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Asian Pacific Journal of Tropical Biomedicine

journal homepage: www.elsevier.com/locate/apjtb

Original article http://dx.doi.org/10.1016/j.apjtb.2015.04.009

Prevalence and burden of gastrointestinal helminths in wild and domestic guineafowls (*Numida meleagris*) in the Southern Province of Zambia

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ARTICLE INFO

Article history:
Received 8 Apr 2015
Received in revised form 20 Apr 2015
Accepted 29 Apr 2015
Available online 30 June 2015

Keywords:
Gastrointestinal helminths
Guineafowl
Numida meleagris
Zambia

ABSTRACT

Objective: To determine the gastrointestinal tract helminthic fauna in domestic and wild guineafowl in Zambia.

Methods: Post-mortem and laboratory parasitological examinations for helminth identification and enumeration were conducted on 198 guineafowls (148 domestic and 50 wild) from November 2010 to October 2011.

Results: All guineafowls were infested with one or more helminths. Eleven helminth species, namely, *Raillietina echinobothrida*, *Raillietina tetragona*, *Raillietina cesticillus*, *Ascaridia galli*, *Allodapa suctoria*, *Gongylonema ingluvicola*, *Tetrameres* spp., *Heterakis* spp., *Acuaria spiralis*, *Syngamus trachea*, and *Streptocara pectinifera* were identified with no trematodes recorded. Mean nematode burden between domestic and wild fowl showed no differences having 113.7 [confidence interval (*CI*) 98.9–128.6] and 108 (*CI* 76.6–139.5) nematodes respectively. In contrast, female guineafowls had a mean of 151.9 (*CI* 128.4–177.8) nematodes per host which was significantly more than the males that had a mean of 79.6 (*CI* 66.8–94.4). However, there were differences in helminth species richness between domestic and wild guineafowls with domestic guineafowls having more species present at a mean of 4.2 (*CI* 3.91–4.44) than the wild ones at a mean of 3.4 (*CI* 2.92–3.88) but there were no sex differences. Eight of the eleven helminth species co-occurred in domestic and wild fowl and five of the helminth species had higher prevalence in domestic guineafowls.

Conclusions: *Syngamus trachea*, *Streptocara pectinifera* and *Acuaria spiralis* are reported for the first time in domestic poultry in Zambia. This study represents the first comparative study of helminths in domestic and wild guineafowls at an interface area and adds to the knowledge base in a discipline where a dearth currently exists.

1. Introduction

Helmeted guineafowls [*Numida meleagris* (*N. meleagris*)] are known to be widely distributed in the wild. In Africa, they have emerged as an important economic resource in several communities where they have been successfully domesticated. Domestically, they are reared together with other poultry such as chickens and ducks to promote food security and enhance reproduction efficiency. The overall demand for poultry meat in Zambia has increased as indicated by the increased off-take from hatcheries. However, more people are now opting to eat organic poultry meat due to the well-known benefits compared to meat raised through more intensive production systems. This organic poultry meat comes in the form of village chickens, guineafowls and other wild birds.

Guineafowls are known to harbour a great variety and number of parasites [1]. Both infestation/infection by many

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Peer review under responsibility of Hainan Medical University.
Foundation Project: Supported by the University of Zambia under UNZA-MAN No: 07193.

parasites/pathogens is exacerbated by the farmers' practises of collecting wild and domestic guineafowl eggs for their poultry enterprises and raising mixed poultry species. This type of contact is suspected to play a key role in disease transmission. Further, wild birds are also in close contact with domestic fowl in a number of areas in Zambia. With increasing human settlements accompanied by various other anthropogenic activities, the *status quo* has been observed to have increased in the last decade with a corresponding growth of the poultry industry in Zambia both under intensive and extensive rearing systems. It is known that parasites of fowl, whether domestic or not, are not host specific, consequently, wild fowl can act as reservoirs for a number of parasitic infections and may transmit parasites to domestic fowl and *vice versa*. Common gastrointestinal helminths of poultry include those of the genus *Hymenolepis*, *Raillietina*, *Ascaridia*, *Heterakis* and *Capillaria* [2–6]. A comprehensive list of guineafowl helminths has also been compiled and core guineafowl helminths described in South Africa include *Subulura suctoria*, *Cyrnea parrotti*, *Raillientina* spp. and *Ortleppolepis multiuncinata* [1]. Although rarely reported, some researchers have reported trematodes in guineafowl, but more researchers have found poultry infected with cestodes and nematodes but no trematodes [7]. This has been attributed to the absence in these study areas of the snail intermediate hosts for the trematodes [1]. Differences in endoparasite prevalence between free-living and captive poultry have been reported [8] as well as changes in nematode prevalence in wild fowl due to interaction with domestic fowl [9]. A difference in worm burdens between captive and wild birds has been described and is partially attributed to high infection densities where the wild birds or free-living ones are associated with exposure to a more varied parasitic fauna in the wild than the captive ones [10]. Differences in helminth burdens in related species can be caused by a number of factors that include genetics [11], habitat, host feeding ecology, distance between populations [12].

