



Toxoplasmosis in Humans and Animals in Ghana (1962 – 2020): A Review

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Toxoplasmosis is a worldwide zoonosis caused by the ubiquitous, Apicomplexan parasite, *Toxoplasma gondii*. This disease remains a significant aetiological factor in pregnant women and HIV patients. In Sub-Saharan African countries like Ghana, the low antiviral therapy coverage exacerbates the risk of HIV-related mortality resulting from concurrent infections like toxoplasmosis. This paper reviews published data on toxoplasmosis in both humans and animals in Ghana. Serological surveys in humans indicate high prevalence of toxoplasmosis (up to 92.5%) in a cross-section of Ghanaians, including pregnant women and their neonates, blood donors, as well as HIV and eye patients. Limited data from epidemiological surveys also show *Toxoplasma* infections in four food animals, with the prevalence ranging from 7.5% to as high as 64%. Molecular analyses in animals have also revealed three novel genotypes, TgCkGh1, TgCkGh2 and TgCtGh1. There are, however, no reports in other food animals like dogs, cattle and grass cutters in Ghana. The role of environmental matrices in the epidemiology of the disease also needs to be investigated. There is paucity of data in the Northern part of Ghana, with most reports concentrated on Southern Ghana, thus necessitating nationwide surveys under a 'One-Health' concept to inform management of the disease. Policies which mandate screening of expectant mothers and blood donors are recommended to limit disease transmission in Ghana.

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ABBREVIATIONS

AS	:	Ashanti Region
BA	:	Brong Ahafo Region
CR	:	Central Region
DT	:	Dye Test
ELISA	:	Enzyme-Linked Immunosorbent Assay
GAR	:	Greater Accra Region
HAT	:	Haemagglutination Test
HIV	:	Human Immunodeficiency Virus
KBTH	:	Korle-Bu Teaching Hospital
LAT	:	Latex Agglutination Test
NR	:	Northern Region
PCR	:	Polymerase Chain Reaction
UW	:	Upper West Region

1. INTRODUCTION

Toxoplasmosis is an opportunistic, parasitic zoonosis caused by the intercellular protozoan, *Toxoplasma gondii*, with felids as the definitive hosts [1]. This zoonosis is of both public health and veterinary importance, infecting at least one billion people worldwide [2]. *Toxoplasma* infections in immunocompetent people are typically asymptomatic, with more severe consequences in vulnerable groups, including children, HIV patients and pregnant women [3]. The high incidence of HIV infections coupled with the low Antiviral therapy coverage in Africa is of concern as it increases the chances of HIV mortality resulting from co-morbidity with diseases like toxoplasmosis [4]. Clinical manifestations of *Toxoplasma* infections may include headache, profuse sweating, retinochoroiditis, fatigue, fever, listlessness, muscle and joint pains [5]. Given similarities between symptoms of toxoplasmosis and diseases like malaria and influenza, there is a greater propensity of misdiagnosis, considering that malaria in particular remains endemic in Ghana.

Toxoplasmosis is a neglected tropical disease which is common in tropical countries like Ghana, where climatic conditions are suitable for the survival of the parasite [6]. In addition to climate, pet keeping, contact with soil, poor sanitation, free-ranging animals and lack of hand hygiene may also influence the distribution of the disease. So far, there is paucity of data on the disease and its impact on health in both humans and animals in Ghana. More epidemiological

surveys are needed for policy formulation in the management of the disease in Ghana. In this paper, the current status of *Toxoplasma* infections in humans and animals in Ghana are discussed.

2. MODE OF TRANSMISSION AND RISK FACTORS

Infections in humans can be broadly classified as either congenital or acquired. Acquired infections primarily result from ingestion of raw foods (meat, vegetables and fruits) and soil containing oocysts [7]. Transmissions through organ transplantation and blood transfusion have also been documented [8-10]. Congenital transmissions during pregnancy may result in serious consequences in neonates [11]. Reactivation of latent infections may also occur in immunocompromised individuals, including HIV patients [12]. Infections in non-felid animals result from ingestion of water or food containing sporulated oocysts shed through the faeces of infected cats. Infections in the definitive hosts result from consumption of meat of animals containing tissue cysts of the parasite [13]. The distribution of infection in these hosts is influenced by age and status of the cat (stray vs confined), with higher infection rates in stray cats. The prevalence of toxoplasmosis varies with geographical location, with several factors, including hot climates favouring survival of the parasite. Free-ranging animals exacerbate the risk of transmission, with higher infection rates in areas with poor sanitation.

3. HISTORY OF TOXOPLASMOSIS IN GHANA

The estimated population of humans in Ghana is over 30 million. The landmass is divided into 260 districts spread across sixteen administrative regions. Apparently, the first documented report of human toxoplasmosis in Ghana was published in 1962 by French as cited in [14]. The author provided evidence of the clinical manifestation of congenital toxoplasmosis in four children in Kumasi. A decade later, De Roever-Bonnet reported a reaction rate of 80% to a dye test. Following De Roever-Bonnet's report, Godwin and Remington showed anti-*Toxoplasma* antibodies in 49.5% of 225 Ghanaians using the same method in 1973 (as cited in [15]). In 1978, a report showed a prevalence of 57.1% in 364

adults and children, while antibodies were identified in 76% of 250 pregnant women tested in the same year [15, 16]. After that, several studies have reported varying prevalence of toxoplasmosis in a cross-section of Ghanaians, including pregnant women, eye patients, blood donors, children and HIV patients.

