Original paper

Epidemiological studies of *Eimeria* species of cattle in Ilorin, North-Central Nigeria

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ABSTRACT. Coccidiosis is the most economically impactful enteric protozoan disease of animals including cattle. A year (March 2018 to February 2019) study was conducted on cattle in Ilorin, North-Central Nigeria with the objective of determining the prevalence, intensity of infection, diversity of *Eimeria* species, co-infection patterns and risk factors associated with the enteric protozoan infection in cattle. To address this, faecal samples from 478 cattle of different age groups, breeds and sex were subjected to the floatation technique, the McMaster counting technique and sporulation procedure. One hundred and eighty-six (38.91%) of the sampled cattle were positive, and 8 different species were identified (*Eimeria bovis*, *E. zuernii*, *E. auburnensis*, *E. cylindrica*, *E. subspherica*, *E. canadensis*, *E. bukidnonensis* and *E. alabamensis*) with *E. bovis* (25.94%) and *E. zuernii* (23.43%) been the most prevalent. *Eimeria* oocysts were detected all through the year. The intensity of *Eimeria* species among infected cattle ranged between 200–12900 oocyst per gram of faeces. Following univariate analysis, breed, age, sex, physiological status, faecal consistency and PCV were significantly (*p*<0.05) associated with *Eimeria* infection. Multivariate analysis revealed that breed, age and physiological status were the significant risk factors associated with eimeriosis. The present study constitutes the first attempt to analyse the prevalence, intensity, diversity and epidemiological risk factors involved in bovine eimeriosis in North-Central Nigeria. It is envisaged that the data obtained will facilitate better control and prevention measures for *Eimeria* infection among cattle in the region.

Keywords: cattle, coprology, *Eimeria* species, epidemiology, Nigeria

Introduction

Epidemiological studies include the prevalence, spread and risk factor analysis for the occurrence of diseases in a population over a period of time [1,2]. Epidemiological studies for enteric protozoa (*Eimeria*) infection among cattle are important as this protozoan pose a threat to the productivity and survival of animals in most parts of the world [3–7].

Eimeriosis also known as coccidiosis is caused by protozoa of the phylum Apicomplexa, family Eimeriidae and genus *Eimeria* [6,8]. About 1800 *Eimeria* species have been documented to colonize and infect the intestinal tract of different animal species including cattle [3,9], with more than twenty species identified in cattle worldwide [4]. Infection with this protozoan normally occurs through ingestion of feed or water contaminated with sporulated oocysts [9]. *Eimeria* infections are one of the most common and important disease of cattle all over the world [3,6]. Bovine coccidiosis has been observed in almost all areas where cattle are raised [6].

The life cycle of *Eimeria* species, requires the destruction of the host's enterocytes causing loss of blood, water, albumin and electrolytes to the intestinal lumen. These effects may lead to diarrhoea, dehydration, prostration, tenesmus and eventually death, depending on the period of exposure and infective dose [6]. Coccidiosis in cattle commonly occurs as subclinical, without typical signs of the disease; as clinical disease usually only occurs if they are subjected to heavy infection or if their resistance is lowered through

stress, poor nutrition or intercurrent disease [10,11].

Till date, reports on bovine coccidiosis are limited to few studies carried out in Nigeria [12,13] with both having limited information on the epidemiology of the protozoan. However, there are no published data on cattle coccidiosis in Ilorin, North-Central part of Nigeria. The main aim of the current study was to determine the prevalence, intensity of infection, diversity of *Eimeria* species, co-infection patterns and risk factors associated with the enteric protozoan infection in cattle in Ilorin, North-Central Nigeria.

Materials and Methods

Study area. The study was conducted in Ilorin, the administrative capital of Kwara State. Ilorin covers three local government areas (Ilorin East, Ilorin South and Ilorin West). Ilorin is about 482 km from Abuja the Federal Capital of Nigeria. Ilorin has been the administrative capital of Kwara State since 27th of May 1967. Kwara State is located between latitude 8°05′N and 10°15′N and longitude 2°73′E and 6°13′E. It is located in the middle belt (North-Central) within the forest-savanna region of Nigeria. The state is bordered in the west by Benin Republic, in the east by Kogi State, and the south by Oyo, Osun, and Ekiti States and it covers a total area of 34,500 km^2 comprising rainforest in the south and wooded savannah in the larger part of the state. The state has two seasons, the dry (December to March, and August) and wet (April to July and September to November) seasons. There is a mean rainfall of 44.4 cm during the dry season and 160.3 cm during the wet season. The average temperature of the dry and wet seasons ranges from 20.3°C to 33.3°C and 21.4°C to 31.4°C respectively, while their mean relative humidity is 57.5% and 81.5%, respectively. [14,15].