Viral, bacterial and protozoan diseases may appear to be more economically important to the farmer because they cause obvious losses in form of deaths of many birds at a time. However, the less obvious but ubiquitous losses due to reducing productivity caused by helminthiasis are economically very important to the poultry industry and may be in the form of poor egg production, poor weight gain (especially in young growing chickens), poor immune responses to disease pathogens and vaccines [13] and other diseases that are caused by the helminths being carriers of other pathogenic agents [14].

Many rural farmers in Africa recognize the high prevalence of poultry gastrointestinal nematodes and due to lack of an in-depth understanding of the negative consequences they may have in terms of causing mortalities [15]. Village poultry generally scavenge for food and hence are at a higher risk of picking up infective forms of helminths from the environment.

Helminth infections may lead to severe morbidity and mortality as has been shown by fatal outbreaks of ascaridiasis caused by *Ascaridia numidae* [16] and capillariosis [17]. Although some researchers have shown no statistically significant effect of the nematode *Ascaridia* infection on the pathogenesis of bacterial diseases, others have shown significant effects of concurrent infections of *Ascaridia* with bacterial disease.

Limited work has been done in Africa on parasites specifically on domestic guineafowl [1,18,19]. Not all parasite species reported in guineafowl are reported in chickens [1]. No work has been done in Zambia to determine seasonal parasite burdens in guineafowls (both domestic and wild fowl). This cross-sectional study was therefore designed to meet this gap and delimit the seasonal parasite fauna found in domestic and wild guineafowls and the effect on body weights in Zambia using post-mortem examination.

2. Materials and methods

2.1. Study area

The present study was conducted in the Namwala Game Management Area (GMA) surrounding Kafue National Park in the Southern Province of Zambia and villages bordering this GMA. Zambia has a distinct warm and wet rainy season between November and April, followed by a cooler dry season (May–July) and, finally, a hot dry season precedes the rainy season. The wild guineafowls were collected from the Namwala district's Mulela plains-Ila forest interface (15°48.879′ S, 26°22.743′ E; elevation 989 m); whereas domesticated ones were collected from villages in the GMAs periphery. Linear distance ranged from areas where the wild guineafowls and the domestic ones were sampled approximately 5–25 km.

2.2. Study design

The study was a cross sectional comparative study that involved the monthly sampling of wild and domestic guineafowls from November 2010 to October 2011 to determine the gastrointestinal helminth fauna. A total of 148 domestic and 50 wild guineafowls were collected and a comprehensive necropsy was performed. Licensing restrictions and difficulties in hunting wild guineafowls limited the collection of similarly sample sizes between the purchased domestic fowl and the wild fowl.

2.3. Sampling and laboratory analysis

The wild guineafowls were sampled by ethical shooting with number AAA 12B shotgun pellets/shells and geo-referencing of sampling points were done using GPS coordinates of the shooting sites. Sampling was done fully complying with local and international ethical provisions and was approved by the Zambia Wildlife Authority (permit number ZAWA-BHL 15121). The birds were immediately tagged, sexed and placed in individual plastic bags and chilled until examination within 8 h.

Domestic birds were concurrently bought at monthly intervals, from villages surrounding the GMA where wild fowls had been correspondingly harvested. GPS coordinates of the sampling sites were also recorded. The live birds were subsequently euthanized humanely and similarly examined as for the wild birds.

