



Research Article

Microscopy-Based Detection and Characterization of *Eimeria* Oocyst Shedding in Chickens (*Gallus domesticus*) across Diverse Poultry Production Systems in Yobe State, Nigeria

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Coccidiosis caused by *Eimeria* spp. remains a major constraint to poultry production worldwide, yet epidemiological data from northeastern Nigeria remain scarce. This study investigated the prevalence, intensity, and species composition of *Eimeria* oocyst shedding in chickens across different production systems in Yobe State, Nigeria, between September 2022 and October 2023. A total of 1,400 fecal and intestinal content samples were collected from backyard flocks, commercial farms, and live-bird markets in four Local Government Areas (Damaturu, Fika, Fune, and Potiskum) and were examined using flotation and McMaster techniques. Microscopic examination revealed an overall prevalence of 37.2% (95% CI: 34.7–39.8) with most infections of low to moderate intensity, although a smaller proportion of birds carried heavy oocyst burdens. Seasonal variation was evident, with higher ($p < 0.0001$) prevalence and shedding during the rainy (22.7%) season compared to the dry (14.5%) season. Infection distribution varied across locations, with Potiskum (10.4%) recording the highest prevalence while Fika had the lowest infection rate (8.2%). Infection rates also differed ($p = 0.0003$) across production settings, with birds sampled from live-bird markets (43.3%) and backyard (37.9%) flocks carrying heavier burdens than those from commercial farms (30.4%). Younger chickens ($p < 0.0001$) were more frequently infected than adults, while sex had no ($p = 0.2213$) significant effect. Morphological characterization identified five *Eimeria* species, with *E. tenella* and *E. acervulina* predominating, often occurring in mixed infections. These findings provide updated epidemiological evidence of the endemicity of poultry coccidiosis in Yobe State, this emphasize the need for targeted, context-specific control strategies to reduce the economic impact of coccidiosis in Nigerian poultry systems.

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INTRODUCTION

Coccidiosis remains one of the most economically significant parasitic diseases of poultry worldwide, with substantial impacts on productivity and profitability in both commercial and smallholder systems (Mesa-Pineda *et al.*, 2021; Tirfie and Lulie, 2024). The disease, caused by protozoa of the genus *Eimeria*, leads to intestinal damage, reduced feed efficiency, stunted growth, and mortality in susceptible flocks (Mathis *et al.*, 2025). Transmission occurs via ingestion of sporulated oocysts shed in feces, allowing persistence and environmental contamination that complicate control efforts (Wondimu *et al.*, 2019; Saeed and Alkheraije, 2023).

In Nigeria, avian coccidiosis is endemic across all geopolitical zones and remains a major constraint to profitable poultry production (Akanbi *et al.*, 2022; Usman *et al.*, 2022; Tadausus *et al.*, 2024). Reported prevalence varies among states and production systems. Previous studies in Gombe State recorded infection rates ranging from 21.0% to 42.7%, with *E. tenella* and *E. acervulina* predominating (Adang and Isah, 2016; Jemimah *et al.*, 2020). While similar studies in Borno State, a prevalence of 31.8% was reported among both village and exotic chickens, with higher infection rates in younger and exotic breeds (Lawal *et al.*, 2016). Similarly, investigations in Bauchi State documented rates between 26.9% and 50.0%, and identified multiple *Eimeria* species, particularly *E. tenella* and *E. necatrix* (Ismail *et al.*, 2021; Auwal *et al.*, 2022). These findings collectively indicate that *Eimeria* infections are widespread in the North-East region.

However, despite Yobe State's close proximity to these areas and its expanding poultry sector, there are no published reports on the prevalence or species composition of *Eimeria* infections within its poultry populations. The state presents unique ecological and management contexts characterized by semi-arid climatic conditions, limited veterinary infrastructure, and growing small- and medium-scale farms that may influence *Eimeria* transmission dynamics differently from neighbouring states. Understanding the local epidemiological pattern is therefore crucial for region-specific control

strategies and for integrating coccidiosis management into broader poultry health programmes.

Microscopy remains a practical and widely accessible diagnostic approach for detecting *Eimeria* oocysts in resource-limited settings (Akanbi *et al.*, 2022; Bharti *et al.*, 2024; Bawer *et al.*, 2025). While molecular methods offer superior precision, light microscopy through flotation and morphometric examination continues to be valuable for field surveillance and routine epidemiological assessments.

Given the paucity of baseline data from Yobe State, this study was designed to investigate the occurrence and microscopic characterization of *Eimeria* oocyst shedding in chickens across different poultry production systems in the state. The findings are expected to provide essential epidemiological information for guiding effective control and prevention strategies in the region.

MATERIALS AND METHODS

Study area

This study was conducted in Yobe State, northeastern Nigeria. Yobe lies within the Sudano-Sahelian ecological zone and was created from the western half of Borno State in 1991, with Damaturu as the capital and Potiskum as the largest urban center. The state shares an international boundary to the north with the Republic of Niger (Diffa and Zinder Regions) and interstate boundaries with Borno to the east, Gombe to the south/south-west, Bauchi to the west, and Jigawa to the north-west. Geographically, Yobe spans roughly the latitude/longitude band of about 10.6–13.4° N and 9.7–12.7° E, with the capital Damaturu situated near 11.75° N, 11.97° E and major population centers including Potiskum (~11.71° N, 11.08° E), Gashua (~12.87° N, 11.05° E), and Geidam (~12.89° N, 11.93° E) (Jajere *et al.*, 2015; Babagana-Kyari and Boso, 2020). These coordinates place the state in a hot semi-arid climate belt with extensive drylands and seasonal river systems (e.g., the Komadugu–Yobe). Yobe's climate is strongly seasonal. The rainy (wet) season typically begins from late April/May and lasts to September/October, peaking in July–August; the dry season extends from about October/November through April, with a pronounced Harmattan period (dry, dusty

northeasterly winds) in December–February. In the far-north Sahelian zone of the state the effective rainy period can be relatively short (≈ 3 –4 months), and rainfall is characteristically variable from year to year (Babagana-Kyari and Maina-Bukar, 2018).