Study population. A total of 478 apparently healthy cattle were sampled from four abattoirs and five farms between March 2018 and February 2019. Cattle of different ages, breeds and sexes were reared together in the farms sampled. Animals from the sampled farms were grazed freely on pastures and sometimes feed with concentrates, water from both the natural and the fresh water sources was used for the animals. All age and sex groups of different breeds of cattle were included in this study, as there was no history of previous anticoccidial treatment given to the animals. Random sampling technique was used to select cattle for the study. The age of the sampled cattle were estimated as described by Lasisi et al. [16]. Body condition scores were performed using the protocol as described by Shittu et al. [17].

Sample size determination. The minimum sample size required for this study was calculated as determined by Thrusfield [18] for the estimation of prevalence in a large population. Calculation was done based on the expected prevalence of 35.4% [13] and the absolute precision of ±5% at 95% confidence interval.

Using the formula below, the calculated minimum sample size is 351.

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

Where: N = required sample size; P_{exp} = expected prevalence (35.4%); and d = desired level of precision (5%).

Faecal and blood samples collection. Faecal and blood samples were collected at the same time from all the sampled cattle. About 5 g of faecal samples were collected directly from the rectum of each animal or during defecation with strict sanitation into well labelled sterile sample bottles and put in a cool box. About five millilitres of blood was collected either at slaughter (slaughtered cattle: from the jugular vein) or via the jugular or coccygeal venepuncture using an 18-gauge needle for adult cattle and 20-gauge needles for calves (cattle in farms). The blood samples were collected into labelled ethylenediaminetetraacetic acid (EDTA) tubes and put also in a cool box. The samples (blood and faecal) collected into separate cool boxes were immediately transported to the Parasitology Laboratory of the Faculty of Veterinary Medicine, University of Ilorin, Nigeria, for further parasitological processing. Faecal consistency was assessed immediately after sampling and classified as normal or diarrheal without any additional differentiations [19].

Coprological examination. The samples were subjected to the simple floatation technique using saturated sodium chloride as described by Cheesbrough [20]. Briefly, 2 g of each faecal sample was mixed with quantity of saturated sodium chloride solution and filtered through a tea strainer into a glass test tube that is placed on test tube rack. Afterward, the mixture was filled to the brim (forming a convex meniscus) with saturated sodium chloride solution, and a clean coverslip was gently
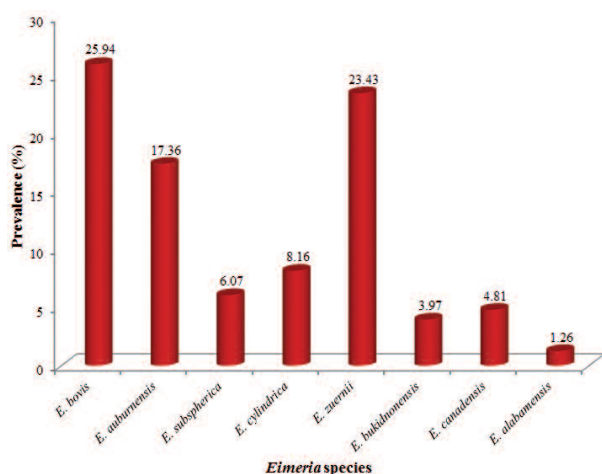
Figure 1. Total prevalence (%) of the different *Eimeria* species of cattle in Ilorin, North-Central Nigeria

placed on top of the test tube, thereby avoiding spillage. The coverslip was left for about 20 min.; afterward, the coverslip (having the harvested *Eimeria* oocysts) was carefully placed on a clean glass slide and examined with the light microscope using the 10× and 40× objective lenses.

Positive faecal samples were subjected to the McMaster counting technique so as to determine the intensity of *Eimeria* infection. This technique was carried out as described by Soulsby [21].

