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Prevalence and pathology of trichomoniasis in domestic pigeons in Makurdi, Benue State, Nigeria

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Abstract

This study was undertaken to determine the prevalence of *Trichomonas gallinae* and the pathologies associated with it in domestic pigeons in Makurdi, Benue State Nigeria. A total of 310 domestic pigeons comprising 171 (55.2%) males and 139 (44.8%) females were sampled. Of this number, 133 (42.9%) were sampled during the dry season and 177 (57.1%) were sampled during the wet season. Prevalence of infection, deviations in body weight, haematology, serum proteins as well as gross and histopathological changes were investigated. The prevalence was 67.7% (210 pigeons). Based on sex and season distribution, the prevalence of trichomoniasis was significantly higher in males ($P < 0.05$) (37.7%) than in females (30.0%) and not significantly higher during the wet season (35.5%) than in the dry season (32.3%) ($P > 0.05$). The mean (± SD) body weight was significantly ($P < 0.05$) lower in pigeons infected with *Trichomonas gallinae* (223.3 ± 47.96 g) than in non-infected pigeons (244.0 ± 46.21 g). The total protein and globulin levels of *Trichomonas gallinae*-infected pigeons were significantly ($P < 0.05$) lower than those of the non-infected group. The total leukocyte counts, heterophil, monocyte and eosinophil counts were also significantly ($P < 0.05$) higher in the *Trichomonas gallinae* infected group than non-infected pigeons. Grossly, the lesions observed included raised caseous materials in the crop, pale areas on the proventricular mucosa and congested liver. Microscopically, marked infiltration of mononuclear inflammatory cells in the mucosa of the crop and proventriculus, with multifocal degeneration and necrosis of the proventricular glands. In conclusion, Trichomoniasis is common in domestic pigeons in Makurdi, Benue State, Nigeria and the parasite is capable of causing marked pathology in tissues.

Keywords: Benue State, Domestic pigeons, Makurdi, Nigeria, Pathology, Prevalence, Trichomoniasis

Introduction

Pigeons (*Columba livia domestica*) are ubiquitous birds which belong to the order *Columbiformes* and family *Columbidae* (Marques *et al*., 2007) with an average weight and length of about 369gm and 11 inches respectively (Momoh *et al*., 2013). In Makurdi, domestic pigeons are reared for meat production by some households. Its, thereby contributing significantly to the protein needs of the local populace (Mohammed *et al*., 2017). They are kept in lofts and fed with leftovers and grains by owners and neighbouring communities but often fly out to scavenge for more food supplements, thereby, increasing contact with other birds (Haemig *et al*., 2015; Matsubara *et al*., 2017).

Trichomoniasis in birds is caused by the flagellated pear-shaped protozoan *T. gallinae* in pigeons. It

causes a condition known as "canker" (McDougald *et al*., 2020). This disease agent is known to infect the upper digestive tract and various organs in several avian species. Symptoms include: anorexia, inability to swallow, vomiting, dehydration, weight loss, depression, weakness, diarrhea and respiratory distress (Ombugadu *et al*., 2020). The disease is responsible for economic loses as it is associated with high mortality especially in squabs and high morbidity (Samour *et al*., 1995; Elbahy *et al*., 2023). There is paucity of information on the status of Trichomoniasis in Makurdi, Nigeria and the potential threat of this infection on the poultry value chains is enormous. For this reason, this survey was undertaken to contribute to the much needed data for integrated control of Trichomoniasis in Makurdi, Benue State, Nigeria.

Materials and Methods

Study area

The study was conducted in Makurdi, the capital of Benue State located in the north central zone of Nigeria. Makurdi is located at the north eastern part of Benue State, within the flood plain of lower River Benue valley.

Sampling

A total of 310 apparently healthy domestic pigeons sourced from local farmers within Makurdi town were used in this study. Each bird was weighed using a weighing balance and the sex of each bird was recorded. Gross examination of the oral cavity was done and oropharyngeal swabs were taken from the throat and homogenized in 0.9% saline solution within 30 minutes of sample collection. They were taken to the Parasitology and Clinical Pathology Laboratory of the Veterinary Teaching Hospital, Joseph Sarwuan Tarka University, Makurdi, where a wet mount was done and the microscope slides viewed under the light using X40 microscope objective for oscillating movements of motile parasites as described by Samour & Naldo (2003).

