodes, with a prevalence of 18.0% (95% CI: 15.2–21.1). In rural areas, a higher prevalence of 23.2% (151/325) was observed (95% CI: 20.2–26.6), with an overall nematode infection rate of 41.2% (95% CI: 37.5–45.1). A statistically significant difference was noted between urban and rural areas ($p = 0.0067$, $\chi^2 = 7.34$), with the relative risk (RR) of nematode infection being 0.8018 and an odds ratio (OR) of 0.6482, indicating a lower likelihood of infection in urban turkeys. For cestode infections, 11.1% (36/325) of urban turkeys were infected (prevalence: 5.5%, 95% CI: 4.0–7.6), while rural areas recorded 17.5% (57/325) prevalence (8.8%, 95% CI: 6.8–11.2). The overall cestode prevalence was 14.3% (95% CI: 11.8–17.2), with a statistically significant difference ($p = 0.0187$, $\chi^2 = 5.53$). The RR of infection was 0.7461, and the OR was 0.5857, indicating a lower risk of cestode infection in urban turkeys. Mixed infections were observed in 7.4% (24/325) of urban turkeys (prevalence: 3.7%, 95% CI: 2.5–5.4), compared to 15.7% (51/325) in rural areas (prevalence: 7.8%, 95% CI: 6.0–10.2). The overall prevalence of mixed infections was 11.5% (95% CI: 9.3–14.2), with a significant difference between urban and rural areas ($p = 0.0009$, $\chi^2 = 10.99$). The RR for mixed infections was 0.6113, and the OR was 0.4284, reflecting a much lower risk of mixed infections in urban turkeys.

**Table 7: Prevalence of Gastrointestinal Helminths According to Study Location (n = 650) in Borno State, Northeastern Nigeria**

| Gastrointestinal Helminths infection | Study location | Number Examined | Number (%) Infected | Prevalence (%; 95% CI) | p - value | χ2 | Relative risk | Odd ratio |
|---|---|---|---|---|---|---|---|---|
| Nematodes | Urban | 325 | 117 (36.0) | 18.0[a] (15.2 – 21.1) | 0.0067 | 7.340 | 0.8018 | 0.6482 |
| | Rural | 325 | 151 (46.5) | 23.2[b] (20.2 – 26.6) | | | | |
| Overall (%; 95% CI) | | | 268 (41.2) | 41.2 (37.5 – 45.1) | | | | |
| Cestodes | Urban | 325 | 36 (11.1) | 5.5[a] (4.0 – 7.6) | 0.0187 | 5.534 | 0.7461 | 0.5857 |
| | Rural | 325 | 57 (17.5) | 8.8[b] (6.8 – 11.2) | | | | |
| Overall (%; 95% CI) | | | 93 (14.3) | 14.3 (11.8 – 17.2) | | | | |
| Mixed | Urban | 325 | 24 (7.4) | 3.7[a] (2.5 – 5.4) | 0.0009 | 10.99 | 0.6113 | 0.4284 |
| | Rural | 325 | 51 (15.7) | 7.8[b] (6.0 – 10.2) | | | | |
| Overall (%; 95% CI) | | | 75 (11.5) | 11.5 (9.3 – 14.2) | | | | |

[a,b] Different superscripts indicate significant ($p < 0.05$) difference in prevalence; $\chi^2$ = Chi-square; CI = Confidence Interval

## Discussion

This study presents the first comprehensive investigation into the prevalence and risk factors of gastrointestinal helminth infections in turkeys in Borno State, Northeastern Nigeria. The overall prevalence of gastrointestinal helminths was found to be 67.1%, with nematode infections accounting for 41.2%, cestodes for 14.3%, and mixed infections for 11.5%. These findings highlight a considerable helminth burden in turkeys within the study area, suggesting potential adverse effects on their health and productivity. The results concurs with previous studies that have consistently reported a high prevalence of gastrointestinal helminths in poultry, particularly in areas where free-range rearing systems are predominant [8, 27].

Comparatively, previous studies in Nigeria have documented prevalence rates of gastrointestinal helminths in turkeys ranging from 47.8% in Ilorin, Kwara State [11], to as high as 95.0% in Abuja, the Federal Capital Territory [28]. Similarly, prevalence rates from other countries have reported comparable results, such as 75.0% in Amol, Iran [29], and 74.0% in Dhaka, Bangladesh [30].

