



Strongylid Nematode Infections of Humans, Ruminants and Pigs in Kumasi, Ashanti Region of Ghana

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Authors' contributions

This work was carried out in collaboration between both authors. Author CA carried out the survey and sample processing and examination and wrote the draft of the manuscript. Author BWL conceived, designed and advised on the study and its implementation and also reviewed the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: Human *Oesophagostomum* infections are considered zoonotic. In Ghana, the human infections are known to be focally distributed in the north-eastern parts of the Northern and the Upper East regions. Factors involved in the distribution of the human infection are not clear. It is also not known whether the human and animal infections occur outside these regions. The present study, therefore, sought to determine the types of strongylid nematode parasites infecting ruminants and pigs and also, whether human *Oesophagostomum* infections occur in Kumasi.

Study Design and Methodology: Stool samples were obtained from Hospital outpatients, abattoir workers and dealers in ruminants and pigs in Kumasi, processed by coproculture and examined microscopically for strongylid nematode larvae.

Results: No human *Oesophagostomum* infections were detected in the sampled Hospital

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outpatients, abattoir workers and dealers in ruminants and pigs. However, there were infections with *Necator* sp. and *Strongyloides stercoralis* at prevalences of 8.4% and 7.4%, respectively. Prevalences of *Oesophagostomum* in the animals sampled, during the rainy and dry seasons were 39.9% and 49.5% respectively for pigs: 41.9% and 16.1% for cattle: 44.1% and 15.1% for sheep: 37.1% and 38.2% for goats. These prevalence levels were comparable to prevalences obtained in a study conducted in sampled population of human, ruminants and pigs at the Bolgatanga slaughterhouse in the Upper East Region of Ghana.

Conclusion: The results may be indicative of different species of *Oesophagostomum* being infective to humans and the various animals. Further investigations into the conditions that determine the presence and transmission of the human and animal parasites are recommended.

Keywords: Strongylid nematodes; *Oesophagostomum* sp. Humans; pigs; ruminants; Kumasi.

1. INTRODUCTION

Helminth infections are endemic in areas where environmental sanitation is poor and health education virtually non-existent [1]. Studies in Latin America [2] indicate that intestinal parasites are prevalent in both rural and urban populations. High prevalence in urbanized developing countries has been attributed to poor sanitary conditions of low income populations, being worse in overcrowded cities than in most rural communities [3]. Intestinal parasitic infections are encountered as occupational hazards by workers whose job brings them into contact with soil, soil contaminated materials or contaminated water.

Strongylid nematodes are parasites of mammals (including humans and domestic animals). Identification of these nematodes by demonstration of eggs is hampered by the fact that they all produce morphologically identical eggs described as strongyle in appearance [4]. *Oesophagostomum* species are strongylid nematodes usually parasitizing monkeys, pigs, sheep, goats, cattle, camels and antelopes. Human infections are rare. Reports in literature according to Krepel et al. [5], include those from Brazil (1910); Nigeria (1911 & 1913); Guinea (1920); Indonesia (1949, 1989 & 1992); Ivory Coast (1958 & 1975); Uganda (1972) and Malaysia (1992). Besides these earlier reports, human oesophagostomiasis has been reported in northern Togo and in the north-eastern border area of Ghana with Togo [5-9].

Three species of *Oesophagostomum* have been recognised as causing occasional infections in humans, namely, *O. oculoatum*, *O. bifurcum* and *O. stephanostomum*. Polderman et al. [8] demonstrated that man was a definitive host to *O. bifurcum* in northern Togo and Ghana. Further studies of the human infection in parts of the

northern region of Ghana [10,11] yielded prevalence values ranging up to 87%. Studies on the taxonomy, treatment and transmission of *O. bifurcum* have also been undertaken [12,13]. In humans, the infection is noticed as an epigastric or peri-umbilical mass, described as "The Dapaong Tumor" after the town in northern Togo where it was first described [7].