Haematology

One millilitre of blood was collected from each pigeon through the right jugular vein into a labeled sample bottle containing 1 mg of ethylene diamine tetra acetic acid (EDTA) powder as an anticoagulant and used immediately for haematologic analysis using standard procedures. Packed cell volume (PCV) was determined by the microhaematocrit method (Thrall & Weiser, 2002), while haemoglobin concentration (HbC) was determined by the cyanomethemoglobin method (Higgins *et al*., 2008). Red blood cell (RBC) and total white blood cell (WBC) counts were done by the haemocytometer method using Natt and Herrick's solution as the diluting fluid (Natt & Herrick, 1952). The smears for differential leukocyte count were prepared and stained by the Giemsa technique and enumerated by the battlement counting method (Thrall & Weiser, 2002). The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated using the standard formulae (Campbell & Coles, 1986; Campbell & Ellis, 2013). The body weights of the individual pigeons were measured using a Camry® weighing scale and their sexes determined.

Blood for serum biochemical procedures were collected into plain bottles immediately after the birds were humanely sacrificed and allowed to coagulate for one hour before centrifuging at 3,500 rpm for 5 minutes using a centrifuge. The serum was then separated using a Pasteur pipette into plain tubes. The serum total protein was measured using Biuret method and albumin levels were determined chronologically using Randox. The globulin fraction was calculated by subtracting the albumin fraction from the total protein.

Pathological examination

Euthanized birds in the infected group were necropsied for gross lesions according to the procedure outlined by Rea (2003). Samples of the esophagus, crop, proventriculus and liver were fixed in 10% formal saline for 48 hours and processed for histopathology. Sections (5 µm) were stained with hematoxylin and eosin as previously described by Drury & Wallington (1967) and Kiernan (1999). The sections were examined under light microscope.

Data analysis

Data collected from this study was represented based on the presence or absence of parasitic infection among the pigeon population sampled according to sex (male/female) and season (wet/dry). Data collected from the study were analyzed using Graph Pad Prism® software version 5.0 (USA) and presented as means with standard deviations. Unpaired student-t test was used to compare between the 2 groups (infected/not infected) and Chi square was also used to determine the association between prevalence of the disease with sex and season. Values of $p<0.05$ were considered significant.

Prevalence (P) was calculated using the formula;

(i) Prevalence of Trichomoniasis in Pigeons

$$P = \frac{\text{Number of pigeons infected}}{\text{Total number of pigeons sampled}} \times 100$$

Results

The distribution of *T. gallinae* infection based on sex and season is shown on Table 1. Of the 310 pigeons, 210 (67.7%) were infected with *T. gallinae*. Based on sex, 117 (37.7%) males and 93 (30.0%) females were infected with *T. gallinae*. Based on season, 100 (32.3%) and 110 (35.5%), were infected with *T. gallinae* in the dry and wet seasons, respectively. The infection was significantly higher in the male compared with the female ($P < 0.05$) and not significantly higher in the wet season compared with the dry season ($P > 0.05$).

The distribution of the mean (± SD) body weights of pigeons infected with *T. gallinae* within Makurdi metropolis, Benue State, Nigeria are presented in Table 2. The overall mean (± SD) body weight was significantly ($P < 0.05$) lower in pigeons infected with *T. gallinae* (223.3 ± 47.96 g) than in non-infected ones (244.0 ± 46.21 g). Male (231.6 ± 50.68 g) and female (214.5 ± 46.38 g) infected pigeons had significantly ($P < 0.05$) lower mean (± SD) body weight compared to their non-infected pigeons (242.6 ± 44.94 g; 245.7 ± 59.47 g). Based on season, non-infected pigeons had significantly ($P < 0.05$) higher mean (± SD) body weight during the dry (247.0 ± 54.40 g) and wet (242.6 ± 41.67 g) seasons compared to infected (226.0 ± 46.86 g; 220.6 ± 49.16 g) pigeons. The mean (± SD) body weight was non-significantly ($P > 0.05$) higher during the dry season in all pigeons than in the wet season.

The overall mean (± SD) packed cell volume (PCV), haemoglobin concentration (Hb), total erythrocyte count (RBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) showed no significant ($P > 0.05$) differences between non-infected and *T. gallinae*-infected pigeons (Tables 3a & b). Based on sex and season distributions, there were no significant ($P > 0.05$) differences in the mean (± SD) PCV, Hb, RBC, MCV, MCH and MCHC of *T. gallinae*-infected and non-infected pigeons (Table 33a & b).