Sporulation and identification of *Eimeria* oocysts. For the purpose of sporulation, the technique described by Balicka-Ramisz et al. [22] was adopted with some modifications. Briefly, 2 g of positive faecal samples were emulsified and then placed in Petri dishes, sprinkled with water to make it damp. About 25 ml of 2.5% potassium dichromate solution was then added to the sample and allowed to stand for 2–5 days at room temperature to permit the sporulation of the coccidian oocysts. After sporulation, flotation technique was again used to examine the sporulated oocyst.

Identification of *Eimeria* species was based on the morphological features of the oocysts (size, form index, shape, colour and texture of oocyst wall, presence or absence of micropyle and polar cap) with the aid of taxonomic keys [11,21].

Determination of packed cell volume (PCV) Packed cell volume (PCV) was determined using the haematocrit technique as described by Cheesbrough [23]. Briefly, capillary tubes are filled with blood by means of capillary forces. The filled capillary tubes were sealed with sealant. The sealed capillary tubes were centrifuged at 11,800 rpm for 5 min. The PCV was then read using a Micro-haematocrit card reader. The PCV was categorized

into anaemic (≤30%) and non- anaemic (>30%) as described by Fielder [24].

Data management and statistical analyses. All data collected from the study were recorded in Microsoft excel spreadsheet and the statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, Chicago, Illinois, USA) for windows version 22.0. Descriptive statistics were conducted to estimate the prevalence using percentages in tables and figures. Prevalence was calculated by dividing the number of positive animals for *Eimeria* infection(s) by the total number of animals sampled multiplied by 100. The univariate analysis (Chi-square) test and odds ratios (ORs) with 95% confidence interval (CI) were used to determine the association between each risk factor and the presence or absence of *Eimeria* oocysts. The ORs were calculated with respect to a reference category as indicated in the respective tables. Multivariable unconditional logistic regression was used to determine the factors for infection controlling for other covariate at $p<0.2$ and biologically plausible variables (e.g. sex). Hosmer and Lemeshow (H-L) goodness of fit test was used to assess the final multivariable model. The association between the intensity of *Eimeria* species and the different risk factors was analysed using the one-way analysis of variance (ANOVA), with the Least Significant Difference (LSD) used at the post hoc test. Significant level was set at $p<0.05$ for all statistical analyses.

Results

Total prevalence (%) of *Eimeria* species

From a total of 478 faecal samples examined, 186 (38.91%) were positive for one or more *Eimeria* species. A total of 8 different *Eimeria* species were detected with *E. bovis* (25.94%) and *E. zuernii* (23.43%) being the most prevalent species. *Eimeria bukidnonensis* and *E. alabamensis* were the least prevalent species representing 3.97% and 1.26% respectively of the sampled population (Fig. 1).

Monthly prevalence (%) of *Eimeria* species

Eimeria oocysts were detected in all the months of the year, with no defined pattern. The highest prevalence was recorded in April (6.28%). The months of January, June, August and September had the lowest prevalence of 1.67%. The prevalence in the other months ranged from 5.44% (May) to 2.09 (October) (Fig. 2).
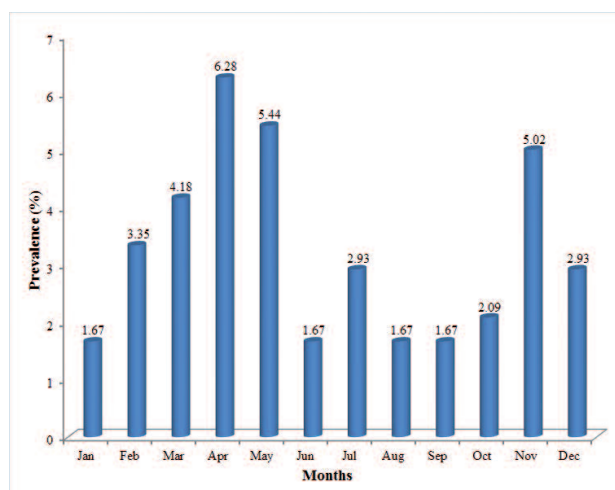
Figure 2. Monthly prevalence (%) of *Eimeria* infections among cattle in Ilorin, North-Central Nigeria

Intensity of *Eimeria* species infection

The intensity of *Eimeria* species mean oocyst per gram (OPG) among cattle in Ilorin, North-Central Nigeria is presented in table 1. Significantly higher ($p<0.05$) oocyst count of *Eimeria* was observed among the Friesian cross compared to other breeds of cattle. Younger cattle had higher count of *Eimeria* oocyst compare to older cattle and the difference was significant. There was a significant difference ($p<0.05$) in the oocyst count of *Eimeria* within faecal consistency and PCV, but the association of *Eimeria* oocyst count within sex, body condition score, physiological status and season was not significant ($p>0.05$).