In the present study, a total of eight gastrointestinal helminth species were identified in poultry, comprising four nematode species and four cestode species. Among the nematodes, *Ascaridia galli* was the most predominant, which supports the findings of Jegede *et al*. [28] and Udoh *et al*. [31] in turkeys. Similarly, *Ascaridia galli* has been reported as the most common helminth species in studies involving other poultry species conducted in similar climatic regions by Jajere *et al*. [10] and Inuwa *et al*. [32].

Contrary to our findings, Udoh *et al*. [31] identified nine species, while Jegede *et al*. [28] reported 12 species. In contrast, Ola-Fadunsin *et al*. [11] recorded only four species, Mohammad *et al*. [33] reported one species, and Nipu [30] found two species, each with varying prevalence rates and species composition compared to our study. Additionally, Dauda *et al*. [22] documented seven nematode species, which is higher than the four species reported in the present study.

The present study also reveals a significant prevalence of *Heterakis gallinarum* and *Capillaria* species in turkeys in Borno State, this signifies an important implications for turkey health and poultry production in the region. These findings are consistent with previous studies by Udoh *et al*. [31] in Kaduna State, Dauda *et al*. [22] in Plateau State, Nipu [30] in Bangladesh, Ola-Fadunsin *et al*. [11] in Kwara State, Jegede *et al*. [28] in Abuja, and Inuwa *et al*. [32] in Taraba State, who have all reported similar helminth infections in turkeys and chickens.The management practices in the area may contribute to the increased risk of infection.

The detection of *Heterakis gallinarum* in 13.1% of the turkeys is particularly concerning due to its established role as a vector for *Histomonas meleagridis*, the causative agent of blackhead disease (histomoniasis). *Heterakis gallinarum* facilitates the transmission of *H. meleagridis* by harboring the protozoan in its eggs, which turkeys ingest through contaminated feed, water, or soil. Blackhead disease primarily affects the liver and ceca, leading to necrotic lesions, reduced feed efficiency, weight loss, and higher mortality, especially in young turkeys [17, 18]. The moderate prevalence of *H. gallinarum* in this study suggests that turkeys in the region are at considerable risk of histomoniasis, potentially jeopardizing flock health and productivity. Effective control measures, such as improved sanitation, rotational grazing, and regular deworming, are crucial to mitigate this risk and limit the spread of blackhead disease.

Moreover, the identification of *Capillaria* species in the examined turkeys is another significant finding. These threadworms primarily infect the crop, esophagus, and intestines, causing chronic wasting, diarrhea, and malabsorption. Infected birds often show poor growth and reduced egg production, and in severe cases with heavy worm burdens, morbidity and mortality can occur [10]. Although *Capillaria* infections were less prevalent than *Heterakis gallinarum*, their impact on turkey health should not be overlooked. The parasite's ability to cause inflammation and damage to the intestinal lining disrupts nutrient absorption, leading to suboptimal weight gain and performance, particularly in commercial and backyard poultry systems where economic viability relies on productivity [32]. Controlling *Capillaria* infections requires targeted anthelmintic treatments and enhanced biosecurity measures to prevent and manage infestations.

Nematodes are recognized as the most significant group of helminth parasites in poultry, both in terms of the number of species and the damage they cause. This is particularly evident with genera such as *Ascaridia*, *Heterakis*, and *Capillaria*, which have been extensively documented as the major nematode parasites [32, 34, 35]. The high prevalence of nematode infections in poultry can largely be attributed to their life cycle, which does not rely on intermediate hosts. These parasites are directly transmitted when birds ingest helminth eggs from contaminated environments. The ability of adult nematodes to lay numerous eggs daily, which remain viable in the soil for up to twelve months, exacerbates the situation. Free-range and scavenging birds are particularly vulnerable, as they continuously ingest viable eggs from contaminated droppings in the soil while foraging, resulting in heavy parasitic burdens [8, 36].

The present study identifies a prevalence of cestode infections in turkeys, with an overall rate of 14.3%, highlighting the importance of gastrointestinal helminth parasitism in the sampled turkey population. Cestode infections, though less prevalent than nematode infections in the turkeys examined in this study, were still significant, with *Raillietina tetragona* being the most commonly identified species. The overall prevalence of 14.3% aligns with previous reports documenting a moderate occurrence of cestodes in poultry, particularly in regions with abundant intermediate hosts such as beetles and ants. This finding corroborates the results of Jegede *et al*. [28], who also identified *Raillietina* species in turkeys in a similar study. Additionally, the present study supports the work of Udoh *et al*. [31], who reported the presence of *Raillietina cesticillus* in infected turkeys. Other researchers, such as RanjbarBahadory *et al*. [29], have reported *Raillietina tetragona* and *Raillietina echinobothrida* in native turkeys, while Inuwa *et al*. [32] documented *Raillietina tetragona* as the most prevalent cestode species in chickens. Jajere *et al*. [10] further recorded the presence of *Raillietina tetragona*, *Raillietina echinobothrida*, *Raillietina cesticillus*, and *Raillietina magninumida* in guinea fowl.