Oesophagostomum columbianum is reported as a pathogen of sheep, whilst *O. radiatum* and *O. dentatum* occur in the colon of cattle and pigs respectively [14]. Transmission is believed to occur by ingestion of infective third stage larvae (L₃). Thus, poor hygienic conditions of communities especially where pigs and ruminants live close to human dwelling could facilitate the transmission. It was, however, not known which ecological and behavioural factors are key to the focal distribution and the high local prevalence of the infection. Nevertheless, the role of pigs as carriers of *O. bifurcum* and *Necator americanus* have been documented [15].

The relationship between the human and animal infections is not clear as different species are reported to infect humans, ruminants and pigs. *Oesophagostomum* infections have not been reported in Kumasi although Prof. Amon Kotei (personal communication) reported seeing nodular swellings on the intestines of three humans during separate autopsies at the Komfo Anokye Teaching Hospital in Kumasi. The present study was, therefore, undertaken to determine whether human *Oesophagostomum* infections occur in Kumasi and to determine the types and prevalence levels of related strongylid nematode infections in pigs and ruminants slaughtered at the Kumasi Abattoir. In a related study conducted in Bolgatanga, (community endemic to human *Oesophagostomum*) in the

Upper East Region of Ghana, prevalences and intensities of *Oesophagostomum* and related strongylid nematode infections were determined in the abattoir workers as well as in sampled groups of ruminants and pigs [16].

2. MATERIALS AND METHODS

2.1 Study Population

2.1.1 Humans

The study population consisted of three groups of people. The first group was individuals who reported at the major health centers in Kumasi with stool samples for laboratory examination. The second group were workers at the Kumasi abattoir and the third group were cattle dealers and herdsman. All persons investigated were registered by name and identification codes on questionnaire forms. Each questionnaire had two parts. The first part dealt with the background information on the individual. Information relating to residence, ethnicity, age, and occupation was obtained by interview. The second part dealt with the results of the parasitological examination.

2.1.2 Ruminants and pigs

Animals sampled in were those brought to the abattoir for slaughter where every second cattle, sheep and goats to be slaughtered in a day was sampled. All pigs brought for slaughter during a visit was sampled (due to low numbers).

2.2 Collection of Stool/Fecal Samples

Individuals recruited for the study at the slaughterhouses and cattle markets were volunteers who consented and willingly provided samples of their stool for examination after the purpose of the study was explained to them. At the hospitals, samples were collected from patients who presented at the laboratory, on request by the medical officer, stool for diagnostic examination. Each person sampled was given a plastic container with identification code number for their stool samples. A total of 1428 stool samples were collected; 1379 from the hospitals, 428 from Kumasi abattoir workers, cattle dealers and herdsman.

At the slaughterhouse samples were taken directly from the colon of each animal at slaughter with clean short sticks into clean, individually labeled, plastic containers. Sample

sizes were based on the availability of the animals during the sampling period and are presented the Table 1:

Table 1. Sample sizes of ruminants and pigs at the Kumasi abattoir

Animal host	Sample size
Cattle	563
Sheep	321
Goats	34
Pigs	311

Approximately 3 grams of stool were collected and taken to the laboratory for culture. Each stool sample was cultured in duplicate (1 gm each) on the day of collection. Each gram (1 gm) of faeces was mixed with same weight of vermiculite and processed for coproculture.

2.3 Coproculture of Fecal Samples

A plastic disc (40 mm x 4 mm) was placed in the centre of a 9 cm diameter petri-dish (Fig. 1). A Whatman filter paper of 8 cm diameter was placed on the plastic disc and a little distilled water was introduced into the petri-dish to the level just below the top of the plastic disc. One gram of stool was mixed with an equal quantity of vermiculite and transferred onto the moist filter paper. The stool-vermiculite mixture was left in culture at room temperature for seven days and stirred every other day to aerate it. Eggs of nematodes present in the stool hatched into larvae, wriggled out of the stool-vermiculite mixture into the clean water in the petri dish. On the eighth (8th) day of culture, the fluid containing L₃ larvae was harvested into separate conical tubes. The petri-dishes were rinsed once with distilled water and added to the content of the conical tubes. A sedimentation time of at least two (2) hours was allowed for the larvae to settle and 100 µl of sediment was observed using x10 and x40 objectives of the light microscope after staining with a drop of diluted Lugol's iodine. Two readings were made for each sample and the mean larval counts calculated. Photographs of larval specimens were taken at x100 or x400 magnification. Identification of filariform larvae was based on their respective characteristic features as indicated by Little [17].