Study Design

A descriptive cross-sectional study was conducted between September 2022 and October 2023 in four Local Government Areas (LGAs) of Yobe State, Northeastern Nigeria: Damaturu, Fika, Fune, and Potiskum. The study aimed to determine the microscopy-based detection and characterization of *Eimeria* oocyst shedding in chickens (*Gallus domesticus*) across different poultry production systems.

A purposive non-probability sampling technique was adopted due to practical constraints, including security challenges and restricted accessibility to some parts of the state. Nevertheless, deliberate efforts were made to minimize potential sampling bias and enhance representativeness by selecting diverse poultry settings (household/backyard flocks, commercial farms, and live-bird markets) that reflect the major poultry management systems in the study area. Within each setting, sampling covered birds of both sexes, various age categories (growers ≤ 3 months and adults > 3 months), and both rainy and dry seasons.

Sampling Locations and Procedures

Fecal samples were collected from chickens representing three major poultry management systems in the study area: household/backyard flocks, commercial poultry farms, and live-bird markets (LBMs). Both sexes and age categories were included, as defined above, while very young chicks were excluded due to practical difficulties in obtaining fecal samples.

The inclusion criteria comprised local or exotic chicken breeds (*Gallus domesticus*) that were either apparently healthy or showing clinical signs suggestive of coccidial infection within the selected sites. Birds that had received anticoccidial treatment within seven days before or during sampling were excluded from the study.

Although purposive sampling limits the generalizability of findings to the entire poultry population of Yobe State, this approach was considered the most feasible under prevailing

conditions and was appropriate for generating baseline epidemiological data on *Eimeria* occurrence.

Sample Size Determination

The sample size was determined according to the formula described by Thrusfield (2018), using an expected prevalence (P_{exp}) of 31.85% previously reported by Lawal *et al.* (2016) for chickens in Maiduguri, Borno State. The calculation was performed at a 95% confidence level and a desired absolute precision of 5%, as follows:

$$N = \frac{Z^2 \times P_{exp} (1 - P_{exp})}{d^2}$$

$$N = \frac{1.96^2 \times P_{exp} (1 - P_{exp})}{d^2}$$

Where N = required sample size, Z = Z statistic for the desired confidence level (1.96 at 95% confidence); P_{exp} = expected prevalence, d = desired absolute precisions.

$$N = \frac{3.8416 \times 0.318 (1 - 0.682)}{0.0025} = \frac{1.2216288 \times 0.682}{0.0025}$$

$$= \frac{0.8331508416}{0.0025}$$

$$N = 333.26$$

Thus, a minimum of **333 samples** was required for statistical validity. However, to enhance the **precision of estimates, account for potential data loss** (e.g., damaged or contaminated samples), and ensure **adequate representation across the four study locations**, the sample size was proportionally increased. Following recommendations by Dohoo *et al.* (2009) and Martin *et al.* (1987) that larger sample sizes improve reliability in multi-site epidemiological studies, approximately **350 samples per LGA** were targeted. This yielded a total of **1,400 fecal samples (350 × 4 LGAs)** analyzed during the study period.

This adjustment was therefore **not arbitrary**, but rather a deliberate effort to improve representativeness, precision, and statistical power across different geographic strata.

Faecal Sample Collection and Transportation

A structured questionnaire was administered to selected farms to obtain information on poultry management practices and anticoccidial drug use. Concurrently, faecal samples were

aseptically collected from clinically examined poultry flocks or individual birds.

On farms, freshly voided droppings were gathered using sterile spatulas, while cloacal samples were obtained directly from birds. The spatula was washed after each collection to prevent cross-contamination. Each sample was transferred into sterile, pre-labelled tubes and arranged in a transport container. To avoid duplicate sampling, sampled birds were marked with coloured ink.

In live-bird markets, chickens were randomly selected with vendor consent and tagged for identification. During slaughter, 5–10 cm of the distal ileum and caeca were ligated, excised, and their contents gently expressed into sterile, labelled containers.

All samples were transported in insulated boxes to the Parasitology Laboratory, Department of Veterinary Medicine, University of Maiduguri, and stored at 4 °C until analysis. Laboratory procedures followed biosafety protocols, including disinfection of work surfaces and the use of protective clothing.

Microscopy for Detection and Quantification

Fecal and intestinal samples were processed using standard flotation and McMaster counting techniques for *Eimeria* oocyst detection and quantification (Wichit *et al.*, 2015; Allam *et al.*, 2021). Briefly, oocysts were concentrated using Sheather's sugar flotation (specific gravity ≈ 1.27) and quantified via a modified McMaster method following established parasitological protocols (Lozano *et al.*, 2021; Gałazka *et al.*, 2022). Infection intensity was expressed as oocysts per gram (OPG) and categorized as low (50–499 OPG), moderate (500–4,999 OPG), or high ($\geq 5,000$ OPG) (Hafeez *et al.*, 2022).

Morphological Identification and Quality Control

Microscopic identification of *Eimeria* oocysts was based on recognized morphological criteria—size, shape, wall features, and sporocyst/sporozyte structure—compared against standard identification keys for avian coccidia (Mares *et al.*, 2023; Al-Shaebi *et al.*, 2024; Blake *et al.*, 2021). Given the known overlap among morphological traits, identifications were reported conservatively as *Eimeria* spp. unless morphological features were unequivocal. To enhance reliability, 10% of

randomly selected samples were re-evaluated by an independent microscopist, with consistency assessed using Cohen's kappa. Where feasible, representative oocyst preparations were preserved for potential molecular confirmation in future studies to support species-level identification.

Case definitions and outcomes

A sample was deemed microscopy-positive when at least one morphologically consistent *Eimeria* oocyst was observed in either flotation slides or McMaster chambers. Infection intensity was expressed as OPG (arithmetic mean), and intensity classes were categorized a priori as low (50–499 OPG), moderate (500–4,999 OPG), and high ($\geq 5,000$ OPG) for descriptive summaries (Hafeez *et al.*, 2022).