The prevalence of cestode infections observed in this study may be partly attributed to the common practice of mixed poultry farming in the region, where households frequently rear turkeys, chickens, and guinea fowl together. This co-habitation could facilitate the transmission of cestode infections among different poultry specie [37].

The present study identified a significant prevalence of mixed helminth infections (11.5%) in turkeys, aligning with previous reports by Jegede *et al*. [28] and Udoh *et al*. [31], who documented multiple helminth species co-infecting turkeys. Although these earlier studies reported higher prevalence of multiple infections than single infections, the current study observed only double helminth infections. This co-infection pattern emphasizes the potential health risks to turkeys, as multiple helminth species may lead to more severe clinical outcomes compared to single-species infections. Mixed infections, common in free-range systems across sub-Saharan Africa, have been reported with prevalence rates of 8–15% [38, 39], suggesting similar environmental and management factors, such as exposure to contaminated environments, play a role. Notably, the interaction between helminths like *Heterakis gallinarum* and *Capillaria* spp. may exacerbate pathogenicity, increasing stress on the host's immune system, impairing nutrient absorption, and reducing body weight gain [30, 40].

The recovery of co-infections involving nematodes (*Capillaria* spp.) and cestodes (*Raillietina* spp.) highlights their detrimental effect on turkey health, as these parasites compete for nutrients and damage the intestinal lining, leading to malnutrition, suboptimal growth, and reduced productivity. In addition, co-infection with *Ascaridia galli* and *Capillaria* spp. may further compromise the immune response, making turkeys more susceptible to secondary infections. Chronic gastrointestinal disturbances caused by these helminths can pose long-term health challenges and result in economic losses for poultry farmers due to poor flock performance and reduced carcass quality. Thus, the findings emphasize the need for effective parasite control measures to mitigate these health risks in turkeys.

This study reveals significant differences in the prevalence of gastrointestinal helminths between free-range and intensively managed turkeys. Nematode infections were notably higher in free-range systems ($p < 0.0001$), likely due to increased exposure to contaminated environments. This finding is consistent with reports by Jajere *et al*. [10], Ola-Fadunsin *et al*. [11] and Jegede *et al*. [28], which similarly highlighted a greater helminth prevalence in extensively managed birds. Free-range systems, with less biosecurity, expose turkeys to infective larvae, while intensive systems mitigate this risk through controlled environments. The relative risk (RR = 1.907) and odds ratio (OR = 3.965) indicate free-range turkeys are almost twice as likely to contract nematode infections.

Cestode infections also showed higher prevalence in free-range turkeys, with significant differences compared to intensive systems. The relative risk (RR = 1.384) and odds ratio (OR = 2.116) suggest greater susceptibility due to exposure to intermediate hosts like insects, a risk minimized in intensive systems with better biosecurity. This aligns with findings by Lawal *et al*. [37], who documented higher gastrointestinal cestode prevalence in extensively reared birds.

Mixed helminth infections were significantly more common in free-range turkeys ($p < 0.0001$), with an odds ratio of 10.29, suggesting that free-range birds are more prone to multiple infections due to their interactions with various contamination sources [11, 41]. Intensive systems reduce this risk by limiting scavenging and exposure to infected substrates [14, 42].

The study also highlights significant seasonal variation in helminth infections, with higher nematode prevalence during the rainy season ($p < 0.0001$). This increase is likely due to favorable environmental conditions for nematode transmission, such as moisture and humidity, which enhance larval survival [43, 44]. The significant relative risk (RR = 2.310) and odds ratio (OR = 6.242) further underscore the heightened infection risk during the rainy season.

Similarly, cestode infections were more prevalent in the rainy season, likely due to an increase in intermediate hosts like insects, which thrive in moist conditions. In contrast, during the dry season, high temperatures and reduced humidity limit helminth development and transmission. The significant relative risk (RR = 1.460) and odds ratio (OR = 2.501) for mixed infections during the rainy season suggest co-infections are more common when environmental conditions favor both nematodes and cestodes.