3. STATISTICAL ANALYSIS

The data collected were entered into SPSS (windows) and the prevalence and intensity of

infections computed. Prevalences of infection were given as the percentage of individuals infected with a parasite out of the number examined and the intensity of infection computed from mean larval counts in 100 µl of sediment of the culture fluid. Significant differences were determined at 5% level, using one-way ANOVA (LSD) after outliers were removed using the Pearson and Hartley, Biometric Tables for statisticians [18].

4. RESULTS

4.1 Human Strongylid Nematode Infections

No human Oesophagostomum infection was detected in this study. However, there were *Necator americanus* and *Strongyloides stercoralis* infections. Table 2 gives details of the prevalence of hookworm and *Strongyloides* infections recorded in hospital outpatients. Prevalences were generally low. Ranging from

2.0% to 8.6% for *Necator americanus* and 3.0% to 12.3% for *Strongyloides stercoralis*. The highest prevalence for hookworm infections were recorded at the Kumasi South urban health center (8.6%).

At the cattle market and the Kumasi abattoir also, no human Oesophagostomum infection was detected in the sampled population of dealers and abattoir workers. However, prevalences of *Necator americanus* recorded in the dealers and the abattoir workers were 56% and 36.9% respectively, and for *S. stercoralis* it was 24% and 23.9% respectively (Table 3). Higher prevalence of infection was observed for both *N. americanus* and *S.stercoralis* among workers at the abattoir and cattle market than among the hospital out-patients (Table 2). Intensity values (mean no. of larvae/100 µl of stool culture sediment) recorded for both *N. americanus* and *S. stercoralis* infections were generally low (Table 3).

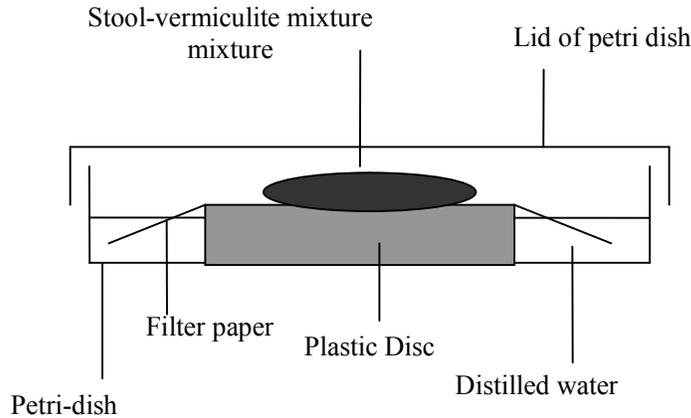


Fig. 1. Setup for coproculture

Table 2. Prevalence of *N. americanus* and *S. stercoralis* infections in outpatients of six Hospitals in Kumasi

Hospital	<i>N. americanus</i>		<i>S. stercoralis</i>	
	Number infected	Prevalence (%)	Number infected	Prevalence (%)
Tafo	21	8.1	4	5.4
UST	4	2.0	14	7.0
Kumasi South	19	8.6	9	4.0
Manhyia	15	7.5	6	3.0
KATH	7	3.3	11	5.2
North Suntresu	13	4.7	35	12.3
Total	79	5.7	79	5.7

4.2 Strongylid Nematode Infections in Ruminants and Pigs

4.2.1 Prevalence of strongylid nematode infections in ruminants and pigs

Strongylid nematodes identified in fecal samples of ruminants and pigs were *Oesophagostomum* sp., *Necator*, *Strongyloides* sp. and *Trichostrongylus* sp. In Fig. 2, the prevalence of *Oesophagostomum* infections in cattle, sheep, goats and pigs in Kumasi both in the rainy and dry seasons are presented. Generally,

prevalence values were higher during the rainy season. In pigs and goats, higher prevalences were recorded in the dry season.