Coinfection patterns of *Eimeria* species

A total of 42 cattle (8.79%; 95% CI=6.49, 11.56) were infected with a single species of *Eimeria*. In this category, *E. zuernii* was the most prevalent, while *E. auburnensis* and *E. subspherica* where the least prevalent. Seventy cattle from the sampled population were infected with 2 *Eimeria* species simultaneously. This represents 14.64% (95% CI=11.69, 18.03) of the study population. *Eimeria bovis + E. zuernii* (24/478; 5.02%) and *E. bovis + E. auburnensis* (14/478; 2.93%) infections were the most prevalent combinations. Fourteen different combinations of three *Eimeria* species coinfection were detected in this study, with a total of 50 cattle (50/478; 10.46%; 95% CI=7.95, 13.45) being affected. *Eimeria bovis + E. zuernii + E. auburnensis* was the most prevalent combination in this category, representing 3.56% (17/478) of the total study population. Sixteen and eight cattle were

detected to be infected with four and five different *Eimeria* species coinfection, respectively. *Eimeria bovis + E. zuernii + E. auburnensis + E. cylindrica* combination was the most prevalent in the four coinfection category, while *E. bovis + E. zuernii + E. auburnensis + E. cylindrica + E. canadensis* combination was the more prevalent in the five coinfection category (Table 2).

Univariate and multivariate models of risk factors associated with *Eimeria* infections

Breed, age, sex, physiological status, faecal consistency and PCV were significantly associated with *Eimeria* infection. *Eimeria* infection was 2.3 and 2.7 times more among the Sokoto Gudali and Friesian cross respectively and 2 times less among the Red Bororo compared to the White Fulani breed. Younger cattle were more prone to the infection compared to older animals ($p=<0.01$), with cattle less than a year old having the highest prevalence (72.50%). Higher prevalence was seen among male than female (OR=4.43; 95% CI=2.33, 8.75; $p<0.01$). Higher prevalence of *Eimeria* infection was recorded among matting and young cattle compared to cattle that are dry. *Eimeria* oocysts were less likely to be detected in soft faecal samples compared to samples with normal consistency. Higher prevalence of infection was recorded in cattle with normal PCV count compare to anaemic cattle (OR=0.60; 95% CI=0.41, 0.88; $p=0.01$) (Table 3). These putative risk factors associated with *Eimeria* infections were subjected to multivariable logistic regression, which revealed that breed, age and physiological status were risk factors associated with *Eimeria* infections (Table 4).

Discussion

This study constitutes the first attempt in identifying the different species and the epidemiological risk factors involved in *Eimeria* infections among cattle in North-Central Nigeria.

A 38.91% prevalence of *Eimeria* infection among cattle recorded in this study calls for concern as coccidiosis is a serious economic problem in subclinically infected animals because they appear normal outwardly, but developmental stages damage the absorptive surface of the intestine and weaken the immune system, leading to reduced feed consumption, poor feed conversion, slow weight gain and increased susceptibility to other infections [5,10]. A prevalence of 35.4% and 56.0% has been

Table 1. Intensity of *Eimeria* species mean oocyst per gram (OPG) among cattle in Ilorin, North-Central Nigeria