The study found higher infection rates in female turkeys across all helminth groups, particularly cestodes, with a relative risk (RR = 1.254) and odds ratio (OR = 1.675) indicating females were more susceptible, potentially due to physiological stress associated with egg-laying, which weakens immune defenses [11, 45]. This finding contrasts with earlier reports of higher male susceptibility [22, 31, 46].

Age-related differences were also evident, with adult turkeys showing significantly higher prevalence of helminths compared to juveniles ($p < 0.05$). This may be due to prolonged exposure to contaminated environments, increasing their chances of ingesting infective stages [37]. Adults also foraged more widely, encountering intermediate hosts that spread cestodes. This trend held true for mixed infections as well, with adults more likely to have co-infections, possibly due to cumulative exposure over time.

Clinically sick turkeys had significantly higher helminth prevalence than apparently healthy ones, particularly for nematodes ($p < 0.0001$). The immunosuppressive effects of illness likely made these birds more susceptible [37, 47]. The relative risk (RR = 1.629) and odds ratio (OR = 2.453) for nematodes, along with similar findings for cestodes and mixed infections, emphasize the vulnerability of sick turkeys to parasitic infections, potentially due to weakened immune systems.

Finally, the study revealed higher helminth prevalence in rural turkeys compared to urban birds. This difference is likely due to poorer husbandry practices, biosecurity, and sanitation in rural areas, where turkeys are more likely to scavenge and encounter helminths in contaminated soil and water [10, 48]. Improved management in urban areas reduces but does not eliminate the risk of infection, as helminths remain a challenge even in controlled environments

## Conclusion

This study comprehensively assessed the prevalence and risk factors of gastrointestinal helminth infections in turkeys in Borno State, Nigeria, revealing a high overall prevalence of 67.1%. Nematodes were the most common helminths (41.2%), dominated by *Ascaridia galli* (17.7%) and *Heterakis gallinarum* (13.1%), followed by cestodes (14.3%) and mixed infections (11.5%). These findings indicate a substantial burden of helminthiasis among turkeys in the region, with significant variations influenced by management systems, seasons, sex, age, and health status. Free-range turkeys exhibited significantly higher infection rates across all helminth categories compared to their intensively managed counterparts. For nematodes, the prevalence in free-range turkeys was nearly double that of intensive systems, with a relative risk of 1.9 and odds ratio of 3.97. Similarly, cestode and mixed infections were markedly higher in free-range birds, emphasizing the vulnerability associated with this management system. Seasonality profoundly influenced helminth prevalence, with rainy-season infections significantly surpassing those in the dry season. Nematode prevalence was threefold higher during the rainy season, while cestode and mixed infections also showed marked increases. The relative risk and odds ratios highlighted the substantial seasonal impact on helminth transmission dynamics. Sex-based analysis indicated higher prevalences of cestode and mixed infections in female turkeys compared to males, though nematode prevalence was comparable between sexes. This suggests potential biological or behavioral factors predisposing females to increased infection risks. Age and health status were critical determinants of helminth burden. Adult turkeys had significantly higher prevalences across all helminth categories than juveniles, with nematode prevalence almost doubling in adults. Clinically sick turkeys were also more likely to harbor infections than apparently healthy birds, underlining the association between compromised health and increased susceptibility to gastrointestinal helminths. The study revealed a significantly higher prevalence of gastrointestinal helminth infections in rural turkeys compared to urban turkeys, with rural areas showing higher rates of nematode, cestode, and mixed infections.

## Recommendations

The findings of the present study highlight the need for targeted interventions to mitigate helminth infections in turkeys within the study area and its environs. Accordingly, the following recommendations are made:

1. Improved Management Practices

   The significantly higher prevalence of gastrointestinal helminth infections in free-range turkeys compared to those in intensive systems underscores the need for improved management practices, particularly in free-range systems. It is recommended that free-range turkey farmers adopt semi-intensive or intensive rearing systems where feasible to limit exposure to infective stages of helminths in the environment. Implementing regular deworming schedules and rotational grazing to minimize pasture contamination can further reduce infection rates. Additionally, providing access to clean water and hygienic feeding practices is essential to mitigate the risk of infection.