Hookworm infection was detected in goats and pigs in the wet season and only in pigs in the dry season, in each case, at low prevalence. *Strongyloides* infections were, however, detected both in the dry and rainy seasons in the ruminants and pigs sampled (Table 4). Prevalence of *Trichostrongylus* infection was lower in the dry season than in the rainy season in the ruminants and pigs.

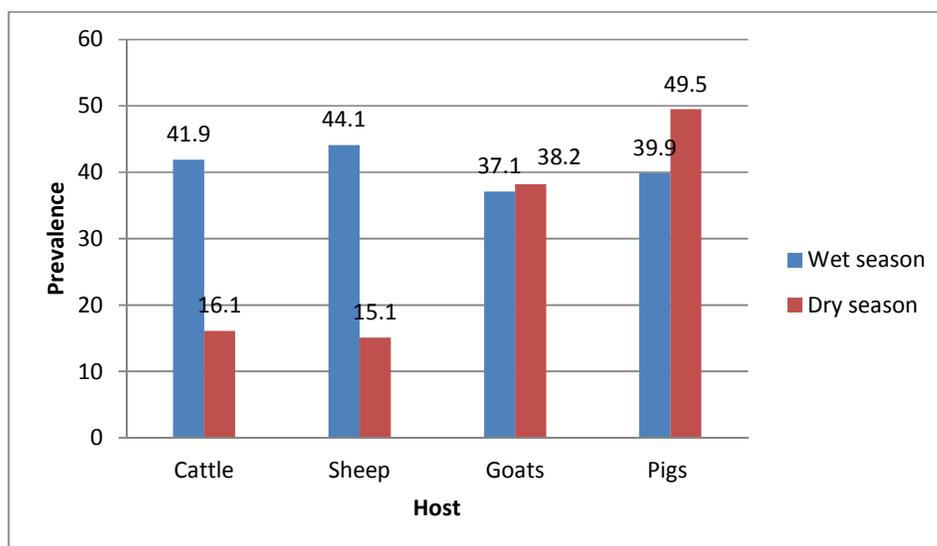


Fig. 2. Prevalence (%) of *Oesophagostomum* infections in cattle, sheep goats and pigs

Table 3. Prevalence and intensity of strongylid nematode infections in sampled population of humans in Kumasi

Parasite	Kumasi					
	Hospital		Cattle market		Abattoir workers	
	%	Intensity	%	Intensity	%	Intensity
<i>Oesophagostomum</i>	0.0	0.0	0.0	0.0	0.0	0.0
<i>Necator americanus</i>	5.7	9.7	56.0	6.4	36.9	9.5
<i>Strongyloides stercoralis</i>	5.7	7.6	24.0	5.4	23.9	17.7
<i>Trichostrongylus</i>	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Prevalence (%) of hookworm, *Strongyloides* and *Trichostrongylus* infections

Host	Hookworm		<i>Strongyloides</i>		<i>Trichostrongylus</i>	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Cattle	0.0	0.0	2.7	4.8	18.2	10.8
Sheep	0.0	0.0	16.6	9.1	26.3	14.5
Goats	4.8	0.0	17.3	15.6	19.5	10.8
pig	2.1	1.0	16.1	10.7	23.7	13.6

4.2.2 Intensity of strongylid nematode infections in ruminants and pigs

Intensities of *Oesophagostomum* infections were generally higher in the rainy season (Fig. 3). Pigs* showed the highest intensity of *Oesophagostomum* infection in the rainy season and this differed significantly from intensity in cattle ($P = .006$). Significant differences were also observed between goats* and cattle ($P = .002$) in the rainy season. During the dry season, differences were observed between pigs* and all the other animal hosts ($P = .000$) and between goats* and cattle ($P = .004$).

Table 5 presents intensities of hookworm, *Strongyloides* and *Trichostrongylus* infections recorded. A high intensity of hookworm infection was recorded in pigs (32.0 larvae/100 µl) during the dry season.

Intensity of *Strongyloides* infection were higher during the rainy season than in the dry season with pigs again recording the highest (24.1 larvae/100 µl; Table 5). However, significant differences were only observed in *Strongyloides* infection between sheep* and cattle ($P = .012$) and between goat* and cattle ($P = .003$). In the dry season, Significant differences were observed between goats* and cattle ($P = .015$) and also between goats* and sheep ($P = .031$).