Data Analysis

All data were independently entered and cross-validated by two trained personnel to ensure accuracy and reliability. Discrepancies between entries were verified against original field or laboratory records, and agreement between the two data entry personnel was quantified using Cohen's kappa statistic ($\kappa = 0.94$; 95% CI: 0.91–0.97), indicating an excellent level of inter-observer agreement. Data consistency and completeness were further assessed through random double-entry verification and logical validation checks prior to analysis.

Descriptive statistics were used to summarize the prevalence of *Eimeria* oocyst shedding, with exact 95% confidence intervals (Clopper–Pearson) computed overall and stratified by location, sex, season, and age group. Associations between *Eimeria* positivity (binary outcome) and potential predictors (poultry setting, season, age, sex) were examined using multivariable logistic regression models, with robust standard errors to account for clustering within flocks or sampling sites.

Infection intensity, expressed as oocysts per gram (OPG) of feces, was log-transformed [$\ln(\text{OPG} + 1)$] prior to analysis to normalize distribution. Linear regression was used to assess predictors of infection intensity, with non-parametric alternatives (e.g., Mann–Whitney U or Kruskal–Wallis tests) applied where normality assumptions were violated. Effect modification by season and poultry production system was evaluated through inclusion of

interaction terms, and model fit was assessed using likelihood ratio tests and diagnostic plots. Statistical significance was set at $\alpha = 0.05$, and all analyses were performed using R statistical software (version 4.3.2; R Core Team, 2023).

Ethical Considerations

Although formal ethical clearance was not obtained for this study, all procedures were conducted in strict compliance with established international guidelines for the care and use of animals in research. The study involved no invasive experimentation or deliberate harm to animals. Sample collection from live birds was carried out with utmost care to minimize stress or discomfort. For household and farm sampling, written or verbal informed consent was obtained from owners or farm managers prior to sample collection. Intestinal contents sampled at live bird markets (LBMs) were obtained only from birds that had already been slaughtered for human consumption; no birds were euthanized or sacrificed for research purposes. All activities were carried out under strict adherence to animal welfare, biosafety, and humane handling standards as recommended by the World Organisation for Animal Health (WOAH, formerly OIE, 2021) and in accordance with the principles outlined by Orimadegun (2020).

RESULTS

The overall prevalence of *Eimeria* oocyst shedding in chickens examined across Yobe State was 37.2% (521/1,400; 95% CI: 34.7–39.8). Infection intensity varied markedly, with the majority of infected chickens harboring low to moderate levels of oocyst output (Table 1). Specifically, low-intensity infections accounted for 13.9% (194/1,400; 95% CI: 12.2–15.8) of the sampled chickens, with mean oocyst per gram (OPG) counts of 242 ± 116 and an infection range of 50–499 OPG. Moderate infections were more common, detected in 16.5% (231/1,400; 95% CI: 14.7–18.5) of the birds, with a mean OPG of $2,216 \pm 1,273$ and values ranging between 500 – 4,999 OPG. In contrast, high-intensity infections were less frequently observed, occurring in 6.9% (96/1,400; 95% CI: 5.7–8.3) of infected chickens, though these cases were associated with substantially elevated oocyst counts, averaging $9,864 \pm 3,078$ OPG and ranging from 5,000 up to 18,200 OPG.

The prevalence and intensity of *Eimeria* infection in chickens varied significantly between the rainy and dry seasons (Table 2). During the rainy season, 318 out of 708 chickens examined were positive for *Eimeria* oocysts, representing a seasonal prevalence of 44.9% and an overall prevalence of 22.7% (95% CI: 20.6–25.0) relative to the total population examined ($n = 1,400$). In the dry season, 203 out of 692 chickens were infected, corresponding to a seasonal prevalence of 29.3% and an overall prevalence of 14.5% (95% CI: 12.8–16.4). Statistical analysis revealed a significant difference in prevalence between the two seasons ($\chi^2 = 36.36$, $p < 0.0001$), with chickens sampled in the rainy season being approximately 1.53 times more likely to be infected than those in the dry season (RR = 1.531; OR = 1.964).

The mean oocyst per gram (OPG) of feces, an indicator of infection intensity, also followed this seasonal pattern. Chickens sampled during the rainy season had a significantly higher mean OPG ($4,372 \pm 4,506$) compared to those sampled during the dry season ($2,961 \pm 3,581$), suggesting that both the prevalence and shedding intensity of *Eimeria* oocysts were greater during the rainy season.

The prevalence of *Eimeria* oocyst shedding in chickens across the surveyed Local Government Areas (LGAs) of Yobe State is presented in Table 3. The distribution of infection varied across LGAs, the highest prevalence was recorded in Potiskum, where 145 of 350 chickens (41.4%) were infected, corresponding to a prevalence of 10.4% (95% CI: 8.9–12.1); followed by Fune that recorded the next highest prevalence with 128 of 350 chickens (36.6%) infected, corresponding to 9.1% (95% CI: 7.7–10.8) and Damaturu with a prevalence of 9.0% (95% CI: 7.6 – 10.6) with 126 out of 350 chickens (36.0%) infected, while Fika had the lowest infection rate, with 115 of 350 chickens (32.9%) positive, corresponding to a prevalence of 8.2% (95% CI: 6.9–9.8). Statistical analysis revealed a significant variation in prevalence between the LGAs ($\chi^2 = 8.94$, $df = 3$, $p = 0.030$), indicating a heterogeneous distribution of coccidial infection within the state.