2. Targeted Seasonal Control Measures
   The study revealed a higher prevalence of helminth infections during the rainy season compared to the dry season, suggesting that seasonal factors play a critical role in the epidemiology of these infections. Seasonal deworming programs timed before the onset of the rainy season should be prioritized to preemptively control parasite burdens. Farmers should also be encouraged to improve housing structures and drainage systems during the rainy season to minimize exposure to wet and contaminated environments that favor the survival and transmission of helminth eggs and larvae.

3. Focused Interventions Based on Age and Health Status
   Given the significantly higher prevalence of helminth infections in adult and clinically sick turkeys, routine health checks and targeted deworming for these groups are recommended. Juvenile turkeys, while having lower infection rates, should not be overlooked; preventive measures, including early deworming and vaccination programs, can reduce susceptibility to infections as they age. Additionally, education and outreach programs for farmers on recognizing signs of infection and implementing biosecurity measures can help improve the overall health and productivity of turkey flocks.

**Acknowledgment**
The authors extend their heartfelt gratitude to the turkey owners for their invaluable cooperation throughout the sample collection process. We also wish to express our sincere appreciation to the technical staff of the Department of Veterinary Medicine Research Laboratories, Faculty of Veterinary Medicine, for their unwavering support and expertise during the sample analysis. Their dedication greatly contributed to the success of this research.

## References

1. Oyeagu, C. E., Iwuchukwu, J. C., Falowo, A. B., Akuru, E. A., Adetunji, A. T., Lewu, F. B., Yiseyon, S. H. and Idamokoro, E. M. (2022). Assessment of turkey farming management practices by small-scale rural farmers in Eastern Nigeria. *Asian Journal of Agriculture and Rural Development*, 12(1): 30-39. doi: 10.55493/5005.v12i1.4428.
2. Anosike, F. U., Rekwot, G. Z., Owoshagba, O. B., Ahmed, S. and Atiku, J. A. (2018). Challenges of poultry production in Nigeria: A review. *Nigerian Journal of Animal Production*, 45(1): 252-258.
3. Okoroafor, O. N., Ezema, W. S., Animoke, P. C., Okosi, R. I., Nwanta, J. A., Anene, B. M., Okoye, J. O. A. and Ani, A. O. (2020). Constraints and prospects of turkey production in Enugu State, South-eastern Nigeria. *Nigerian Journal of Animal Production*, 47(5): 142-155.
4. Dotché, I. O., Agbokounou, A., Baba, L., Adebo, N., Okambawa, L., Koffi, M. and Youssao Abdou Karim, I. (2024). Constraints to the development of turkey farming in southern Benin. *World Veterinary Journal*, 14(1): 38-52. DOI: https://dx.doi.org/10.54203/scil.2024.wvj6.
5.Ngu, G. T., Butswat, I. S. R., Mah, G. D. and Ngantu, H. N. (2014). Characterization of small-scale backyard turkey (*Meleagris gallopavo*) production system in Bauchi State-Nigeria and its role in poverty alleviation. *Livestock Research for Rural Development*, 26(1): Article #19. Retrieved September 20, 2024, from http://www.lrrd.org/lrrd26/1/ngu26019.html.
6. Dal Bosco, A., Mattioli, S., Cartoni Mancinelli, A., Cotozzolo, E. and Castellini, C. (2021). Extensive rearing systems in poultry production: The right chicken for the right farming system. A review of twenty years of scientific research in Perugia University, Italy. *Animals (Basel)*, 11(5): 1281. doi: 10.3390/ani11051281.
7. Choi, J., Kong, B., Bowker, B. C., Zhuang, H. and Kim, W. K. (2023). Nutritional strategies to improve meat quality and composition in the challenging conditions of broiler production: A review. *Animals (Basel)*, 13(8): 1386. doi: 10.3390/ani13081386.
8. Shifaw, A., Feyera, T., Walkden-Brown, S.W., Sharpe, B., Elliott, T. and Ruhnke, I. (2021). Global and regional prevalence of helminth infection in chickens over time: a systematic review and meta-analysis. *Poultry Science*, 100(5): 101082. doi: 10.1016/j.psj.2021.101082.
9. Yazwinski, T. A., Höglund, J., Permin, A., Gauly, M. and Tucker, C. (2022). World association for the advancement of veterinary parasitology (WAAVP): Second edition of guidelines for evaluating the efficacy of anthelmintics in poultry. *Veterinary Parasitology*, 305, 109711. doi: 10.1016/j.vetpar.2022.109711.
10. Jajere, S. M., Lawal, J. R., Atsanda, N. N., Hamisu, T. M. and Goni, M. D. (2018). Prevalence and burden of gastrointestinal helminths among grey-breasted helmet guinea fowls (*Numida meleagris galeata*) encountered in Gombe State, Nigeria. *International Journal of Veterinary Science and Medicine*, 6(1): 73-79. doi: 10.1016/j.ijvsm.2018.04.007.