The mean (± SD) total leukocyte counts (TLC) of pigeons infected with *T. gallinae* are presented in Table 4. The overall mean (± SD) TLC was significantly ($P < 0.05$) higher in *T. gallinae*-infected ($27.83 \pm 4.63 \times 10^9$/L) pigeons compared to non-infected pigeons ($24.16 \pm 4.02 \times 10^9$/L). In male pigeons, there was significantly ($P < 0.05$) higher mean (± SD) TLC in those infected with *T. gallinae* ($28.30 \pm 5.97 \times 10^9$/L) than in the non-infected pigeons ($24.62 \pm 3.71 \times 10^9$/L). In female pigeons, mean (± SD) TLC was significantly ($P < 0.05$) higher in *T. gallinae*-infected ($27.79 \pm 3.50 \times 10^9$/L) than in non-infected ($23.63 \pm 4.33 \times 10^9$/L) pigeons. No significant ($P > 0.05$) difference existed in the mean (± SD) TLC based on sex and season distributions.

Table 1: Demographic characteristic of pigeons sampled and Distribution of pigeons infected with *Trichomonas gallinae* within Makurdi Metropolis, Benue State, Nigeria

Characteristic	Number of pigeons sampled (%)	Number of pigeons infected with *Trichomonas gallinae* (%)
Sex		
Male	171 (55.2)	117 (37.7)[a]
Female	139 (44.8)	93 (30.0)[b]
Season		
Dry	133 (42.9)	100 (32.3)[a]
Wet	177 (57.1)	110 (35.5)[a]
Total	310 (100.0)	210 (67.7)

Values with different superscript alphabet within the same row differ significantly at $P < 0.05$.

Table 2: Distribution of mean (±SD) body weights (g) of pigeons naturally infected with *Trichomonas gallinae* in Makurdi, Benue State, Nigeria

Characteristic	*Trichomonas gallinae*	
	Infected	Non- infected
Sex		
Male	231.6 ± 50.68[a]	242.6 ± 44.94[b]
Female	214.5 ± 46.38[a]	245.7 ± 59.47[b]
Season		
Dry	226.0 ± 46.86[a]	247.0 ± 54.40[b]
Wet	220.6 ± 49.16[a]	242.6 ± 41.67[b]
Overall	223.3 ± 47.96[a]	244.0 ± 46.21[b]

Values with different superscript alphabet within the same row differ significantly at $P < 0.05$.

Table 3a: Comparison of the erythrocyte profile based on sex and season among domestic pigeons infected with *Trichomonas gallinea* and those not infected in Makurdi, Benue State Nigeria

Characteristic	Mean packed cell volume (%)		Mean haemoglobin concentration (g/dl)		Mean erythrocyte count (10^6/l)	
	Infected	Non-infected	Infected	Non-infected	Infected	Non-infected
Sex						
Male	45.66 ± 6.48[a]	46.41 ± 5.87[a]	14.92 ± 2.11[a]	15.50 ± 1.96[a]	2.65± 0.54[a]	2.86 ± 0.44[a]
Female	44.49 ± 4.94[a]	45.91 ± 4.37[a]	14.55 ± 1.61[a]	15.34 ± 1.45[a]	2.75± 0.78[a]	2.92 ± 0.82[a]
Season						
Dry	45.38 ± 5.25[a]	45.24 ± 4.41[a]	15.17 ± 1.71[a]	15.21 ± 1.80[a]	2.52± 0.92[a]	2.71 ± 1.03[a]
Wet	44.97 ± 6.66[a]	46.46 ± 5.13[a]	14.98 ± 2.19[a]	15.50 ± 1.71[a]	2.78± 0.97[a]	3.00 ± 0.97[a]
Overall	45.26 ± 5.95[a]	45.78 ± 5.03[a]	15.12 ± 1.98[a]	15.40 ± 1.74[a]	2.68± 0.94[a]	2.84 ± 0.96[a]

Values with different superscript alphabet within the same row differ significantly at P < 0.05

Table 3b: Comparison of the erythrocyte profile based on sex and season among domestic pigeons infected with *Trichomonas gallinea* and those not infected in Makurdi, Benue State Nigeria