The estimated mean oocyst output, expressed as oocysts per gram of feces (OPG), also varied across LGAs. Potiskum recorded the highest

mean OPG ($4,416 \pm 4,463$), followed by Fune ($3,945 \pm 4,188$), Damaturu ($3,568 \pm 3,984$), and Fika ($3,241 \pm 3,726$). Despite these numerical differences, analysis of variance did not reveal a statistically significant variation in mean OPG across LGAs ($F = 1.82$, $df = 3$, $p = 0.143$). This suggests that while infection prevalence differed significantly between LGAs, the intensity of oocyst shedding among infected chickens was relatively comparable across the surveyed areas. The prevalence of *Eimeria* oocyst shedding among chickens sampled across different poultry production systems, age groups, and sexes in Yobe State, Nigeria, is presented in Table 4. A statistically significant variation in infection rates was observed among the different production systems ($\chi^2 = 16.35$, $p = 0.0003$). The highest prevalence was recorded in chickens sampled from live-bird markets, where 199 out of 460 birds were positive for *Eimeria* oocysts, representing a market-specific prevalence of 43.3% and an overall prevalence of 14.2% (95% CI: 12.5–16.1) relative to the total population examined ($n = 1,400$). This was followed by chickens reared under household/backyard systems, where 182 of 480 birds were found shedding *Eimeria* oocysts, corresponding to a system-specific prevalence of 37.9% and an overall prevalence of 13.0% (95% CI: 11.3–14.9). The lowest prevalence was recorded in chickens from commercial farms, where 140 out of 460 birds were infected, representing a farm-specific prevalence of 30.4% and an overall prevalence of 10.0% (95% CI: 8.5–11.7). Overall, the differences in *Eimeria* oocyst shedding across the production systems were statistically significant ($p = 0.0003$), with chickens from live-bird markets and backyard flocks exhibiting markedly higher infection burdens compared to those from commercial farms.

Age was found to be a strong predictor of *Eimeria* infection, with growers (≤ 3 months) showing a significantly higher prevalence compared to adults (> 3 months) ($p < 0.0001$) (Table 4). Out of 690 growers examined, 361 were positive for *Eimeria* oocysts, corresponding to a grower-specific prevalence of 52.3% and an overall prevalence of 25.8% (95% CI: 23.6–28.2). In contrast, among 710 adult chickens examined, 160 were infected, giving an

adult-specific prevalence of 22.5% and an overall prevalence of 11.4% (95% CI: 9.9–13.2). The difference in prevalence between these two age categories was highly significant ($\chi^2 = 132.9$, $p < 0.0001$). Risk estimates further revealed that growers were approximately 1.85 times more likely to shed *Eimeria* oocysts compared to adults (RR = 1.851), while the odds of infection in growers were nearly four times higher than in adults (OR = 3.772).

Sex-specific prevalence, however, did not differ significantly ($\chi^2 = 1.496$, $p = 0.2213$). Although females exhibited a slightly higher prevalence than males, the difference was not statistically significant. Of the 720 female chickens examined, 279 were positive for *Eimeria* oocysts, representing a female-specific prevalence of 38.8% and an overall prevalence of 19.9% (95% CI: 17.9–22.1). Conversely, among 680 males examined, 242 were infected, corresponding to a male-specific prevalence of 35.6% and an overall prevalence of 17.3% (95% CI: 15.4–19.4). The calculated risk ratio (RR = 0.9322) and odds ratio (OR = 0.8733) further indicated no statistically meaningful association between sex and infection risk.

Microscopy and sporulation-based characterization of oocysts isolated from infected chickens in Yobe State confirmed the presence of five distinct *Eimeria* species, along with cases of mixed infections (Table 5). Species identification was initially based on oocyst size, shape, and distinguishing morphological features, and subsequently validated by sporulation characteristics following incubation in 2.5% potassium dichromate solution at 28 °C for 48–72 hours.

Among the identified species, *Eimeria tenella* was the most prevalent, detected in 231 (16.5%) of infected chickens. Its oocysts were typically ovoid with smooth double-layered walls, averaging $22.8 \times 19.3 \pm 1.4 \mu\text{m}$, lacking a micropyle. Sporulated oocysts contained four ellipsoidal sporocysts, each with a prominent Stieda body and four sporozoites.

Eimeria acervulina was the second most frequent species, occurring in 112 (8.0%) of infected chickens. Oocysts were small, elliptical ($18.4 \times 13.2 \pm 1.1 \mu\text{m}$), with a thin, smooth wall and a distinct polar granule. Upon sporulation,

the oocysts contained four sporocysts with clearly defined Stieda and sub-Stieda bodies, confirming species identity.

Eimeria maxima was detected in 55 (3.9%) of infected birds. Its conspicuously large ovoid oocysts ($29.2 \times 21.5 \pm 1.8 \mu\text{m}$) lacked a micropyle and sporulated to form four large sporocysts without residual bodies, conforming to standard morphologic keys for *E. maxima*.

Eimeria necatrix was identified in 34 (2.4%) of infected chickens. The oocysts were ovoid ($21.7 \times 19.1 \pm 1.3 \mu\text{m}$) with a smooth wall and a prominent residual body. Sporulated oocysts revealed four sporocysts with characteristic

Stieda and sub-Stieda bodies. *Eimeria brunetti* was the least frequent, found in 22 (1.6%) of infected chickens. Oocysts were ellipsoidal ($26.3 \times 18.7 \pm 1.2 \mu\text{m}$), featuring a distinct micropyle and refractile polar granule. Sporulation produced four sporocysts with smooth walls and distinct Stieda bodies, confirming the species identification.

Mixed-species infections were observed in 67 (4.8%) of infected chickens, with two or more *Eimeria* species oocysts identified within the same host. These were verified through both morphological and sporulation characteristics.