11. Ola-Fadunsin, S. D., Ganiyu, I. A., Rabiu, M., Hussain, K., Sanda, I. M., Musa, S. A., Uwabujo, P. I. and Furo, N. A. (2019a). Gastrointestinal parasites of different avian species in Ilorin, North Central Nigeria. *Journal of Advanced Veterinary and Animal Research*, 6(1): 108-116. doi: 10.5455/javar.2019.f320.
12. Hamid, L., Alsayari, A., Tak, H., Mir, S. A., Almoyad, M. A. A., Wahab, S. and Bader, G. N. (2023). An insight into the global problem of gastrointestinal helminth infections amongst livestock: Does nanotechnology provide an alternative? *Agriculture*, 13(7): 1359. https://doi.org/10.3390/agriculture13071359.
13. Serbessa, T. A., Geleta, Y. G. and Terfa, I. O. (2023). Review on diseases and health management of poultry and swine. *International Journal of Avian and Wildlife Biology*, 7(1): 27-38. doi: 10.15406/ijawb.2023.07.00187.
14. Nemathaga, M., Smith, R. M. and Malatji, D. P. (2023). Interactions between the helminth and intestinal microbiome in smallholder chicken farming systems. *Frontiers in Veterinary Science*, 10, 1309151. doi: 10.3389/fvets.2023.1309151.
15. Sharma, N., Hunt, P. W., Hine, B. C. and Ruhnke, I. (2019). The impacts of *Ascaridia galli* on performance, health, and immune responses of laying hens: new insights into an old problem. *Poultry Science*, 98(12): 6517-6526. doi: 10.3382/ps/pez422.
16. Höglund, J., Daş, G., Tarbiat, B., Geldhof, P., Jansson, D. S. and Gauly, M. (2023). *Ascaridia galli* – An old problem that requires new solutions. *International Journal for Parasitology: Drugs and Drug Resistance*, 23, 1-9. https://doi.org/10.1016/j.ijpddr.2023.07.003.
17. Daş, G.,Wachter, L., Stehr, M., Bilic, I., Grafl, B., Wernsdorf, P., Metges, C. C., Hess, M. and Liebhart, D. (2021). Excretion of *Histomonas meleagridis* following experimental co-infection of distinct chicken lines with *Heterakis gallinarum* and *Ascaridia galli* *Parasites and Vectors*, 14(1): 323. doi: 10.1186/s13071-021-04823-1.
18. Beer, L. C., Petrone-Garcia, V. M., Graham, B. D., Hargis, B. M., Tellez-Isaias, G. and Vuong, C. N. (2022). Histomonosis in poultry: A comprehensive review. *Frontiers in Veterinary Science*, 9,880738. doi: 10.3389/fvets.2022.880738.
19. Sapp, S. G. H. and Bradbury, R. S. (2020). The forgotten exotic tapeworms: a review of uncommon zoonotic Cyclophyllidea. *Parasitology*, 147(5): 533-558. doi: 10.1017/S003118202000013X.
20. Esteban-Sánchez, L., García-Rodríguez, J. J., García-García, J., Martínez-Nevado, E., de la Riva-Fraga, M. A. and Ponce-Gordo, F. (2024). Wild animals in captivity: An analysis of parasite biodiversity and transmission among animals at two zoological institutions with different typologies. *Animals (Basel)*, 14(5): 813. https://doi.org/10.3390/ani14050813.
21. Ola-Fadunsin, S. D., Uwabujo, P. I., Sanda, I. M., Ganiyu, I. A., Hussain, K., Rabiu, M., Elelu, N. and Alayande, M. O. (2019b). Gastrointestinal helminths of intensively managed poultry in Kwara Central, Kwara State, Nigeria: Its diversity, prevalence, intensity, and risk factors. *Veterinary World*, 12(3): 389-396. doi: 10.14202/vetworld.2019.389-396.