Each of the collected birds were weighed and examined macroscopically for any gross lesions. Necropsy was proceeded by dissecting the birds and extracting the entire gastrointestinal tract (GIT). As soon as the GIT was removed from the body cavity, the crop, proventriculus, gizzard, small intestines, caeca and colon were tied off with a nylon ligature to prevent transfer of parasites from one site to the other. Post-mortem for thorough examination of viscera and identification of helminths was performed. The trachea was also cut open longitudinally to

search for tracheal helminths. The trachea was also washed through a 212 μm Endecott sieve. Sex was positively determined by cloacal examination of live birds and/or gonad examination of dead birds at post-mortem.

2.4. Helminth collection, identification and counting

The ligated sections of the GIT were separated by transecting through the point of ligation. Each of the section was opened with an enterotomy scissors into a stainless steel tray, rinsed and scraped over a 212 μm Endecott sieve to collect the helminths. The sieve contents were transferred into 200 mL screw-capped plastic containers containing 70% ethanol. To ensure that no helminths were missed, each section of the GIT was examined under a dissecting microscope to recover helminths that had remained. The gizzard was peeled and examined under a dissecting microscope for any remaining helminths.

For the purpose of identification, nematodes were cleared in lactophenol while cestodes were prepared in Hoyer's medium, and examined as temporary wet mounts using Hoyer's medium or as permanent mounts using Canada balsam. Each sample was examined using a compound microscope for measurement and morphological assessment. Cestodes were stained with carminic acid procedures.

All the nematode helminths recovered from each GIT section were identified and counted individually to get the actual worm burdens. Helminths were identified using the taxonomic keys previously described [7,20,21]. In hosts where a certain cestode only had proglottids without scoleces, these were recorded as "present" only.

2.5. Data analysis and statistical analysis

Data were stored in Microsoft Excel® (Microsoft Ltd) while Minitab® version 14 (Minitab Inc., Pennsylvania, USA) was used for statistical analysis. The mean intensity of infection, prevalence and frequency of distribution and seasonality of helminth parasites in wild and domestic fowls were analysed using the recommendation by Rózsa *et al.* [22]. Parasite richness was determined by enumerating the number of helminth species discovered per host. The *Chi*-square test was used to determine differences in proportion of helminth species positives between wild and domestic guineafowls. Group means were compared using One-way ANOVA and Tukey's multiple comparison *post-hoc* test was used for pair-wise comparison. Linear regression was used to determine correlation. Differences were considered significant when $P \leq 0.05$ at 95% confidence interval (*CI*).

3. Results

The helminth species including the site of recovery encountered in guineafowls are presented in Table 1. All guineafowls were infected with gastrointestinal helminths (cestodes and nematodes). A total of 22 836 helminths were discovered in the 198 guineafowls representing 11 helminth species. The species were the cestodes, namely, *Raillietina echinobothrida* (*R. echinobothrida*), *Raillietina tetragona* (*R. tetragona*), *Raillietina cesticillus* (*R. cesticillus*) and the nematodes, namely, *Ascaridia galli* (*A. galli*), *Allodapa suctoria* (*A. suctoria*), *Gongylonema ingluvicola* (*G. ingluvicola*), *Tetrameres* spp., *Heterakis* spp., *Acuaria*

Table 1
Helminth species from helmeted wild and domesticated guineafowls (*N. meleagris*) in Zambia (n = 198).