Table 1: Overall prevalence and intensity of *Eimeria* oocyst shedding in infected Chickens (*Gallus domesticus*) in Yobe State, Nigeria

Parameter	No. of Chicken Infected (N = 1400)	Prevalence (%) 95% CI (LL – UL)	Mean OPG $\pm$ SD	Intensity Range (OPG)
Low infection	194	13.9 (12.2 – 15.8)	242 $\pm$ 116	50 – 499
Moderate	231	16.5 (14.7 – 18.5)	2,216 $\pm$ 1,273	500 – 4,999
High	96	6.9 (5.7 – 8.3)	9,864 $\pm$ 3,078	$\geq$ 5,000
Total	521	37.2 34.7 – 39.8	3,842 $\pm$ 4,126	50 – 18,200

Key: CI= Confidence Interval; LL – UL = Lower limit – Upper limit; OPG = **Oocysts Per Gram** N = Total number of chicken

Table 2: Seasonal Prevalence and Intensity of *Eimeria* oocyst shedding in infected Chickens (*Gallus domesticus*) in Yobe State, Nigeria

Season	No. of Chicken Examined	No. of Chicken (%) Infected	Prevalence (%) 95% CI (LL – UL)	Mean OPG $\pm$ SD	p-value	χ^2	RR	OR
Rainy	708	318 (44.9)	22.7 ^a (20.6 – 25.0)	4,372 $\pm$ 4,506	<0.0001	36.36	1.531	1.964
Dry	692	203 (29.3)	14.5 ^b (12.8 – 16.4)	2,961 $\pm$ 3,581				
Overall	1400	521 (37.2)	37.2 (34.7 – 39.8)					

Note: Values with different superscripts (^a, ^b) within the same column indicate significant ($p < 0.05$) differences in prevalence rates between seasons.

All prevalence rates were calculated using the total number of chickens examined ($n = 1,400$) during the study period; seasonal prevalence refers to the proportion of infected chickens within each season, while overall prevalence represents the proportion relative to the entire study population.

Key: CI= Confidence Interval; LL – UL = Lower limit – Upper limit; χ^2 = Chi – square; OR = Odd ratio; RR = Relative risk

Table 3. Prevalence of *Eimeria* oocyst shedding in infected Chickens (*Gallus domesticus*) in Yobe State, Nigeria based on Local Government Area (LGA)

LGA	No. of Chickens Examined	No. of Chickens (%) Infected	Prevalence (%)*	95% CI (LL–UL)	Mean OPG ± SD
Damaturu	350	126 (36.0)	9.0	(7.6 – 10.6)	3,568 ± 3,984
Fika	350	115 (32.9)	8.2	(6.9 – 9.8)	3,241 ± 3,726
Fune	350	128 (36.6)	9.1	(7.7 – 10.8)	3,945 ± 4,188
Potiskum	350	145 (41.4)	10.4	(8.9 – 12.1)	4,416 ± 4,463
Total	1,400	521 (37.2)	37.2	(34.7 – 39.6)	3,842 ± 4,126

*Note: The Prevalence (%) values were standardized based on the total number of chickens examined across all LGAs (n = 1400) to ensure comparability of infection burden across locations.

Key: CI= Confidence Interval; LL – UL = Lower limit – Upper limit

Statistical summary: $\chi^2 = 8.94$, df = 3, p = 0.030; F = 1.82, df = 3, p = 0.143.

Table 4. Prevalence of *Eimeria* oocyst shedding in infected Chickens (*Gallus domesticus*) in Yobe State, Nigeria based on poultry production system, age, and sex

Category	No. of chicken examined	No. of Chicken (%) Infected	Prevalence (%) 95% CI (LL – UL)	χ^2	p-value	RR	OR
Production system							
Household/backyard	480	182 (37.9)	13.0 ^a (11.3 – 14.9)	16.35	0.0003	–	–
Commercial farms	460	140 (30.4)	10.0 ^b (8.5 – 11.7)				
Live-bird markets	460	199 (43.3)	14.2 ^c (12.5 – 16.1)				
Age category							
Growers (≤3 months)	690	361 (52.3)	25.8 ^a (23.6 – 28.2)	132.9	<0.0001	1.851	3.772
Adults (>3 months)	710	160 (22.5)	11.4 ^b (9.9 – 13.2)				
Sex							
Male	680	242 (35.6)	17.3 ^a (15.4 – 19.4)	1.496	0.2213	0.9322	0.8733
Female	720	279 (38.8)	19.9 ^a (17.9 – 22.1)				

*Note: Values with different superscripts (^a, ^b, ^c) within the same column indicate significant (p < 0.05) differences in prevalence rates between seasons.

All prevalence rates were calculated using the total number of chickens examined (n = 1,400) during the study period; specific prevalence refers to the proportion of infected chickens within each category, while overall prevalence represents the proportion relative to the entire study population.

Key: CI= Confidence Interval; LL – UL = Lower limit – Upper limit; χ^2 = Chi – square; OR = Odd ratio; RR = Relative risk

Table 5. Morphological and sporulation characteristics of *Eimeria* species oocysts isolated from infected chickens (*Gallus domesticus*) in Yobe State, Nigeria

<i>Eimeria</i> species identified	Mean size (µm) (Length × Width)	Frequency (%) among infected chickens	Key morphological and sporulation features
<i>E. tenella</i>	22.8 × 19.3 ± 1.4	231 (16.5)	Ovoid, smooth double-layered wall, micropyle absent; sporulated oocysts with 4 sporocysts, prominent Stieda body
<i>E. acervulina</i>	18.4 × 13.2 ± 1.1	112 (8.0)	Elliptical, thin wall, polar granule; sporulated oocysts with 4 sporocysts, distinct Stieda/sub-Stieda bodies
<i>E. maxima</i>	29.2 × 21.5 ± 1.8	55 (3.9)	Large ovoid oocysts, micropyle absent; sporulated oocysts with 4 large sporocysts lacking residual body
<i>E. necatrix</i>	21.7 × 19.1 ± 1.3	34 (2.4)	Ovoid, smooth wall, prominent residual body; sporulated oocysts with distinct Stieda/sub-Stieda bodies
<i>E. brunetti</i>	26.3 × 18.7 ± 1.2	22 (1.6)	Ellipsoidal, distinct micropyle; sporulated oocysts with 4 sporocysts, distinct Stieda body
Mixed infections	–	67 (4.8)	Two or more <i>Eimeria</i> species identified per host sample

DISCUSSION

The present study provides microscopy-based evidence on the prevalence and intensity of *Eimeria* oocyst shedding in chickens across Yobe State, Nigeria. An overall prevalence of 37.2% was recorded, with infection intensities ranging from low to high, though the majority of infections fell within the low to moderate infection categories. This finding reveals the endemicity of coccidiosis in the region and highlights its potential economic and health implications for poultry production systems.