Intensities of *Trichostrongylus* infections were also generally higher during the rainy season. Significant differences were observed in intensity

of *Trichostrongylus* infection between sheep* and cattle ($P = .011$), goat* and cattle ($P = .000$) and pig* and cattle ($P = .035$). In the dry season however, differences were observed between pigs* and cattle ($P = .027$).

5. DISCUSSION

5.1 Human Strongylid Nematodes

Results of the study indicate that *Necator* and *Strongyloides* species are the main strongylid nematodes infecting the study populations in Kumasi and is comparable to prevalences observed at the Bolgatanga slaughter house [16]. The comparatively higher prevalence observed for hookworm among the workers at the Kumasi abattoir and cattle markets could be explained by the fact that most of the workers are of northern origin where hookworm infections are reported to be endemic [10,11]. Nevertheless, the possibility of these workers contracting the infection in Kumasi cannot be ruled out since hookworm infections have been reported in Kumasi as well [19]. From responses to questionnaires administered it became apparent that majority of these workers live in compound houses and squatter settlements where basic sanitary facilities are virtually lacking. These facilities are also nonexistent at the cattle market. Since hookworm infections are found whenever unsanitary disposal of human excreta is common [20], this could explain the high prevalence observed (Table 3).

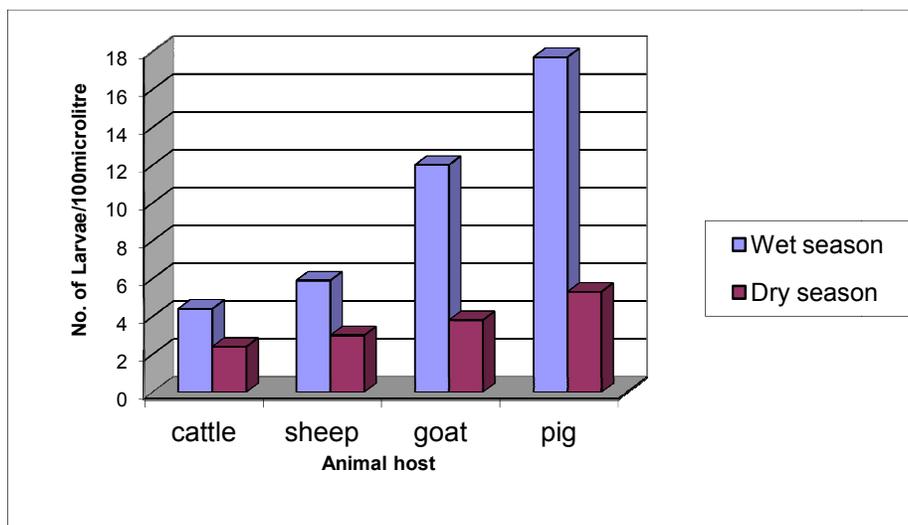


Fig. 3. Intensity of *Oesophagostomum* infection in ruminants and pigs

Table 5. Intensity of hookworm, *Strongyloides* and *Trichostrongylus* infection in ruminants and pigs

Host	Hookworm		<i>Strongyloides</i>		<i>Trichostrongylus</i>	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Cattle	0.0	0.0	7.1	4.3	2.5	1.8
Sheep	0.0	0.0	9.3	5.4	5.6	1.7
Goats	7.7	0.0	14.1	4.6	8.3	2.7
pig	5.0	32.0	24.1	5.5	19.5	3.5

None of the workers interviewed at the abattoirs (both in Kumasi and Bolgatanga) admitted suffering frequent ailments. Forty-eight percent of the workers at the Bolgatanga slaughterhouse also engage in farm work ranging from millet to paddy-rice farming and 44% of them also kept domestic animals [16].

Majority of the hospital outpatients are females who reported for routine antenatal check-ups. Only 41% of the patients including one male suffer frequent ailments ranging from fevers to stomach pains; 69% of the outpatients also work on farms and 93% keep domestic animals. Majority of the people interviewed do not take dewormers.