Parasites		Site in the host	Domesticated guineafowls (n = 148)					Wild guineafowls (n = 50)				Comparative statistics	
			No. infected	Prevalence (%)	Median	Range	Mean ± SE	No. infected	Prevalence (%)	Median	Range	Mean ± SE	χ^2 (df = 1)	P value
Cestodes	*R. echinobothrida*	SI	102	68.9	N/A	N/A	N/A	25	50.0	N/A	N/A	N/A	5.82	0.016[a]
	R. tetragona	SI	106	71.6	N/A	N/A	N/A	38	72.0	N/A	N/A	N/A	0.36	0.548
	R. cesticillus	SI	61	41.2	N/A	N/A	N/A	7	14.0	N/A	N/A	N/A	12.28	<0.001[a]
Nematodes	*A. galli*	SI	96	64.9	13.5	1–79	20.90 ± 2.00	19	38.0	25	7–50	27.30 ± 5.30	11.08	0.001[a]
	A. suctoria	Caecum	140	94.6	82.5	6–392	98.40 ± 6.70	43	86.0	85	19–264	101.40 ± 14.30	3.94[b]	0.047[a]
	G. ingluvicola	Crop	84	56.8	6.0	1–69	11.80 ± 1.70	14	28.0	2	1–14	4.57 ± 1.80	12.36	<0.001[a]
	Tetrameres spp.	Proventriculus	23	15.5	6.0	3–13	4.30 ± 0.75	13	26.0	10	9–30	8.86 ± 3.84	2.75	0.097
	Heterakis spp.	Caecum	3	2.0	64.0	29–72	55.00 ± 13.20	10	20.0	51	18–55	41.00 ± 7.50	19.68[b]	<0.001[a]
	A. spiralis	Provent	4	2.7	27.0	6–116	44.00 ± 25.40	0	0.0	N/A	N/A	N/A	N/A	N/A
	S. pectinifera	Gizzard	1	0.7	3.0	3	N/A	0	0.0	N/A	N/A	N/A	N/A	N/A
	S. trachea	Trachea	1	0.7	3.0	3	N/A	0	0.0	N/A	N/A	N/A	N/A	N/A

SI: Small intestine; [a]: Significant difference in proportions of guineafowl with that species between domestic and wild; [b]: One cell with expected counts less than 5.

spiralis (*A. spiralis*), *Syngamus trachea* (*S. trachea*), and *Streptocara pectinifera* (*S. pectinifera*). Domestic guineafowls had all the 11 species identified, but no *A. spiralis*, *S. trachea* or *S. pectinifera* were found in the wild fowls (Table 1). No trematodes were seen in both the domestic and wild guineafowl. Table 1 also shows the proportions of the guineafowls that had infestation with the different species of helminths as well as the median/mean intensity of each nematode species for the wild and domesticated guineafowls. There were significant differences in positive proportion per helminth species between wild and domestic fowls with *R. echinobothrida*, *R. cesticillus*, *A. galli*, *A. suctoria*, *G. ingluvicola* and *Heterakis* spp. The caecum had higher number of worms in both domestic and wild fowl than any other gastrointestinal organ and the difference was significant [ANOVA $F_{5,193} = 47.5$, $P < 0.001$; mean of helminths in per organ: caecum (96), crop (11.3), gizzard (3), proventriculus (10), intestine (21.6), trachea (3)]. There was no correlation between body weight and species richness (Pearson's correlation of body weight and species richness = 0.065, *P* value = 0.439). There was a mild positive correlation between body weight and total worm burden per host (Pearson's correlation of body weight and total worm burden = 0.41, *P* value < 0.01).

3.1. Helminth species richness

There were differences in helminth species richness between domestic and wild guineafowls with domestic fowls having more species present than the wild fowls. Where a particular helminth species was present in both domestic and wild guineafowls, there was no statistical difference in mean numbers between them. The highest number of helminth species infecting domestic guineafowls was seven while in wild fowls it was five. Among domestic fowls, 82% (122/148) had three or more species of helminths, while among wild fowls it was 76% (38/50) (Table 2). Mean helminth species per host was 4.177 (SD: 1.654; Range: 1–7; *CI*: 3.91–4.44) for domestic fowls and 3.40 (SD: 1.107; Range: 1–5; *CI*: 2.92–3.88) for wild fowls. There was an overall difference in mean species richness between domestic and wild fowls (ANOVA $F_{1,197} = 5.10$, $P = 0.025$). Wild guineafowls had lower species richness during the rainy season and subsequent cool dry season, but there was no significant difference in species richness during the hot dry season (Figure 1).

3.2. Intensity of infection

There was also no difference in mean total nematode burden per bird between domestic and wild fowls (ANOVA $F_{1,197} = 0.16$, $P = 0.69$, mean ± SD of overall domestic nematode burden 113.72 ± 91.32, *CI*: 98.9–128.6; mean ± SD of overall wild nematode burden 108.04 ± 75.40, *CI*: 76.6–139.5) and neither was there a difference in mean total nematode burden per bird between domestic and wild fowls.