Characteristic	Mean corpuscular volume (fl)		Mean corpuscular haemoglobin (pg)		Mean corpuscular haemoglobin concentration (g/dl)	
	Infected	Non-infected	Infected	Non-infected	Infected	Non-infected
Sex						
Male	185.7 ± 79.37[a]	163.8 ± 22.06[a]	60.69 ± 25.91[a]	54.74 ± 7.37[a]	32.68 ± 0.07[a]	33.41 ± 0.06[a]
Female	177.1 ± 64.82[a]	172.8 ± 66.49[a]	57.90 ± 21.20[a]	57.72 ± 22.16[a]	32.70 ± 0.12[a]	33.40 ± 0.14[a]
Season						
Dry	198.9 ± 75.47[a]	181.7 ± 55.68[a]	61.23 ± 19.23[a]	59.23 ± 16.95[a]	33.01 ± 0.08[a]	33.39 ± 0.12[a]
Wet	188.4 ± 77.96[a]	182.2 ± 74.44[a]	59.67 ± 13.87[a]	58.98 ± 15.67[a]	33.25 ± 0.10[a]	33.47 ± 0.09[a]
Overall	193.3 ± 84.11[a]	182.2 ± 71.56[a]	63.84 ± 25.31[a]	60.85 ± 22.46[a]	33.78 ± 5.27[a]	34.00 ± 5.20[a]

Values with different superscript alphabet within the same row differ significantly at P < 0.05

Table 4: Comparison of the leukocyte profile based on sex and season among domestic pigeons infected with *Trichomonas gallinea* and those not infected in Makurdi, Benue State Nigeria

Characteristic	Mean (± SD) total leukocyte counts (10^9/l)		Mean (± SD) heterophil counts (10^9/l)		Mean (± SD) lymphocyte counts (10^9/l)		Mean (± SD) monocyte counts (10^9/l)	
	Infected	Non-infected	Infected	Non-infected	Infected	Non-infected	Infected	Non-infected
Sex								
Male	28.30 ± 5.97[a]	24.62 ± 3.71[b]	12.59 ± 3.59[a]	7.95 ± 2.19[b]	13.45 ± 3.33[a]	14.70 ± 2.79[a]	0.75± 0.66[a]	0.31 ± 0.41[b]
Female	27.23 ± 1.77[a]	23.63 ± 4.33[b]	13.64 ± 2.41[a]	7.89 ± 1.89[b]	11.42 ± 2.24[a]	13.85 ± 3.08[a]	0.88± 0.59[a]	0.42 ± 0.47[b]
Season								
Dry	27.73 ± 4.10[a]	24.22 ± 4.87[b]	12.87 ± 3.02[a]	7.73 ± 1.98[b]	11.63 ± 3.26[a]	13.64 ± 3.17[a]	0.71± 0.58[a]	0.35 ± 0.47[b]
Wet	28.04 ± 5.86[a]	23.95 ± 2.95[b]	13.35 ± 2.75[a]	8.09 ± 2.03[b]	13.21 ± 2.77[a]	14.88 ± 2.98[a]	0.92± 0.62[a]	0.39 ± 0.37[b]
Overall	27.83 ± 4.63[a]	24.16 ± 4.02[b]	13.05 ± 3.16[a]	7.92 ± 2.05[b]	12.55 ± 3.06[a]	14.31 ± 2.94[a]	0.81 ± 0.63[a]	0.36 ± 0.43[b]

Values with different superscript alphabet within the same row differ significantly at P < 0.05

The mean (± SD) heterophil counts of pigeons infected with *T. gallinae* are presented in Table 4. There were significantly (P < 0.05) higher overall mean (± SD) heterophil counts in *T. gallinae*-infected (13.05 ± 3.16 × 10^9/L) pigeons compared to non-infected pigeons (7.92 ± 2.05 × 10^9/L). Based on sex and season, no significant (P > 0.05) differences existed for the mean (± SD) heterophil counts of the *T. gallinae*-infected and non-infected pigeons.

There was no significant (P > 0.05) difference in the overall mean (± SD) lymphocyte counts between pigeons infected with *T. gallinae*, and non-infected pigeons. Based on sex and season distributions, no significant (P > 0.05) difference existed in the mean (± SD) lymphocyte counts of all pigeons (Table 4).