22. Dauda, J., Lawal, J. R., Bello, A. M., Mustapha, M., Ndahi, J. J. and Biu, A. A. (2016). Survey on prevalence of gastrointestinal nematodes and associated risk factors in domestic turkeys (*Meleagris gallopavo*) slaughtered in poultry markets in Bukuru – Jos, Plateau State, Nigeria. *International Journal of Innovative Agriculture and Biology Research*, 4(4): 27-36.
23. Maimadu, A. A., Ogbu, K. I., Olabode, M. P., Waziri, I. A., Salami, C. A. and Ochai, S. O. (2018). The prevalence of human African trypanosomosis in Maiduguri, Nigeria. *IOSR Journal of Agriculture and Veterinary Science*, 11(4 Ver. I): 60-63.
24. Nalubamba, K. S., Bwalya, E. C., Mudenda, N. B., Munangandu, H. M., Munyeme, M. and Squarre, D. (2015). Prevalence and burden of gastrointestinal helminths in wild and domestic guinea fowls (*Numida meleagris*) in the Southern Province of Zambia. *Asian Pacific Journal of Tropical Biomedicine*, 5(8): 663-670. doi: 10.1016/j.apjtb.2015.04.009.
25. Bowman, D. D. (2009). *Georgis' Parasitology for Veterinarians* (9th ed.). Saunders Elsevier, St. Louis, USA, pp. 451.
26. Soulsby, E. J. L. (1982). Helminths, Arthropods, and Protozoa of Domestic Animals (7th ed.). Bailliere and Tindall, London; UK, 3–115.
27. Afia, U. U., Usip, L. P. and Udoaka, U. E. (2019). Prevalence of Gastro-Intestinal Helminths in Local and Broiler Chickens in Ibesikpo Local Government Area, Akwa Ibom State, Nigeria. *American Journal of Zoological Research*, 7(1): 1-7. doi: 10.12691/ajzr-7-1-1.
28. Jegede, O. C., Adetiba R. O., Kawe, S. M., Opara, M. N., Mohammed, B. R., Obeta, S. S. and Olayemi, O. D. (2019). Gastrointestinal Parasites of Local and Exotic Breeds of Turkeys (*Meleagris gallopavo*) In Gwagwalada Area Council, Abuja, Federal Capital Territory, Nigeria. *Journal of Veterinary and Biomedical Sciences*, 2 (1): 247-256
29. RanjbarBahadory, Sh., Hoghoghi Rad, N., Ramezani, A., Babazadeh, D., Falah, S. and Ghavami, S. (2014). Evaluation of Gastrointestinal Helminths of Native Turkeys in Amol, Iran. *Journal of World's Poultry Research*, 4(4): 86-88.
30. Nipu, N. J. (2019). Prevalence of gastrointestinal helminths of turkeys in wet markets of Dhaka City. A thesis submitted to the Department of Microbiology and Parasitology, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of Master of Science (M.S) in Parasitology, 1-43.
31. Udoh, N. A., Luka, S. A. and Audu, P. A (2014). Prevalence of Gastrointestinal Parasites of Domestic Turkey (*Meleagris gallopavo*) Linnaeus, (1758) Slaughtered in Kaduna Metropolis, Kaduna State, Nigeria. *Journal of Natural Sciences Research,* 4(17): 105-109
32. Inuwa, B., Musa, I. M., Konto, M. and Balami, P. U. (2021). Prevalence of gastrointestinal helminth parasites of local chickens slaughtered at Jalingo Market, Taraba State, Nigeria. *Nigerian Veterinary Journal*, 42(2): 161-170.
33. Mohammad, Z. Z., Suhaila, A. H., NIK, A. I., Izzauddin, N. H. and Khadijah, S. (2017). Parasites prevalence in poultry: Focusing on free range turkeys (*Meleagris gallopavo*). *Malaysian Journal of Veterinary Research*, 8(1): 1-9.