Variable	N	OPG count (Min - Max)	Mean OPG
Breed			
Red Bororo	104	300-4500	2660.0[a]
Sokoto Gudali	74	400-4300	2857.1[a]
Kuri	16	300-4300	3000.0[a]
Friesian cross	16	1000-12900	6375.0[b]
Keteku	48	400-4500	2357.1[a]
White Fulani	220	200-4000	2614.3[a]
Age			
≤ 1 year	40	1000-12900	7065.3[a]
> 1– ≤ 4 years	174	700-7800	5351.0[ab]
> 4– ≤ 10 years	170	300-8900	3865.3[b]
> 10 years	94	200-8900	3582.0[b]
Sex			
Male	48	500-12900	10004.0[a]
Female	430	200-12900	9859.5[a]
Body condition score			
Emaciated	103	1000-12900	7004.3[a]
Moderate	238	500-12900	6881.3[a]
Good	137	200-8900	5978.0[a]
Physiological status			
Young	57	1000-8900	4478.0[a]
Lactating	80	700-12900	4295.0[a]
Matting	16	500-7800	4034.0[a]
Pregnant	11	300-7500	3583.3[a]
Dry	314	200-5600	3473.3[a]
Faecal consistency			
Soft	221	1000-12900	12298.5[a]
Normal	257	200-8900	7565.1[b]
PCV			
≤ 30%	189	200-12900	7853.5[a]
> 30%	289	700-12900	12010.0[b]
Season			
Wet	288	800-12900	11907.6[a]
Dry	190	200-12900	7956.0[a]

N = number of cattle; different alphabets (a,b) within each variable shows significance at ($p<0.05$)

reported among cattle in North-East [13] and South-West [12] Nigeria, respectively. The reported prevalence in this study falls between the prevalence recorded in the previous studies conducted in Nigeria suggesting that bovine *Eimeria* infection is endemic in Nigeria.

Lower prevalence rate of cattle *Eimeria* infection has been reported in different parts of the world, with 8.25% in Iran [4], 13.3% in Germany [25], 17.92% in Poland [26], 20.04% in Turkey [27], 22.1% in the Republic of Korea [28], 26.04% in Ethiopia [7], 31.27% in Saudi Arabia [5], 32.8% in Kenya [29], 34.1% in the United States of America [30] and 35%, in Tanzania [31]. Higher prevalence rate compared to our findings has been reported, with 44.8% in Indonesia [32], 47.09% in Pakistan [3], 47.1 in China [33], 64.2% in Canada [34], 71.22% in Brazil [6], 87.8% in Mexico [35] and

Table 2. Coinfection patterns of *Eimeria* species among cattle in Ilorin, North-Central Nigeria

Number of *Eimeria* species infection(s)	No. positive (%)	95% CI
One	42 (8.79)	6.49, 11.56
Eimeria bovis	18 (3.77)	2.32, 5.77
Eimeria zuernii	20 (4.18)	2.65, 6.28
Eimeria auburnensis	1 (0.21)	0.01, 1.03
Eimeria subspherica	1 (0.21)	0.01, 1.03
Eimeria alabamensis	2 (0.42)	0.07, 1.38
Two	70 (14.64)	11.69, 18.03
E. bovis + E. zuernii	24 (5.02)	3.32, 7.27
E. bovis + E. auburnensis	14 (2.93)	1.68, 4.75
E. bovis + E. subspherica	2 (0.42)	0.07, 1.38
E. bovis + E. canadensis	1 (0.21)	0.01, 1.03
E. bovis + E. bukidnonensis	2 (0.42)	0.07, 1.38
E. zuernii + E. auburnensis	10 (2.09)	1.07, 3.70
E. zuernii + E. subspherica	4 (0.84)	0.27, 2.01
E. zuernii + E. cylindrica	4 (0.84)	0.27, 2.01
E. zuernii + E. bukidnonensis	3 (0.63)	0.16, 1.70
E. auburnensis + E. subspherica	1 (0.21)	0.01, 1.03
E. auburnensis + E. cylindrica	1 (0.21)	0.01, 1.03
E. auburnensis + E. bukidnonensis	2 (0.42)	0.07, 1.38
E. subspherica + E. cylindrica	2 (0.42)	0.07, 1.38
Three	50 (10.46)	7.95, 13.45
E. bovis + E. zuernii + E. auburnensis	17 (3.56)	2.16, 5.52
E. bovis + E. zuernii + E. cylindrical	2 (0.42)	0.07, 1.38
E. bovis + E. zuernii + E. canadensis	2 (0.42)	0.07, 1.38
E. bovis + E. zuernii + E. alabamensis	2 (0.42)	0.07, 1.38
E. bovis + E. auburnensis + E. subspherica	8 (1.67)	0.78, 3.15
E. bovis + E. auburnensis + E. bukidnonensis	2 (0.42)	0.07, 1.38
E. bovis + E. subspherica + E. bukidnonensis	2 (0.42)	0.07, 1.38
E. bovis + E. cylindrica + E. canadensis	2 (0.42)	0.07, 1.38
E. bovis + E. canadensis + E. bukidnonensis	2 (0.42)	0.07, 1.38
E. zuernii + E. auburnensis + E. cylindrica	2 (0.42)	0.07, 1.38
E. zuernii + E. cylindrica + E. canadensis	2 (0.42)	0.07, 1.38
E. auburnensis + E. subspherica + E. cylindrica	3 (0.63)	0.16, 1.70
E. subspherica + E. cylindrica + E. canadensis	2 (0.42)	0.07, 1.38
E. canadensis + E. bukidnonensis + E. alabamensis	2 (0.42)	0.07, 1.38
Four	16 (3.35)	1.99, 5.27
E. bovis + E. zuernii + E. auburnensis + E. cylindrica	10 (2.09)	1.07, 3.70
E. bovis + E. zuernii + E. auburnensis + E. canadensis	2 (0.42)	0.07, 1.38
E. bovis + E. zuernii + E. auburnensis + E. bukidnonensis	2 (0.42)	0.07, 1.38
E. bovis + E. auburnensis + E. subspherica + E. cylindrica	2 (0.42)	0.07, 1.38
Five	8 (1.67)	0.78, 3.15
E. bovis + E. zuernii + E. auburnensis + E. cylindrica + E. canadensis	6 (1.26)	0.51, 2.59
E. bovis + E. subspherica + E. cylindrica + E. canadensis + E. bukidnonensis	2 (0.42)	0.07, 1.38