Furthermore, there were significantly (P < 0.05) higher overall mean monocyte count in *T. gallinae*-infected (0.81 ± 0.63 × 10^9/L) pigeons compared to non-infected pigeons (0.36 ± 0.43 × 10^9/L). Based on sex and season distributions, mean monocyte counts showed no significant (P > 0.05) differences between infected and non-infected pigeons (Table 4).

The overall mean eosinophil counts in *T. gallinae*-infected (1.42 ± 0.64 × 10^9/L) pigeons were

Table 5: Comparison of the total protein, albumin and globulin profiles based on sex and season among domestic pigeons infected with *Trichomonas gallinea* and those not infected in Makurdi, Benue State Nigeria

Characteristic	Mean (± SD) total protein concentrations (g/dl)		Mean (± SD) albumin concentrations (g/dl)		Mean (± SD) globulin concentrations (g/dl)	
	Infected	Non-infected	Infected	Non-infected	Infected	Non-infected
Sex						
Male	3.26 ± 1.41[a]	3.31 ± 1.45[a]	1.21 ± 0.47[a]	1.24 ± 0.42[a]	2.05 ± 1.39[a]	2.07 ± 1.35[a]
Female	2.47 ± 0.94[a]	3.10 ± 1.41[b]	1.09 ± 0.33[a]	1.21 ± 0.29[a]	1.71 ± 1.16[a]	1.90 ± 1.38[a]
Season						
Dry	2.88 ± 1.92[a]	3.14 ± 1.37[a]	1.20 ± 0.33[a]	1.21 ± 0.26[a]	1.68 ± 1.23[a]	1.93 ± 1.19[a]
Wet	3.23 ± 1.22[a]	3.27 ± 1.59[a]	1.11 ± 0.24[a]	1.25 ± 0.47[a]	2.12 ± 1.41	2.02 ± 1.05[a]
Location						
North bank	3.03 ± 1.13[a]	3.02 ± 1.26[a]	1.19 ± 0.41[a]	1.23 ± 0.31[a]	1.84 ± 1.34[a]	1.79 ± 1.38[a]
South bank	2.97 ± 1.21[a]	3.47 ± 1.33[b]	1.17 ± 0.38[a]	1.24 ± 0.28[a]	1.80 ± 1.54[a]	2.23 ± 1.22[a]
Overall	2.91 ± 1.28[a]	3.22 ± 1.43[b]	1.16 ± 0.42[a]	1.23 ± 0.36[a]	12.55 ± 3.06[a]	14.31 ± 2.94[a]

Values with different superscript alphabet along the same row differ significantly at P < 0.05

significantly (P < 0.05) higher than in non-infected pigeons (0.26 ± 0.29 × 10^9/L). Based on sex and season distributions, there were no significant (P > 0.05) differences in the mean eosinophil counts between infected and non-infected pigeons (Table 4).

The mean (± SD) total protein concentrations of pigeons infected with *T. gallinae* are presented in Table 5. There were significantly (P < 0.05) lower overall total protein concentrations in *T. gallinae*-infected (2.91 ± 1.28 g/dL) pigeons than in non-infected pigeons (3.22 ± 1.43 g/dL). Based on sex distribution, mean total protein concentrations were significantly (P < 0.05) lower in *T. gallinae*-infected (2.47 ± 0.94 g/dL) female pigeons compared to male infected (3.26 ± 1.41 g/dL) pigeons. No significant (P > 0.05) differences existed for the mean total protein concentrations between infected and non-infected pigeons based on season distributions.

There were no significant (P > 0.05) differences in overall mean albumin concentrations and mean globulin concentrations between *T. gallinae*-infected and non-infected pigeons (Table 5). Based on sex and seasons distributions, no significant (P > 0.05) differences existed for the mean albumin concentrations between infected and non-infected pigeons (Table 5).

Grossly, the crop and proventriculus showed whitish raised caseous areas (plate I and II). The liver showed enlargement and marked congestion (plate III). Microscopically, the lesions in the crop consisted mainly of inflammatory edema with severe infiltration of mononuclear cells and heterophils with necrosis of the glands (plate IV)). The proventriculus showed severe inflammatory infiltrates and necrosis of the proventricular glands (plate V). The liver showed focal coagulative necrosis of hepatocytes (plate VI), and dilated hepatic sinusoids with mild infiltration of mononuclear inflammatory cells (mainly lymphocytes). There was congestion of the central vein (plate VII).