34. Permin, A., Bisgaard, M., Frandsen, F., Pearman, M., Kold, J. and Nansen, P. (1999). Prevalence of gastrointestinal helminthes in different poultry production systems. *British Poultry Science*, 40(4): 439-443.
35. Permin, A. and Hanson, J. W. (1998). Epidemiology,diagnosis and control of poultry parasites. *FAO Animal Health Manuals*, 144 pp. FAO, Rome, Italy.
36. Permin, A. and Ranvig, H. (2001). Genetic resistance in relation to *Ascaridia galli* in chickens. *Veterinary Parasitology*, 102(1-2): 101-111.
37. Lawal, J. R., Jajere, S. M., Ibrahim, U. I., Biu, A. A., and Jonathan, D. (2023). Epidemiology of gastrointestinal helminths among chickens (*Gallus domesticus*) from Borno State, Northeastern Nigeria: prevalence, helminth burden and associated risk factors. *Revue d'elevage et de Medecine Veterinaire des pays Tropicaux*, 76, 37127. doi: 10.19182/remvt.37127.
38. Chilinda, I., Lungu, J. C. N., Phiri, I. K., Chibinga, O. C. and Simbaya, J. (2020). Prevalence of helminth infestation in indigenous free-ranging chickens in different ecological zones in Zambia. *Livestock Research for Rural Development*, 32(9): 1-7.
39. Mlondo, S., Tembe, D., Malatji, M. P., Khumalo, Z. T. H. and Mukaratirwa, S. (2022). Molecular identification of helminth parasites of the Heterakidae and Ascarididae families of free-ranging chickens from selected rural communities of KwaZulu-Natal province of South Africa. *Poultry Science*, 101(8): 101979. doi: 10.1016/j.psj.2022.101979.
40. Maizels, R. M., Smits, H. H. and McSorley, H. J. (2018). Modulation of host immunity by helminths: The expanding repertoire of parasite effector molecules. *Immunity*, 49(5): 801-818. doi: 10.1016/j.immuni.2018.10.016.
41. Wamboi, P., Waruiru, R. M., Mbuthia, P. G., Nguhiu, J. M. and Bebora, L. C. (2020). Haemato-biochemical changes and prevalence of parasitic infections of indigenous chicken sold in markets of Kiambu County, Kenya. *International Journal of Veterinary Science and Medicine*, 8(1): 18-25. doi: 10.1080/23144599.2019.1708577.

42. Montes-Vergara, D. E., Cardona-Alvarez, J. and Pérez-Cordero, A. (2021). Prevalence of gastrointestinal parasites in three groups of domestic poultry managed under the backyard system in the Savanna subregion, Department of Sucre, Colombia. *Journal of Advanced Veterinary and Animal Research*, 8(4): 606-611. doi: 10.5455/javar.2021.h551.
43. Singh, M., Kaur, P., Singla, L.D., Kashyap, N. and Bal, M.S. (2021). Assessment of risk factors associated with prevalence of gastrointestinal parasites in poultry of central plain zone of Punjab, India. *Veterinary World*, 14(4): 972-977. doi: 10.14202/vetworld.2021.972-977.
44. Makalo, M. J. R., Mtshali, K., Tsotetsi-Khambule, A. M., Mofokeng, L. S., Taioe, M. O., Onyiche, T. E. and Thekisoe, O. M. M. (2022). First report of gastrointestinal nematodes and coccidia parasites from free-range chickens in Mafeteng district, Lesotho. *Veterinary Parasitology: Regional Studies and Reports*, 36, 100798. doi: 10.1016/j.vprsr.2022.100798.

45. Shohana, N. N., Rony, S. A., Ali, M. H., Hossain, M. S., Labony, S. S., Dey, A. R., Farjana, T., Alam, M. Z. and Alim, M. A. (2023). *Ascaridia galli* infection in chicken: Pathobiology and immunological orchestra. *Immunity, Inflammation and Disease*, 11(9): e1001. doi: 10.1002/iid3.1001.
46. Isaiah, B. N., Ibrahim, B., Musa, F. M., Ishaya, A. K., Solomon, B. and Ifeamaechi, N. Z. (2024). The prevalence of endoparasites of local and exotic breeds of domesticated chickens (*Gallus gallus domesticus*) within Kaduna Metropolis. *International Journal of Emerging Multidisciplinaries: Biomedical and Clinical Research*, 2(1): 1-9. https://doi.org/10.54938/ijemdbmcr.2024.02.1.246
47. Zloch, A., Kuchling, S., Hess, M. and Hess, C. (2021). In addition to birds' age and outdoor access, the detection method is of high importance to determine the prevalence of gastrointestinal helminths in laying hens kept in alternative husbandry systems. *Veterinary Parasitology*, 299, 109559. doi: 10.1016/j.vetpar.2021.109559
48. Idika, I. K., Obi, C. F., Ezeh, I. O., Iheagwam, C. N., Njoku, I. N. and Nwosu, C. O. (2016). Gastrointestinal helminth parasites of local chickens from selected communities in Nsukka region of southeastern Nigeria. *Journal of Parasitic Diseases*, 40(4): 1376-1380. doi: 10.1007/s12639-015-0694-9.