The prevalence obtained in this study is higher than 11.4%, 31.8% and 26.9% reported by Grema *et al.* (2016), Lawal *et al.* (2016) and Auwal *et al.* (2022) from Gombe, Borno and Bauchi states respectively in a similar studies. However, the finding the present study is lower than 69.0% reported by Olanrewaju and Agbor (2014) in Abuja, 77.0% by Ojimelukwe *et al.* (2018) in River state, and 40.1% by Agishi *et al.* (2016) in Makurdi, Benue state. The disparities in prevalence rates may be linked to variations in sampling efforts, differences in ecological conditions, management practices, diagnostic techniques and poultry production systems across these regions, with higher prevalence often reported

in areas of higher rainfall and humidity that favor oocyst sporulation and persistence.

The predominance of low to moderate infection intensities observed in this study suggests that while exposure to *Eimeria* oocysts is widespread, most birds may be experiencing subclinical infections. Subclinical coccidiosis is of considerable concern as it contributes to poor feed conversion efficiency, reduced growth rates, and predisposition to secondary infections, even in the absence of overt mortality (Akanbi *et al.*, 2022). The relatively fewer high-intensity infections, although less common, are epidemiologically significant because heavily infected birds can serve as major sources of environmental contamination, seeding poultry houses with large numbers of oocysts and thereby perpetuating the infection cycle (Attree *et al.*, 2021; Sumo *et al.*, 2024).

Environmental and management-related factors likely played a major role in shaping the infection patterns reported in the present study. In Yobe State, characterized by a semi-arid climate, poultry are often reared under extensive or semi-intensive systems with limited access to veterinary care and suboptimal housing conditions. Such settings promote frequent bird-to-bird contact and fecal

contamination of feed and water, facilitating oocyst transmission (Alders *et al.*, 2018; Gentile *et al.*, 2024). Furthermore, litter management practices and seasonal variations in rainfall may further influence infection intensity. It is well established that *Eimeria* oocysts require adequate moisture and moderate temperatures for sporulation and survival (Répérant *et al.*, 2021), conditions that are transient but sufficient during the rainy season in the Sahel region of Nigeria.

The high mean oocyst per gram (OPG) values in severely infected chickens (>9,000 OPG) observed in this study align with thresholds known to cause acute clinical disease, intestinal damage, and production losses (Broadwater *et al.*, 2025; Tongkamsai *et al.*, 2025). Such cases, although relatively few, highlight the risk of sporadic clinical outbreaks with substantial economic consequences for smallholder farmers who typically lack access to effective prophylaxis. This emphasizes the need for context-appropriate control strategies, including improved biosecurity, rational use of anticoccidial drugs, and consideration of vaccination where feasible.

The present study demonstrated a clear seasonal influence on the prevalence and intensity of *Eimeria* oocyst shedding in chickens across various poultry production systems in Yobe State, Nigeria. Both prevalence and oocyst counts were significantly higher during the rainy season than in the dry season, indicating that environmental and management factors interplay to modulate the epidemiology of coccidiosis in the region. In particular, the 1.53-fold higher prevalence recorded during the rainy season suggests a marked amplification of transmission under wet and humid conditions typical of the period.

Beyond general climatic effects, several contextual factors likely contributed to this seasonal disparity. During the rainy season, many small- and medium-scale farms in Yobe State experience structural limitations such as leaky roofs, poor litter drainage, and high stocking densities as farmers attempt to maximize space utilization. These factors promote accumulation of moist litter and fecal material, enhancing the sporulation and survival of *Eimeria* oocysts within the poultry environment. Furthermore, heavy rainfall often restricts regular litter replacement and

sanitation, leading to increased environmental contamination and reinfection cycles.

The higher prevalence observed during the rainy season aligns with reports from other tropical and sub-tropical regions where *Eimeria* infections peak under conditions of high relative humidity and moderate temperature (Akanbi *et al.*, 2022; Sumo *et al.*, 2024). Similar seasonal patterns have been documented in Nigeria, which is evidence from previous studies by Muhammed *et al.* (2022) in Zaria-Kaduna, Ola-Fadunsin *et al.* (2019) in Kwara State and Olajide *et al.*, (2025) in Uyo- Akwa Ibom state who have reported higher prevalence of coccidiosis during the rainy months compared to the dry period. Comparable observations have also been reported in other tropical and subtropical regions such as Egypt (Mohamed *et al.*, 2021), Ethiopia, the Republic of South Sudan and Kenya (Muñoz-Gómez *et al.*, 2024), Cameroun (Sumo *et al.*, 2024), India (Das, 2021; Bora *et al.*, 2024), Columbia (Mesa *et al.*, 2021) and South American countries (Tomazic *et al.*, 2025) highlighting the global relevance of climatic drivers in coccidiosis epidemiology. However, the magnitude of difference observed in this study appears greater than that reported in some earlier works, which may reflect regional differences in microclimate, farm infrastructure, and litter management practices.

Conversely, in the dry season, reduced moisture levels and higher ambient temperatures during the dry season can cause desiccation and inactivation of unsporulated oocysts, thereby reducing the infective dose available to susceptible birds (Attree *et al.*, 2021; Mesa-Pineda *et al.*, 2021). However, it is noteworthy that while prevalence was lower in the dry season, infection was not completely absent, suggesting that oocysts can persist in poultry environments even under suboptimal conditions, possibly through protection in micro-niches such as cracks in the litter, poor litter sanitations, water spillages on litter leading to dampness, or contaminated feed and water sources (Ahad *et al.*, 2015; Wondimu *et al.*, 2019).