Plate I: The crop of domestic pigeon showing raised whitish areas (arrows) on the mucosa

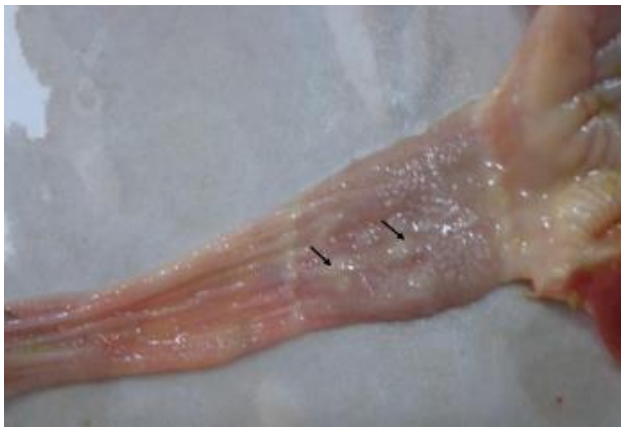

Plate II: The proventriculus of domestic pigeon showing pale areas on the mucosa (arrows)

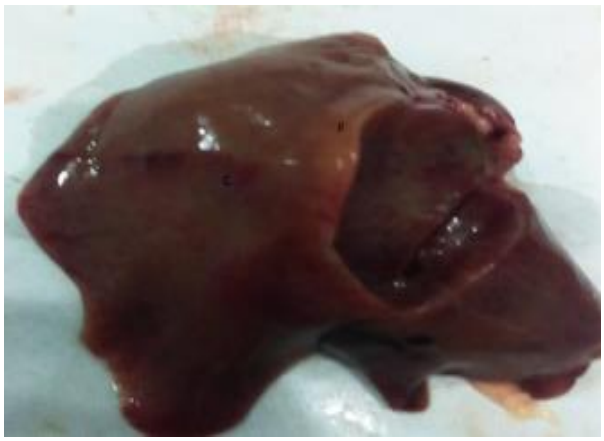

Plate III: The liver of domestic pigeon showing congestion (C) and paleness (P)

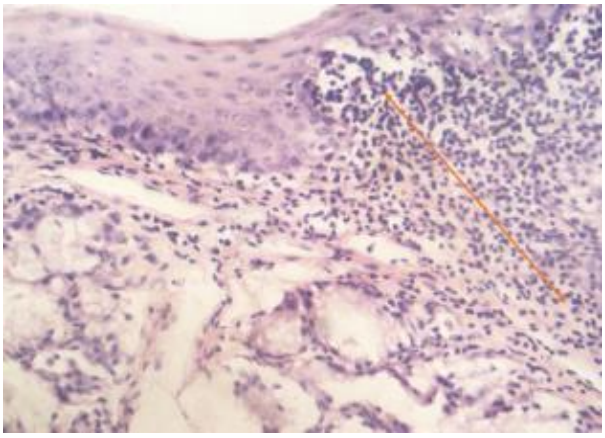

Plate IV: Photomicrograph of the crop of domestic pigeons showing severe infiltration of the mucosa by inflammatory cells (arrow) (H & E stain X400)

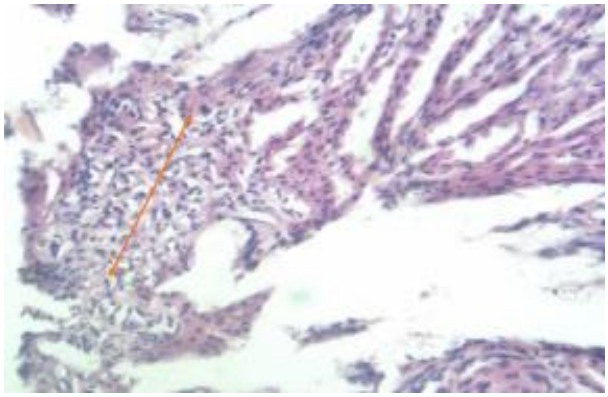

Plate V: Photomicrograph of the proventriculus of domestic pigeon showing the presence of inflammatory cells (arrow). H & E stain. X400