Generally, the prevalences determined for these strongylid infections in the human samples were low and confirm similar results from earlier studies [21]. Strongyloidiasis is quite rare [22]. According to Goldsmid [23] the prevalence of *Strongyloides* could be underestimated if it is based on a single specimen. On the other hand, hookworm larvae have longer life and greater resistance to adverse conditions than *Strongyloides* [24]. This could explain the higher frequencies of hookworm infection compared to *Strongyloides*. Also, *Strongyloides* species are known to have short latent periods [22] though they are capable of autoinfection. The ability to auto infect could affect the numbers of the parasite in each host. In worm endemic communities most individuals harbour few parasites and a few harbour heavy burdens [25].

5.2 Strongylid Nematodes of Ruminants and Pigs

Oesophagostomum infection in livestock is contracted through contaminated food and water [14]. The differences in prevalences recorded may be related to environmental or behavioral factors playing a role in transmission. It is known that the requirements of the infective larva and its previous stages determine the geographical distribution of the adult nematode [13].

Ingested L₃ larvae of *Oesophagostomum* penetrate the intestinal wall where they develop to young adults. The duration of this tissue-dwelling phase may be influenced by various factors notable among them being harsh environmental conditions [26]. It has been postulated that larval stages of some *Oesophagostomum* species do not normally continue their development to adulthood after the start of the dry season. The tissue-dwelling stage enters a dormant phase, to continue much later. Larvae of *O. radiatum* and *O. columbianum* have been shown to remain dormant for up to one year [26]. This postponement of development offers certain advantages to the parasite, so that the production of eggs would be highest during the season when conditions outside the host would be favorable for transmission. Also, it has been postulated that L₃ larvae undergo some form of aestivation during dry seasons. The rainy season, thus, provides suitable environmental conditions for the survival and transmission of the L₃ larvae, since the first and second stage larvae (L₁ and L₂) require abundant moisture to develop to the L₃.

Desiccated L₃ larvae collected from defaecation grounds have been shown to regain their motility and infectivity after they have been rehydrated under laboratory conditions [13]. An infective larva under favorable conditions can complete its cycle to adulthood within 41 days after infection implying that *Oesophagostomum* species can develop through a number of generations during the rainy season. This could account for the higher prevalences observed during the rainy season.

Prevalence of *Strongyloides* was also generally higher during the rainy season. *Strongyloides* larvae develop best in water-saturated soils with abundant organic material [27]. These conditions become available during the rainy seasons, thus favouring the transmission which occurs both orally and percutaneously. Also, *Strongyloides* larvae have only slight resistance to desiccation or marked changes in temperature. This

suggests that the rate of transmission may be reduced during the dry season.

The isolated cases of hookworm infections in the ruminants sampled suggested they are not natural hosts to the parasite. However, when they are exposed to a constant source of infection, they could become infected. Pigs, on the other hand, are known to feed on human excreta, so that a pig that feeds on hookworm infested stool will develop the infection. This was demonstrated by Steenhard et al. [15] when four parasite-free pigs were fed with fresh faeces from people heavily infected with *Oesophagostomum* and *Necator* whereupon third stage larvae of the two parasites were detected from the faeces of the exposed pigs after coproculture.

Ova and larvae of *Trichostrongylus* species require high humidity, abundant shade and the presence of grass or carpet vegetation for their survival. Infection with *Trichostrongylus* in animals thus occurs by ingestion of infective larvae on grass or vegetation. The rainy season, thus, provides the favorable condition for transmission (Table 4). However, if the favorable conditions are present in the local rearing environment of these animals during the dry season, high prevalences can be observed. This was observed in Bolgatanga, where higher prevalences were recorded during the dry season in cattle, sheep and pigs [16].

Generally, filariform larvae show tropisms which are characteristic of all strongylid larvae [28]. They are negatively geotropic, where they climb to the top of soil particles and positively phototropic to mild light. Thus, they will crawl up the grass blades in the early morning, towards the evening and at other times of the day during dull weather [14]. They are also markedly thermostatic and are rapidly stimulated into activity by the warmth of a nearby animal [28]. Moisture is necessary for these movements. All these tropisms would tend to increase the chance of infecting a passing host.