The elevated mean oocyst per gram (OPG) during the rainy season further corroborates the role of environmental conditions in sustaining heavier infections. High OPG values not only reflect increased parasite replication within the host but also contribute

to greater environmental contamination and perpetuation of transmission cycles (Mesa *et al.*, 2021). Such seasonal spikes in oocyst load are epidemiologically important because they predispose to clinical outbreaks and exacerbate production losses, especially in resource-limited settings where anticoccidial interventions may be inconsistent (Pilarczyk *et al.*, 2022).

The present study demonstrated variation in the prevalence of *Eimeria* oocyst shedding among chickens across four Local Government Areas (LGAs) of Yobe State; Potiskum, Fune, Damaturu, and Fika. Interestingly, while prevalence varied across LGAs, the mean oocyst per gram (OPG) output did not differ significantly, suggesting that although the likelihood of infection differed geographically, the intensity of shedding among infected birds remained relatively uniform. These findings highlight the multifactorial nature of coccidiosis epidemiology in northern Nigeria, where both environmental and management conditions strongly shape transmission dynamics (Usman *et al.*, 2022).

Beyond environmental drivers, production systems and management practices remain central determinants of coccidiosis epidemiology. Evidence from Lagos and Akwa Ibom States indicates that, despite awareness among poultry farmers, coccidiosis remains prevalent in flocks, with higher occurrence particularly linked to deep-litter systems, inadequate biosecurity measures, and multi-age housing (Adeyemi *et al.*, 2023; Olajide *et al.*, 2025). Similar trends have been observed in other parts of the world where prevalence rates of up to 84% in backyard and free-range systems in Asia (Badri *et al.*, 2024) and >75% in intensive free-range systems in India (Sharma *et al.*, 2015). These contexts emphasize how poor sanitation, high stocking density, and unrestricted bird movement amplify exposure risks. It is plausible that such factors account for Potiskum's higher burden, where traditional and extensive systems dominate, compared with relatively better-managed operations elsewhere in Yobe.

The present study revealed that chickens sourced from live-bird markets exhibited the highest prevalence of *Eimeria* oocyst shedding, followed by household or backyard flocks, while birds from commercial farms had the lowest prevalence. These differences were

statistically significant, suggesting possible influences of husbandry practices and biosecurity levels across production systems. Although detailed data on flock size, market management, and sanitation practices were not collected in this study, the observed pattern aligns with plausible epidemiological explanations. Live-bird markets typically involve the aggregation of birds from multiple sources under crowded and transient holding conditions, which may facilitate environmental contamination and horizontal transmission of *Eimeria* oocysts. This interpretation is consistent with earlier reports identifying such markets as potential hotspots for enteric and respiratory pathogens due to the mixing of diverse poultry populations and often inadequate hygiene measures (Akanbi *et al.*, 2022; Muñoz-Gómez *et al.*, 2024; Rahman *et al.*, 2025). Similarly, the relatively high prevalence in backyard systems could be related to generally low levels of biosecurity, limited access to veterinary services, and poor implementation of coccidiosis prevention practices, as previously reported in Ethiopia (Ketema and Fasil, 2019) and central Nigeria (Babatunde *et al.*, 2016).

The relatively lower prevalence recorded in commercial farms emphasizes the benefits of improved husbandry and biosecurity protocols, such as routine cleaning, regulated stocking densities, and the use of anticoccidial drugs or vaccines. Although commercial farms are not free from infection, their comparatively lower prevalence highlights the role of structured management practices in mitigating disease risk, a trend similarly reported in studies from some parts of Nigeria (Akanbi *et al.*, 2022) Tanzania (Mramba *et al.*, 2024) and Egypt (Mohamed *et al.*, 2022). However, the persistence of infection in commercial systems despite these measures also emphasizes the resilience of *Eimeria* oocysts in the environment and the challenges of achieving complete control.

Age was identified as a significant determinant of *Eimeria* infection, with growers (≤ 3 months) showing more than twice the prevalence observed in adult chickens. The odds of infection in growers were nearly four times higher, indicating heightened susceptibility among younger birds. This pattern is consistent with several Nigerian studies (Jemimah *et al.*, 2020; Ismail and Ubaidah, 2021; Akanbi *et al.*, 2022; Usman *et*

al., 2022), which reported similar age-associated trends across various states including Kaduna, Kwara, and Borno. However, variations in prevalence magnitude across studies can be partly attributed to differences in diagnostic techniques and study design. For instance, Jemimah *et al.* (2020) employed flotation and sporulation methods, which are more sensitive than direct smear techniques used by Usman *et al.* (2022), potentially explaining their higher detection rates. Similarly, differences in flock type (intensive compared to semi-intensive systems) and management practices may have influenced infection dynamics, as growers reared under floor systems are typically exposed to higher oocyst loads from litter compared to caged birds.

Biologically, young chickens are immunologically naïve, lacking acquired immunity from prior exposures, and are therefore more susceptible to primary *Eimeria* infections. Stressors associated with early growth such as rapid weight gain, dietary transitions, and fluctuating litter hygiene further enhance infection risk (Juárez-Estrada *et al.*, 2021). In contrast, adult birds generally develop partial immunity following repeated subclinical exposures, leading to reduced infection severity and oocyst shedding. Although comparable observations have been reported in Ethiopia (Wondimu *et al.*, 2019), India (Khurshed *et al.*, 2022), and China (Liao *et al.*, 2024), the present study reinforces that this age-related pattern is similarly applicable under Nigerian management conditions and production systems.

Regarding sex-related differences, the current findings showed a slightly higher prevalence in females compared to males, though not statistically significant. This agrees with previous Nigerian investigations (Ismail and Ubaidah, 2021; Usman *et al.*, 2022), which also demonstrated no sex-linked predisposition. Minor discrepancies among reports may stem from differences in flock composition or physiological stress associated with egg production in females. Wondimu *et al.* (2019) in Ethiopia, however, observed higher infection rates in males, possibly reflecting differences in sampling frame and bird purpose (broiler vs. layer populations).