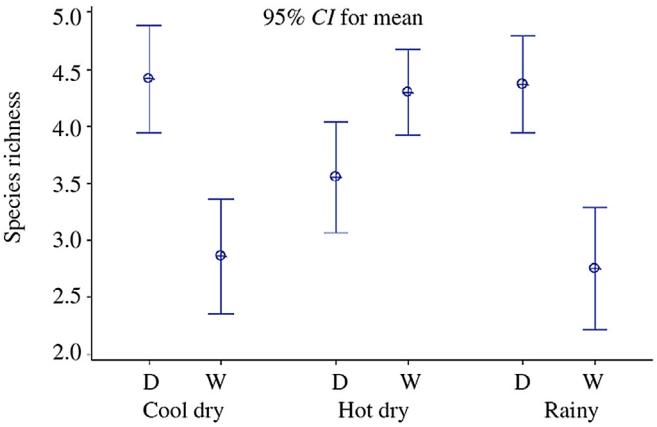

Figure 1. Seasonal parasite species richness of wild (W) and domesticated (D) guineafowls (*N. meleagris*) in Zambia ($n = 198$).

3.3. Seasonal trends

Overall, the most numerous parasites species per bird encountered were *A. suctoria*, in the caecum followed by *Heterakis* spp. and *A. spiralis*. There were no overall seasonal differences in mean total nematode burden per bird (ANOVA $F_{2,196} = 0.76$, $P = 0.467$, mean ± SD of cool dry season: 102.04 ± 91.33; mean ± SD of hot dry season: 114.28 ± 79.34; mean ± SD of rainy season: 120.10 ± 90.11). Although there was a progressive increase from the cool dry season to the hot dry season with the rainy season having the highest mean total nematode burden of per bird (Figure 2). There were no

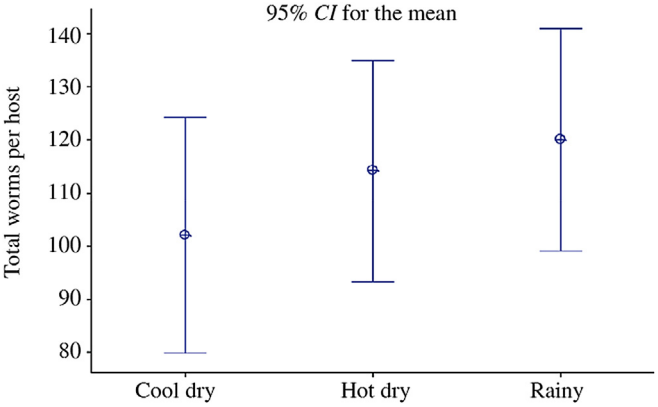

Figure 2. Overall seasonal trends of intensities of infection of helminths in guineafowl in Zambia.

Table 2
Multi-infection of guineafowls by number of helminth species [*n* (%)].

Guineafowl	Number of co-infecting helminth species						
	1	2	3	4	5	6	7
Domestic ($n = 148$)	12 (8.1)	14 (9.5)	24 (16.2)	27 (18.2)	36 (24.3)	27 (18.2)	8 (5.4)
Wild ($n = 50$)	1 (2.0)	11 (22.0)	15 (30.0)	13 (26.0)	10 (20.0)		
χ^2 ($df = 1$)	2.273[b]	5.328	4.489	1.395	0.392		
P value	0.132	0.021[a]	0.034[a]	0.238	0.531		

[a]: Significant difference in proportions of guineafowl with that species between domestic and wild; [b]: One cell with expected counts less than 5.

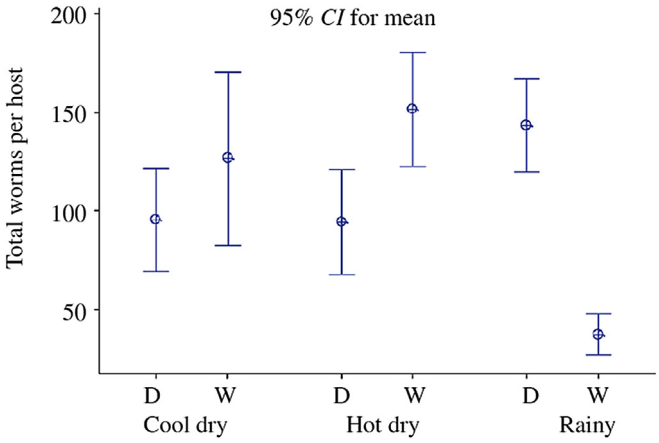

Figure 3. Seasonal trends of intensities of infection of helminths in guineafowl in Zambia between domestic (D) and wild (W) guineafowls.