96.2% in Demark [36]. This inconsistency in the prevalence rate of coccidiosis is most likely attributed to the differences in agroecology, management and husbandry practices of the study animals in different countries, as well as the variation in diagnostic tests, age of the animals, susceptibility of different breeds to the disease, stress level, handling, variation in the study season, number of cattle and the target group of the study animals [3,7].

Eight *Eimeria* species (*Eimeria bovis*, *E. zuernii*, *E. auburnensis*, *E. cylindrica*, *E. subspherica*, *E. canadensis*, *E. bukidnonensis* and *E. alabamensis*) were detected. The recorded species was similar to those recorded by Majaro and Dipeolu [12] except *E. ellipsoidalis* which was not observed in the present work. Alayande et al. [13] also recorded nine species in their study, with seven species similar to those reported in this present study, the difference was in *E. ellipsoidalis* and *E. illinosensis* which they reported and was not identified in this study. Therefore, combining the findings of the previous studies and that reported in this present study, we hypothesize that the cattle populations in Nigeria are inflicted with 10 different species of *Eimeria* (*Eimeria bovis*, *E. zuernii*, *E. auburnensis*, *E. cylindrica*, *E. subspherica*, *E. canadensis*, *E. bukidnonensis*, *E. alabamensis*, *E. ellipsoidalis* and *E. illinosensis*).

Eimeria bovis and *E. zuernii* were recorded as the highest prevalent coccidian species which is in accordance with reports of Majaro and Dipeolu [12] in Nigeria, Ernst et al. [37] in the USA, Cornelissen et al. [38] in Netherlands, Pilarczyk et al. [26] in Poland, Enemark et al. [36] in Denmark, Heidari et al. [4] in Iran, Rehman et al. [3] in Pakistan and Ibrahim et al. [5] in Saudi Arabia. With these reports of *E. bovis* and *E. zuernii* being the most prevalent species in four continents of the world, one may assume that they are the most prevalent *Eimeria* species of cattle worldwide. *Eimeria bovis* and *E. zuernii* are categorized as highly pathogenic, *E. alabamensis, E. auburnensis* and *E. subspherica* as low pathogenic and *E. bukidnonensis, E. canadensis* and *E. cylindrica* as non-pathogenic bovine coccidia [39].

The detection of *Eimeria* species all through the months of the year, with highest prevalence recorded during the wet season explains the epidemiology of *Eimeria* infections in animals. Moisture positively influences warm and humid environmental conditions needed for oocysts sporulation [4,9] as a result the prevalence of the condition is increased.