The microscopy-based identification of five *Eimeria* species, with *E. tenella* and *E. acervulina* being predominant, corroborates

earlier Nigerian findings (Ismail and Ubaidah, 2021; Rahman *et al.*, 2025). However, inter-study differences in reported species composition may reflect variation in regional ecotypes, host immunity, and the precision of oocyst identification techniques used. While morphological characterization remains the standard diagnostic approach in many Nigerian laboratories, it has inherent limitations in differentiating closely related species compared to molecular tools (e.g., PCR). Hence, variation in methodology among Nigerian studies could partially account for observed discrepancies.

The predominance of *E. tenella* observed in this study is consistent with findings reported in Bauchi and Kwara States, where the parasite has been documented as the most frequently encountered species in local and commercial chickens (Ola-Fadunsin *et al.*, 2019; Ismail and Ubaidah, 2021; Akanbi *et al.*, 2022). The high occurrence of *E. tenella* is not unexpected, given its well-recognized pathogenicity and strong adaptation to a variety of production systems. Its life cycle, characterized by the ability to produce large numbers of oocysts and its predilection for the caeca an environment conducive to parasite establishment likely contributes to its epidemiological dominance (Tongkamsai *et al.*, 2025). In addition, *E. tenella* infections are often associated with bloody diarrhea and high morbidity, which may have facilitated its consistent detection in this study.

The second most prevalent species, *E. acervulina*, has been similarly reported at moderate to high frequencies in both intensive and extensive poultry systems in some parts of the world (Liao *et al.*, 2024). Its relatively small oocyst size and thin wall enable efficient sporulation and environmental persistence, particularly under humid conditions, which may explain its notable occurrence in the present study. Furthermore, *E. acervulina* commonly infects the upper intestine, often leading to chronic, subclinical infections that contribute to reduced feed efficiency and growth retardation rather than acute mortality. Such features may allow the parasite to persist undetected for longer periods, contributing to sustained transmission within flocks.

The detection of *E. maxima*, *E. necatrix*, and *E. brunette* at lower frequencies is consistent with previous Nigerian surveys, which also reported these species at comparatively low

prevalence levels (Akanbi *et al.*, 2022; Rahman *et al.*, 2025). The relatively low occurrence of *E. maxima* could reflect its tendency to cause intermediate pathogenic effects, leading to less obvious clinical disease and hence under-detection in field settings. Nevertheless, *E. maxima* is of considerable economic significance due to its impact on weight gain and feed conversion efficiency, particularly in broiler production systems (Blake *et al.*, 2020).

The comparatively low frequency of *E. necatrix* in this study contrasts with reports from intensive farms in Northern Nigeria, where the species was sometimes reported at higher levels (Akanbi *et al.*, 2022; Dikwa *et al.*, 2023). The discrepancy may be attributed to differences in poultry management systems, host immunity, or ecological factors influencing sporulation rates. Similarly, the detection of *E. brunette* as the least prevalent species is in line with earlier studies that have identified it as less frequently distributed in African poultry populations (Wondimu *et al.*, 2019). The presence of a micropyle in its oocysts, while aiding morphological differentiation, has not been linked to increased environmental resilience, which might partly explain its relatively restricted prevalence compared to other species.

Mixed-species infections, detected in 4.8% of infected chickens, highlight the epidemiological complexity of coccidiosis in poultry systems within Yobe State. Co-infections with two or more *Eimeria* species have been documented in various settings, with some reports noting frequencies as high as 20% depending on the production environment (Dikwa *et al.*, 2023). The relatively lower frequency of mixed infections in this study may be linked to the smallholder-dominated poultry systems prevalent in the study area, where flock sizes are generally smaller and opportunities for multiple oocyst exposures are comparatively reduced. However, mixed infections are of particular concern, as they can exacerbate clinical disease severity and complicate control strategies due to the overlapping pathogenic mechanisms of different *Eimeria* species.

CONCLUSION

This study provides valuable microscopy-based insight into *Eimeria* oocyst shedding in chickens across different poultry production systems in Yobe State, Nigeria. The observed

overall prevalence of 37.2% indicates that coccidiosis continues to pose a notable parasitic burden in the region. Infection patterns varied with production setting, age, and season. Live-bird markets and backyard flocks exhibited higher infection rates than commercial farms, suggesting the potential influence of biosecurity and husbandry practices on disease transmission. Younger birds (≤ 3 months) were more frequently affected, reflecting their susceptibility and the need for early preventive interventions. Seasonal variation was also evident, with both prevalence and infection intensity increasing during the rainy season likely due to environmental factors such as humidity and litter moisture that favor oocyst sporulation and survival. Morphological characterization identified five *Eimeria* species, with *E. tenella* predominating, followed by *E. acervulina* and *E. maxima*, including cases of mixed-species infections.

While the microscopy-based approach used in this study provides important baseline data, it has limitations, particularly the absence of molecular confirmation and the use of non-probability sampling. Therefore, future studies integrating molecular diagnostic tools and broader sampling frameworks are recommended to validate species identification and strengthen epidemiological inference.

RECOMMENDATION

Based on the findings of the present study, it was recommended that effective coccidiosis control should therefore be tailored to these epidemiological patterns. Preventive efforts should be intensified during the rainy season when humidity favors oocyst sporulation, with regular flock monitoring and prompt intervention. Smallholder and market-based systems, which recorded higher infection rates, require priority attention through improved hygiene, litter management, and stocking density control. Use of broad-spectrum anticoccidials under veterinary supervision, with rotational programs guided by diagnostic surveillance, is advised to curb resistance. Early vaccination or prophylaxis in young growers (≤ 3 months) is also essential. Finally, local government-level control initiatives and further molecular studies are recommended to enhance surveillance, species identification, and region-specific coccidiosis management for sustainable poultry production in Yobe State.

CONFLICT OF INTEREST

Authors declare no conflict of interest in publishing this article.

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