differences in helminth intensities in domestic birds across seasons, but in the wild fowls, the rainy season had significantly lowered helminth intensities than the dry seasons. The domestic fowl also had significantly higher helminth burdens than the wild during the rainy season (Figure 3) There was also no overall seasonal difference in species richness (ANOVA $F_{2,196}$ = 1.66, P = 0.193, mean ± SD of cool dry season: 4.23 ± 1.70; mean ± SD of hot dry season: 3.71 ± 1.40; mean ± SD of rainy season: 4.17 ± 1.64). However, there were differences in species richness between domestic and wild guineafowls during the cool dry season as well as the rainy season (Figure 1). *Heterakis* spp. were only found during the cool dry season and the rainy season (Figure 4) and the only fowl with *S. trachea* was seen during the rainy season. The nematode *S. pectinifera* was only seen during the hot dry season (Figure 4).

3.4. Sex

There was a significant difference in mean total number of enumerated helminths per host between male and female guineafowls in domestic birds, with the females having more helminths than the males (mean ± SD of overall nematode burden of female: 151.90 ± 104.22, *CI*: 128.4–177.8; mean ± SD of overall nematode burden of male: 79.60 ± 60.28, *CI*: 66.8–94.4). There were no differences in species richness between sexes

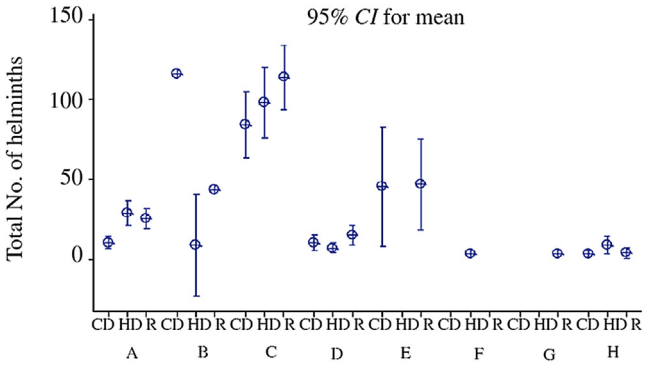

Figure 4. Overall nematode species abundance in guineafowl in Zambia. CD: Cool dry season; HD: Hot dry season; R: Rainy season; A: *A. galli*; B: *A. spiralis*; C: *A. suctoria*; D: *G. ingluvicola*; E: *Heterakis* spp.; F: *S. pectinifera*; G: *S. trachea*; H: *Tetrameres* spp.

(ANOVA $F_{1,147}$ = 0.00, P = 0.96, mean ± SD of overall species richness of female: 4.21 ± 1.57; mean ± SD of overall species richness of male: 4.20 ± 1.67). There were no differences in individual helminth species burden between the sexes for the following species in domestic fowl: *A. galli* (ANOVA $F_{1,92}$ = 4.09, P = 0.046) and *Tetrameres* spp. (ANOVA $F_{1,18}$ = 0.00, P = 0.986, mean ± SD of female: 4.33 ± 3.00; mean ± SD of male: 4.36 ± 4.13). There were differences between the sexes for *A. suctoria* (ANOVA $F_{1,129}$ = 28.67, $P < 0.01$, mean ± SD of female: 138.98 ± 91.48; mean ± SD of male: 69.94 ± 53.43) and *G. ingluvicola* (ANOVA $F_{1,79}$ = 17.09, $P < 0.01$, mean ± SD of female: 18.19 ± 19.09; mean ± SD of male: 5.21 ± 4.66). The results were also comparable with the wild guineafowls.

4. Discussion

Little is known about the prevalence and fauna range of parasites in guineafowl and this study is the first of its kind to be carried out in Zambia to address this dearth of information. In the Southern African region, there are only reported studies on the parasites of guineafowls in South Africa [1,23]. This study clearly shows that the parasite fauna of guineafowls differs with that of free-range chickens reported in Zambia [24] and there are differences in species richness between the wild and domesticated guineafowls. The study also shows that guineafowls in Zambia have more helminth parasite species per host than free-range chickens in Bangladeshi, where only three to six species were reported [2,25]. This study also reports for the first time the presence of helminths, namely, *S. trachea*, *S. pectinifera* and *A. spiralis* in guineafowl in Zambia. *Streptocara* and *Acuaria* have been reported in other tropical countries in the Asian sub-continent [26]. Similar to the findings in South Africa of Junker *et al.* [1] and Davies *et al.* [23], all the guineafowls examined were parasitized. This is similar to the situation found in chickens in Zambia [24]. This however, is unlike with the findings of Shukla and Priti [3] who found a prevalence of 90.2% and 53% in Madhya Pradesh and Nnadi and George [14] in chicken and in Nigeria who found a low prevalence of 35.5%.