The significantly higher shedding of *Eimeria* oocyst among the cross breed of cattle, younger cattle and cattle with soft faecal constituency is not surprising. *Eimeria* infections is known to be endemic among exotic and young cattle [3,4], it is known to cause diarrhoea among heavily infected cattle [11].

Coinfection of *Eimeria* infections is a common phenomenon, as the presence of a species does not hinder the presence of another. Coinfection of more than one of the protozoan species at the same time was also reported among cattle in Turkey [40], Ethiopia [41], China [33], Indonesia [32] and Korea [42]. It is postulated that under natural conditions, mixed-species infection cases are more common than single species infection in cattle [32,33].

Breed is an important index in the epidemiology of bovine eimeriosis. Variation in the prevalence of the disease has been reported among different breeds of cattle despite been raised in the same environment [3,29,43]. We observed that the exotic crossed bred (Friesian cross) were most infected with eimeriosis compared with the indigenous breeds. Similar to our finding, Rehman et al. [3] and Asfaw et al. [43] reported that cross bred cattle were more prone to *Eimeria* infections compared to indigenous breeds. This finding may be attributed to the fact that local cattle have built resistance to the protozoan due to the long and repeated exposure over generations. Furthermore, acclimatization of the local breeds to the local environment would render them hardier and more resistant to stressors that could predispose to the infection.

Age is an important and significant risk factor associated with the prevalence of bovine coccidiosis as all ages are susceptible to the disease [4,29,33]. In line with this, this study reports that all age groups of cattle were infected with *Eimeria* with a significant higher prevalence recorded in young cattle. This finding supports earlier reports by Rehman et al. [3], Bangoura et al. [19] and Abebe et al. [41]. The higher infection rate found in young cattle may be attributed to lower resistance due to lack of previous exposure or less immunity to *Eimeria* species due to immature immune system in young animals compared to the older animals [4,5,32].

This present body of evidence shows that male is more susceptible to bovine eimeriosis compared to

Table 3. Prevalence and epidemiological variables that were investigated as potential risk factors for *Eimeria* detection among cattle in Ilorin, North-Central Nigeria

Variable	N	Positive (%)	OR (95% Cl)	P
Breed				
Red Bororo	104	24 (23.08)	0.50 (0.29, 0.84)	< 0.01[b]
Sokoto Gudali	74	43 (58.11)	2.28 (1.34, 3.93)	< 0.01[b]
Kuri	16	4 (25.00)	0.55 (0.15, 1.71)	0.16
Friesian cross	16	10 (62.50)	2.74 (0.96, 8.40)	0.03[b]
Keteku	48	22 (45.83)	1.40 (0.74, 2.63)	0.15
White Fulani[a]	220	83 (37.73)	1.00	
Age				
≤ 1 year	40	29 (72.50)	7.55 (3.32, 18.02)	< 0.01[b]
1 ≤ 4 years	174	81 (46.55)	2.53 (1.47, 4.45)	< 0.01[b]
4 ≤ 10 years	170	52 (30.59)	1.28 (0.73, 2.29)	0.20
> 10 years[a]	94	24 (25.53)	1.00	
Sex				
Male	48	34 (70.83)	4.43 (2.33, 8.75)	< 0.01[b]
Female[a]	430	152 (35.35	1.00	
Body condition score				
Emaciated	103	36 (34.95)	0.76 (0.44, 1.28)	0.15
Moderate	238	93 (39.08)	0.90 (0.59, 1.39)	0.32
Good[a]	137	57 (41.61)	1.00	
Physiological status				
Young	57	35 (61.40)	2.50 (1.40, 4.52)	< 0.01[b]
Lactating	80	16 (20.00)	0.39 (0.21, 0.70)	< 0.01[b]
Matting	16	11 (68.75)	3.45 (1.19, 11.26)	0.01[b]
Pregnant	11	2 (18.18)	0.35 (0.05, 1.50)	0.09
Dry[a]	314	122 (38.85)	1.00	
Faecal consistency				
Soft	221	77 (34.84)	0.73 (0.50, 1.05)	0.04[b]
Normal[a]	257	109 (42.41)	1.00	
PCV				
≤ 30%	189	60 (31.75)	0.60 (0.41, 0.88)	0.01[b]
> 30%[a]	289	126 (43.60)	1.00	
Season				
Wet	288	120 (41.67)	1.34 (0.92, 1.97)	0.06
Dry[a]	190	66 (34.74)	1.00	