The intensity of *Oesophagostomum* infection (no. of larvae/100 μ l of sample) derived from the geometric mean values shows pigs as having the highest intensity during the wet season (Fig. 3). Similarly highest intensity was observed during the wet season in pigs in Bolgatanga [16]. This comparatively high intensity value, however, may not be attributed only to the coprophagic habits of pigs since the endemicity of a community to

human oesophagostomiasis has not been shown to bear any correlation to the level of infection in pigs. It is also known that pigs harbour certain host-specific *Oesophagostomum* parasites such as *O. dentatum*, *O. brevicaudum*, *O. georgianum*, *O. quadrispinulatum* and *O. granatensis* [14]. Moreover, third stage larvae (L_3) of *Oesophagostomum* species all have the same characteristic features when viewed with the brightfield microscope.

Though pigs are reared in Kumasi, most of the pigs brought to the Kumasi abattoir for slaughter are from northern Ghana. This information was disclosed during interactions with the dealers and customers to the abattoir who also disclosed the sources of ruminants (cattle, sheep and goats) slaughtered as being from various places including Burkina Faso, northern Ghana and from within the Kumasi metropolis. Thus, no specific reason could be attributed to the levels observed for hookworm infections in Kumasi.

The intensity of *Strongyloides* infection was highest in pigs during the wet season. Significant differences were only observed between sheep* and cattle ($P=.012$) as well as goats* and cattle ($P=.003$) (Table 5). Pigs also showed the highest intensity in Bolgatanga [16] in the rainy season and it differed significantly from intensity in cattle ($P=.005$), sheep ($P=.003$) and goats ($P=.002$), [16]. Sheep and goats are usually penned together, so that the differences observed could be due to differential host susceptibility of sheep and goats.

Again no specific reason could be given for the varying levels of *Trichostrongylus* infections in the animals except that this could be a result of the specific behavioural or animal husbandry practices in the communities. Significant differences were observed between infections in sheep* and cattle ($P=0.11$), goats* and cattle ($P=.000$) as well as pig* and cattle ($P= 0.35$) during the rainy season.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Human *Oesophagostomum* infections were not detected in Kumasi during the study period. Infections with the other strongylid nematodes such as *Necator* and *Strongyloides* were, however, detected. An observation, confirming

that made in an earlier study in Bolgatanga in the Upper East Region of Ghana.

Oesophagostomum infections occurred in cattle, sheep and goats, and in pigs in Kumasi.

The possibility of zoonotic infection exists if the species infecting ruminants or pigs are also infective to humans.

6.2 Recommendation

A further study on the species of *Oesophagostomum* infecting the various animal hosts is recommended in order to ascertain their similarity and/or ability to infect humans. Such studies should include DNA analysis and characterization of the various species.

Control measures need be put in place through healthy animal husbandry practices, personal hygiene and health education.

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COMPETING INTERESTS

The authors declare that there are no competing interests.