Similar to the findings of Phiri *et al.* in Zambian chickens, *A. suctoria* was the most abundant helminth species found in the guineafowl followed by *A. spiralis* [24]. Junker *et al.* also found that *A. suctoria* was the most common and abundant helminth species in guineafowl [1]. There was no significant difference between these two species although *A. spiralis* was significantly more during the cool dry season than the proceeding hot dry season and rainy season had a very wide standard deviation. *Tetrameres* spp. prevalence and intensity of infection was found to be low in domestic and wild guineafowls. The prevalence of *Tetrameres* spp. was lower than previously reported by Davies *et al.* in South Africa who found a prevalence of 14.6% [23]. Its prevalence has been shown to decrease with increasing age in chickens. Thus, since most of the guineafowls examined were adults, this could be the plausible explanation for the observation. *S. trachea* is reported in this study for the first time in Zambia. Its prevalence is very low as it was only found in a single host with a correspondingly low intensity of infection. A previous study in chickens in Zambia [24] did not find any *S. trachea* and neither was it reported in two studies carried out in guineafowl in South Africa [1,23]. Weather factors in

Zambia may be unfavourable for the proper development of *S. trachea* compared to weather factors described in Europe where levels of *S. trachea* are higher [4,27]. In other tropical countries such as India where *S. trachea* is reported in poultry, the levels are also very low [28]. *A. spiralis* is also reported in this country for the first time. *Acuaria* has been reported in free-range poultry in other countries such as Bangladesh [25,26]. In this study, *Heterakis* was present in the rainy season and cold dry season but absent during the hot dry season. This study found a low prevalence of *Heterakis* spp. in guineafowls despite the fact that *Heterakis* has been reported at a moderate prevalence in free-range chickens at 32.8% in Zambia [24], and in guineafowls and chickens in sub-region of other countries (Verster and Ptasiniska-Kloryga) [1]. However, unlike all these studies, Mwale and Masika did not find any *Heterakis* in chickens in South Africa [15].

Unlike with the findings of Phiri *et al.*, this study found helminth *S. pectinifera* in the gizzard of a single guineafowl [24]. This helminth is reported for the first time in Zambia. Similar to findings of Katoch *et al.*, chickens and guineafowls in this study showed three species of *Raillientina*, namely, *Raillientina echinobothidria*, *Raillientina cesticillius* and *R. tetragona* [29]. Shukla and Priti only found two species of *Raillientina* [3]. This is unlike with other researchers who only found a single *Raillientina* species in chickens [25,30]. Other cestodes of guineafowl described by other researchers in Africa could have been absent from the guineafowl in this study primarily due to the absence of their specific intermediate hosts that range from slugs, snails, frogs and unknown others or other ecological factors [1]. The absence of intermediate hosts leading to low prevalence of such helminths has been postulated by a number of researchers. Similar to other researchers in poultry endoparasites, this study did not find any trematodes in the guineafowl [1,7,23,24]. However, unlike with other studies, this cannot be attributed to the lack of the intermediate host since snails are often present during the rainy season of each year in the study area [1].

Intensity of infections and overall species richness in this study were lower than described in guineafowl in South Africa [1,23]. A possible explanation is that this study captured older fowls and studies have shown that nematode burdens decrease with increasing age [23]. Similar to Junker *et al.*, this study did not find any significant differences in species richness between gender and there was not any significant difference between seasons [1].