N = number of cattle; OR = odds ratio; CI = confidence interval; [a] – reference category; [b] – significant

Table 4. Multivariate association between epidemiological variables and *Eimeria* detection among cattle in Ilorin, North-Central Nigeria

	β	SE	*P*	OR	95%CI lower	upper
Breed						
Red Bororo	-1.866	0.582	0.001[b]	0.155	0.049	0.484
Sokoto Gudali	-1.312	0.556	0.018[b]	0.269	0.090	0.801
Kuri	-1.027	0.610	0.092	0.358	0.108	1.184
Friesian cross	-1.753	0.795	0.027[b]	0.173	0.036	0.823
Keteku	-1.157	0.620	0.062	0.315	0.093	1.059
White Fulani[a]				1.000		
Age						
≤ 1 year	1.957	0.580	0.001[b]	7.080	2.271	22.069
1 ≤ 4 years	0.928	0.313	0.003[b]	2.529	1.369	4.673
4 ≤ 10 years	0.303	0.309	0.327	1.354	0.739	2.483
> 10 years[a]				1.000		
Physiological status						
Young	1.229	0.879	0.162	3.418	0.611	19.126
Lactating	0.720	0.851	0.398	2.055	0.387	10.901
Matting	1.501	0.807	0.063	4.488	0.924	21.807
Pregnant	2.166	0.974	0.026[b]	8.723	1.292	58.866
Dry[a]				1.000		

[a] – reference category; [b] – significant; OR = odds ratio; CI = confidence interval; β = regression coefficient; SE = standard error

female. Work done by Alayande et al. [13] and Regasa et al. [44] reported males to be more susceptible to the protozoan infection than females. The higher susceptibility of male may be attributed to the more care given to female than male as female are raised for reproduction and milk production [32]. Also, the aggressive nature of male animals when feeding may cause them to pick up more *Eimeria* oocysts on the pasture, making them more susceptible to eimeriosis.

Stress has been documented to favour the prevalence of *Eimeria* infection in cattle [4,5,7]. To this, we report that matting and young cattle were most prone to the protozoan infection. Physiological stress associated with hormonal interplay during and around oestrus and testosterone production in matting female and male cattle respectively and during weaning in young may have led to our findings.

Faecal consistency was significantly associated with *Eimeria* infection as higher prevalence was recorded in cattle with normal faecal consistency. Heidari et al. [4] reported a similar outcome in their study. Although a major clinical sign of bovine coccidiosis is diarrhoea [11], the finding that eimeriosis was not associated with soft faece may be associated with the fact that the sampled cattle where not having the clinical form of the disease. Anaemia is not a sign of clinical coccidiosis in cattle, the reason we reported higher prevalence of the infection in non-anaemic cattle.

Body condition was not significantly associated with the prevalence of bovine coccidiosis. Similarly, Rehman et al. [3] and Gebeyehu et al. [45] reported that body condition was not a significant risk factor of the disease in Pakistani and Ethiopian cattle respectively.

Season was not a significant risk factor of bovine eimeriosis in this study, although higher prevalence of the protozoan infection was recorded during the wet season. Similarly, Rehman et al. [3], Ibrahim et al. [5] and Asfaw et al. [43] reported a higher

prevalence of *Eimeria* infection in cattle during the wet season compared to the dry season. The increased infection risk during the wet season could have occurred through contamination of pastures by the protozoan spreading from other areas by surface water, or through humidity associated effects on oocyst survival and development [29].

In conclusion, this study showed that *Eimeria* infection is endemic in North-Central Nigeria and cattle in the study area are plagued with 8 different species, with *E. bovis* and *E. zuernii* being the most prevalent. Breed, age, sex, physiological status, faecal consistency and PCV were the risk factors associated with the enteric protozoan infection. We recommend that attention be placed on the epidemiology and prevention of this protozoan as it is the most important and most common enteric protozoan of cattle that can cause great economic setback to the dairy and beef industry of Nigeria.

Acknowledgements

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