REFERENCES

1. Ukoli FMA. The socio-economic consequences and prospects for the control of parasitic diseases in Tropical Africa. In: Introduction to Parasitology in Tropical Africa. John Wiley & Sons, New York. 1984;3-17.
2. Canarini G, Batoloni A, Paradisi F, Nunez LE. Parasitological observation of three Bolivian localities including rural communities, cities and institutions. *Annals of Tropical Medicine and Parasitology*. 1989;83: 591.
3. Kan SP, Guyatt HL, Bundy DAP. Geohelminth infection of children from rural plantations and urban slums in Malaysia. *Trans Roy. Soc. Trop. Med. And Hyg*. 1989;83:817.
4. Cheesbrough M. Manual for Tropical Countries. 2nd Edition. Tropical Health Technology and Butterworths. England. 1987;1: 605.
5. Krepel HP, Baeta S, Polderman AM. Human *Oesophagostomum* infection in northern Togo and Ghana: Epidemiological aspects. *Annals of Tropical Medicine and Parasitology*. 1992;86:289-300.
6. Haaf E, van Soest AH. Oesophagostomiasis in man in Northern Ghana. *Trop. Geogr. Med*. 1964;16:743-56.
7. Gigase P, Baeta S, Kumar V, Brandt J. Frequency of symptomatic human Oesophagostomiasis (helminthoma) in northern Togo. In: Helminth zoonoses with particular reference to the tropics. Geerts S, Kumar V, Brandt J. (eds). Martinus Nijhoff, Dordrecht. 1987;228-35.
8. Polderman AM, Krepel HP, Baeta S, Blotkamp J, Gigase P. Oesophagostomiasis, a common infection of man in northern Togo and Ghana. *An. J. Med. and Hyg*. 1991;44:336-334.
9. Polderman AM, Blotkamp J. *Oesophagostomum* Infections in Humans. *Parasitology Today*. 1995;11(12):451-455.
10. Dery GB. Endemicity of human Oesophagostomiasis in the northeastern parts of northern region, Ghana. M. Phil. Thesis, Dept. of Biological Sciences, KNUST, Kumasi; 1999.
11. Storey PA. Human Oesophagostomiasis: Clinical presentations and subclinical colonic pathology. PhD Thesis, University of Leiden, The Netherlands; 2001.
12. Krepel HP. *Oesophagostomum bifurcum* in northern Togo and Ghana. PhD. Thesis, University of Leiden. The Netherlands; 1994.
13. Pit DSS. Diagnosis, transmission and immunology of *Oesophagostomum bifurcum* and hookworm infections in Togo. PhD. Thesis, University of Leiden, The Netherlands; 2000.
14. Soulsby E.J.L. Helminths, arthropods and protozoa of domesticated animals. 7th

- Edition. Bailliere Tindall, London. 1982; 187-191.
15. Steenhard NR, Storey PA, Yelifari L, Pit DSS, Nansen P, Polderman AM. The role of pigs as transport host of human helminths *Oesophagostomum bifurcum* and *Necator americanus*. *Acta Trop* 2000;76:125-30.
 16. Ahiabor C. *Oesophagostomum* and other strongylid nematode infections in humans, ruminants and pigs. M. Phil Thesis. Dept. of Biological Sciences, KNUST, Kumasi; 2002.
 17. Little MD. Differentiation of nematode larvae in coproculture: Guidelines for routine practice in medical laboratories. W.H.O. Tech. Rep. Series. 1981;666.
 18. Pearson ES, Hartley HO. Biometric Tables for Statisticians. Cambridge University Press. U.K; 1954.
 19. Larbi J. Intestinal parasitic infections of school children within the Kumasi metropolis. M. Phil Thesis. Dept. of Biological Sciences, KNUST, Kumasi; 1998.
 20. Blecka LJ. Concise Medical Parasitology. Addison-Wesley Publishing Company. Medical/Nursing Division, Menlo Park, California. 1984;291.
 21. Sarbah-Yalley E. A study of intestinal parasitic infections in patients visiting the Komfo Anokye Teaching Hospital, Kumasi. (B.Sc Project, Dept. of Biological Sciences. U S T, Kumasi); 1986.
 22. Feachem RG, Bradley DJ, Garelick H, Mara DD. Sanitation and Disease: Health aspects of excreta and wastewater management. World Bank Studies in Water Supply and Sanitation. John Wiley and Sons, London. 1983;3:501.
 23. Goldsmid JM. The African hookworm problem: An overview. In: Parasitic helminths and zoonoses in Africa. Craig, P. S. and Macpherson, C.N.L. (eds), Unwin Hyman Ltd., London. 1991;113.
 24. Cavalho. Cited in: Dery GB. Endemicity of human oesophagostomiasis in the northeastern parts of northern region, Ghana. M. Phil. Thesis, Dept. of Biological Sciences, KNUST, Kumasi. 1988;1999.
 25. Anderson RM, May RM. Helminth Infections in Humans: Mathematical models, population dynamics and control. *Advances in Parasitology*. 1985;24:1-101.
 26. Armour J, Duncan M. Arrested larval development in cattle nematodes. *Parasitology Today*. 1987;3:171-176.
 27. Belding DL. Textbook of Parasitology. 3rd Edition. Meredith Publishing Company. New York; 1965.
 28. Smyth JD. Animal Parasitology. 3rd Edition. Cambridge University Press, Great Britain; 1994.

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