Female guineafowls had a mean of 151.9 helminths per host which was significantly more than the males that had a mean of 79.6 per host. This sex bias in worm burdens does not agree with findings by other researchers [31] who found that male grouse had higher occurrence of *Ascarids* than females or those who found no sex bias [2]. It is however, similar to Davies *et al.* who found females guineafowl with a higher helminth burdens than males in local chickens [3,23]. The possible reason given for this is that females have a longer caeca and small intestines and these result in a larger helminth habitat in the females that result in higher burdens. Unfortunately, morphometric analysis of the guts was not done in this study to verify this possible correlation. This would be a useful study to undertake in the future. Unlike these studies that found a bias, Ibrahim *et al.* [8] and Junker *et al.* [1], found no sex bias in a study of helminths of ostriches in Nigeria and guineafowls in South Africa respectively. Species specific sex differences have also been shown within the same chicken population where males show a higher prevalence of some species meanwhile the females show a higher prevalence of other species [3]. Unlike other researchers who found only a greater proportion of free-range poultry being infested with helminths [32], this study found that all the guineafowls had at least one helminth species. The *Tetrameres* in this study were classified as of the genus *Tetrameres* only since we were unable to distinguish between *Tetrameres americana* and the recently described *Tetrameres numidae* in guineafowl [16].

Even with 100% prevalence and moderate infection burdens, the presence of helminths in these hosts seemed to have no outward negative sequela on the birds as there was no correlation between body weights and species richness. This is unlike with the findings of Rahman *et al.* who found that a large proportion of chickens that were parasitized with helminths and were poor body condition [7]. Helminth burdens have also been shown to reduce body weight gains in poultry [29]. Other researchers also found that larger-sized poultry had lower helminth burdens and speculated that this was due to a better immune response in larger hosts [33]. However, higher individual total helminth burdens were found in heavier hosts. No possible explanation could be ascribed to this paradoxical finding. It however, still demonstrates that the worm burdens at the level found in the guineafowl from this study have no serious negative effect to the overall health of the birds. Wild rheas (*Rhea americana*) have also been shown to have a rich helminthic fauna with no associated disease [10]. Some researchers report only local immune responses to helminth infestations [34].

This study did not show differences in mean worm burdens between domestic and wild guineafowls which is different from the findings of Zettermann *et al.* in rheas (*Rhea americana*), who postulated that captive birds have higher burdens due to the younger average age available for sampling than the older animals that are available from the wild cohort [10]. In partridges, Millán *et al.* also found that domestic birds have different and lower species richness than the wild ones, sharing only one common cestode species [35]. The findings in this study may be due to the limited foraging area that domesticated fowl are, resulting in relatively high levels of re-infection, comparable to natural infections in wild fowls. In this study, wild fowls had higher mean intensity of cestodes compared to domestic guineafowls and this could be attributed to the fact that domestic fowls are more likely to be predominantly granivorous than their wild counterparts that are more likely to eat a lot of insects and beetles that may be intermediate hosts for these cestodes [1]. However, the domestic birds had higher species richness than the wild birds. The findings of gastrointestinal parasite prevalence and species spectrum in guineafowls in this study are different from that of chickens in Zambia and in Ethiopia [24,32]. The proportion of monoxenous helminth parasites in this study was lower than reported in chickens in Zambia. This may be due to the fact that guineafowls eat more insects and thus, are more likely to harbour more heteroxenous species [24]. Wild avian species are reported to generally have higher heteroxenous species than domestic species [35]. In the domestic rural set up, chickens and guineafowls tend to be raised together and live side by side. It thus, would be interesting to perform molecular analysis of rDNA of the parasites of domestic and wild poultry species that interface to

determine if they are genetically similar or they are completely different species.

In conclusion, this study reports for the first time the presence of *S. trachea*, *S. pectinifera* and *A. spiralis* in guineafowls in Zambia. The results from this study also show that at moderate infestation burdens, the helminths in both domestic and wild guineafowls do not seem to exert very serious untoward health effects on the birds. The study also opens up opportunities for further research in molecular similarities of parasites of guineafowls in wildlife/domestic animal interface areas.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

This research was supported by the University of Zambia under UNZA-MAN No: 07193. The authors are grateful for the technical assistance provided by Mr. Maxwell Masuku and Mr. Chembensofu at the University of Zambia and Mr. Frederick Milambo. The authors are grateful to Minister of Tourism and the Zambia Wildlife Authority (ZAWA) for granting permission to carry out the sampling of the wild guineafowl in Namwala by granting a special bird hunting licence. The authors are also grateful to Mrs. P Banda-Chishimba for the data entry.

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