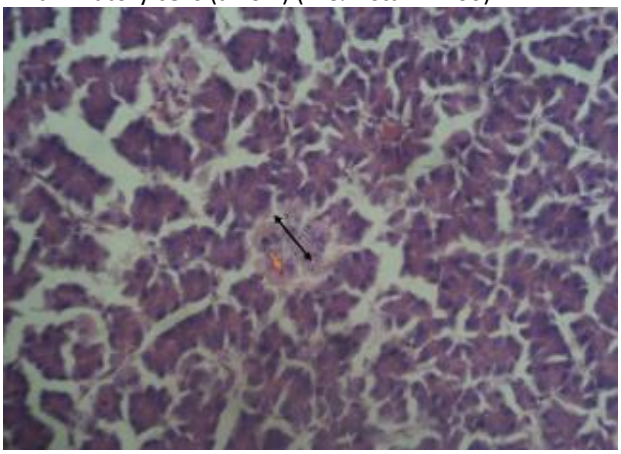

Plate VI: Photomicrograph of the liver showing focal necrosis of hepatocytes (black arrow) and mild inflammatory cells (lymphocytes) (orange arrow). H &E stain, X400

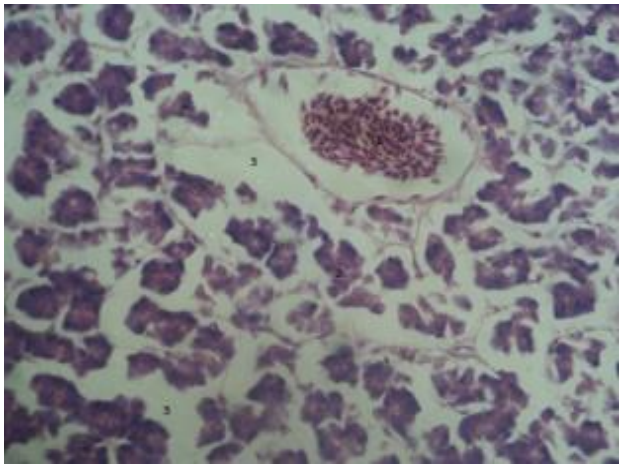

Plate VII: Photomicrograph of the liver of domestic pigeon showing congestion of the central vein (1), degeneration and necrosis of hepatocytes (2) and dilatation of hepatic sinusoids (3). H & E stain, X400

Discussion

The prevalence of trichomoniasis in Makurdi, Benue State, Nigeria in the present study is higher than the 42.8% in Owerri, Imo State (Opara *et al*., 2012); 26% in Pakistan (Saleem *et al*., 2008); 57.4% in Jessore District, Bangladesh (Arfin *et al*., 2019); 44.8% in Spain (Sansano-Maestre *et al*., 2009); 54.5% in Iran (Dehghani-Samani., 2020) and 26.85% in India (Saikia *et al*., 2021). Differences in geographical location, number of birds sampled and type of laboratory tests used might be the possible reasons for the disparity in the prevalence of *T. gallinae* recorded in this study and those by other researchers. In the present study, trichomoniasis was reported in apparently healthy pigeons. The reason for this high prevalence may be due to transmission of the parasite when the adults feed their young with crop milk or from close contact during feeding. Adult birds remain infected and are a

constant source of infection to the young (Soulsby, 1986).

The prevalence of trichomoniasis in the pigeons was higher in males than females, higher during the wet season than the dry season and higher from the North bank compared with the South bank. The significantly higher prevalence of *T. gallinae* recorded in males compared to females in this study are in consonance to those reported by other researchers (Adang *et al*., 2008; Umaru *et al*., 2017; Laku *et al*., 2018; Arfin *et al*., 2019). The sampling of higher number of males might have resulted in this variation in this study.

Similar to this study, Begum *et al*. (2008) recorded higher prevalence in rainy (wet) season than other seasons. Wide variation could be noticed in different studies on the prevalence of *T. gallinae* depending on season. Host factor and other epidemiological factors such as climate, geographical region, host resistance and living status of birds have been reported by other researchers as the contributing factors (Saleem *et al*., 2008; Al-Sadi & Hamodi, 2011; Amin *et al*., 2014).

None of the pigeons displayed clinical signs at the time of sampling. Similar results were observed by Bunbury *et al*. (2008) and Sansano-Maestre *et al*. (2009), who detected a small number of birds with clinical symptoms in pigeon from Mauritius and Spain. This could be explained by the fact that it is usually difficult to find very sick birds because they tend to hide. In addition, the carcasses of birds that have died from disease are rapidly eradicated by other carrion feeders, which would make them impossible to detect (Peterson *et al*., 2000).

T. gallinae has been reported to cause decrease in body weight of birds and this was suggested to result from the parasite burden leading to decreased feed intake (Abbas *et al*., 2010; Katoch *et al*., 2012; Nematollahi *et al*., 2012; Szyszka & Kyriazakis, 2013). Also, the interference of parasites with the absorption of nutrients in ingested feed thus leading to decrease in weight gain might be another possible mechanism. These mechanisms therefore suggest possible reasons for the lower body weights of pigeons infected with *T. gallinae* compared to non-infected ones as observed in this study.

The packed cell volume (PCV) and haemoglobin concentration (Hb) of both infected and non-infected pigeons observed in this study were similar to those reported by Ihedioha *et al*. (2016), but higher than those reported by Orakpoghenor *et al*. (2021) in domestic pigeons. However, the values for mean RBC reported in this study were lower than those reported by Ihedioha *et al*. (2016) and Orakpoghenor *et al*. (2021). Also, mean MCV, MCH and MCHC, leukocytic parameters, total protein, albumin and globulin concentrations of pigeons in this study showed variations with those reported for domestic pigeons by other researchers (Opara *et al*., 2012; Ihedioha *et al*., 2016; Orakpoghenor *et al*., 2021). Differences in ages, health statuses and breeds of pigeons, geographical locations, feed type, seasons, climate, and other environmental factors might be responsible for the disparity in observations of this study and those by other researchers.

T. gallinae have been suggested to induce anemia via interference with iron intake (Seddiek *et al*., 2014). The absence of significant differences in PCV, Hb, RBC, MCV, MCH and MCHC between infected and non-infected pigeons in this study suggests mild infection in infected pigeons, thus the absence of anemia.

There were higher total leucocyte counts in infected pigeons compared to non-infected pigeons and this was due to higher heterophil, monocyte and eosinophil counts. Heterophils and macrophages were reported to play critical role in tissue debris phagocytosis (Coles, 1986; Broom, 2019). Although these pigeons were exposed to various infectious agents and inflammatory responses due to their flying habits, the higher heterophil and monocyte counts in the naturally infected pigeons might have been exacerbated by the parasites. Also, the parasitic infection might have induced a stressful condition in the infected pigeons leading to increased corticosterone levels with consequent higher heterophil and monocyte counts (Davis *et al*., 2008; Cotter, 2015). Thus the higher eosinophil counts in infected pigeons might have resulted from this mechanism induced by destruction of the gastrointestinal tract tissues caused by the parasites.

The lower total protein concentration in infected pigeons might be due to protein loss following starvation induced by the lesions in the esophagus/crop that may have interfered with food uptake by these birds (Mpofu *et al*., 2020). This was accompanied by lower globulin concentration indicating decreased immune status of the infected pigeons.

Pathological changes associated with *T. gallinae* were observed in the crop, proventriculus and liver as raised whitish areas on the crop mucosa, pale necrotic areas on the proventricular mucosa and congestion of the liver. Microscopically, the crop and proventriculus showed degenerative changes, necrosis of glands and infiltration of inflammatory cells. There was congestion of hepatic blood vessels, degeneration as well as necrosis of hepatocytes and

infiltration of leukocytes similar to what has been reported by several researchers (Narcisi *et al*., 1991; Abbas *et al*., 2010; Begum *et al*., 2010; Borji *et al*., 2011; Fedhil *et al*., 2020 Martinez-Herrero *et al*., 2020).

The Pathological changes observed in this study indicates that *T. gallinae* is pathogenic in domestic pigeons in Makurdi, Benue State, Nigeria.

In conclusion, the results of this study indicated a high prevalence of *T. gallinae* (67.7%) in Makurdi, Benue State. The infected birds had decreased body weights, increased total leukocyte counts as a result of the increase in heterophils, monocyte and eosinophil counts. There was also a decrease in the serum total protein levels of the infected pigeons. Gross pathological changes included raised caseous areas on the crop, pale whitish patches on the proventriculus mucosa and hepatic congestion. Histopathological changes observed on the mucosa of the crop and proventriculus were characterized by marked infiltration of inflammatory cells. This result suggests that *T. gallinae* is highly prevalent among pigeons in Makurdi, Benue State and are capable of causing pathological changes in the tissues of the infected pigeons. Therefore, efforts should be put in place by Veterinarians and other relevant authorities to control the disease among domestic pigeons.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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