While data on human infections abounds, there is scanty information on animal toxoplasmosis, with only 6 published reports on animals [17-22] since the year 2000 when data were first published [17, 20]. These epidemiological studies highlighted the risk associated with consumption of meat of five animals, i.e. sheep, goats, pigs, cats and chickens. The increasing numbers of backyard farms and free-ranging animals in Ghana suggest that multiple animals may be involved in the transmission of the disease.

Researchers have employed both direct and indirect diagnostic tests in screening for *T. gondii* infections in Ghana. The dye test was the gold standard for early researchers in Ghana. This was followed by the haemagglutination and the indirect latex agglutination tests. In recent times, most investigators have employed the enzyme linked immunosorbent assay (ELISA), with only a few reports on the use of molecular tools. These methods are, however, expensive and may not be convenient for use in mass screening on the field. The development of rapid diagnostic test kits for toxoplasmosis is therefore needful. To date, membrane-based ELISA systems have shown promise for use in the detection of *T. gondii* antigens, though their efficacy needs to be further investigated [23].

3.1 Toxoplasmosis in Humans

There is relatively more data available on the disease in humans as compared to animals. Data from these surveys indicate a high seroprevalence of anti-*Toxoplasma gondii* antibodies in a cross-section of the Ghanaian populace. However, there are no reports on other high-risk groups, including abattoir workers, nomadic herdsmen and farmers who have regular contact with animals and/or their products. Most of the reports are concentrated on Southern Ghana, with no published data on the Northern part of the country. Data may, however, not be transferrable from one location to another owing to differences in epidemiological settings. The summary of

published reports of human toxoplasmosis in Ghana is presented in Table 1.

3.2 Toxoplasmosis in Pregnant Women and Children

Pregnant women have increased susceptibility to infections owing to physiological changes which can provoke immune suppression during the period [24]. Infections in this vulnerable group may result in insidious consequences, including spontaneous abortions and even the death of neonates. To reduce morbidity and mortality in neonates, pregnant women are periodically screened for congenital diseases. So far, three European countries, namely Slovenia, France and Austria have instituted national policies that mandate prenatal, serological screening for *T. gondii* [25]. This has resulted in a six-fold decrease in congenital transmission in women treated as compared to those without treatment in Austria [26], while France has seen a decrease in maternal toxoplasmosis, from 83% in 1965 to 37% in 2010 [27]. Despite documented evidence of congenital transmission of toxoplasmosis in Ghana, only *Plasmodium*, Hepatitis B virus (HBV) and HIV appear to be the focus of screening during pregnancy [28]. Available reports indicate a high seroprevalence in pregnant women in Ghana, ranging from 51.2 to 92.5% [29-33]. Major risk factors of maternal toxoplasmosis include cat ownership. and gravida status.

The rate of mother to child transmission of toxoplasmosis increases progressively with the gestational age [34]. Early detection of infections and administration of anti-*Toxoplasma* prophylaxis during pregnancy prevents congenital transmission and reduces sequelae in neonates [27]. Neonates and infants infected with toxoplasmosis may remain asymptomatic or present with several symptoms, including jaundice, cerebral calcification, transaminitis, vision loss, hydrocephaly, chorioretinitis, hepatosplenomegaly, hearing loss, and/or anaemia [25]. Serological tests in children in Ghana has shown an average prevalence of 58%. Detection of *T. gondii* DNA in placental tissues indicates a risk of congenital transmissions in Ghana [33, 35]. Surveys in women of child-bearing age indicate a prevalence of 61.1% [36]. These reports necessitate policies under a 'One-Health' concept that mandate prenatal screening as a tool for reducing the incidence of congenital toxoplasmosis.

Table 1. Summary of studies on *Toxoplasma* infections in Ghana highlighting the population surveyed and the prevalence

Author	Year of publication	Method	Location	Number tested	Prevalence (%)	Population surveyed	Ref. Number
Anteson et al	1978	HAT	KBTH, Accra	364	57.1	In-patients, Health pregnant women, Healthy adults and children	[15]
Anteson et al	1978	HAT	Mamprobi Polyclinic, Accra	250	76	Pregnant women	[16]
Anteson et al	1980	Indirect LAT	Accra	30	N/A	Mothers and their infants	[14]
Ayi et al	2004	DT, LAT, Membrane-based ELISA	N/A	80	66.3	Ghanaian patients	[23]
Ayi et al	2009	ELISA (Calbiotech Inc., CA) (IgA, IgG and IgM)	KBTH and Achimota Hospital, Accra	159	92.5	Pregnant women	[30]
Ayeh-Kumi et al	2010	ELISA (Calbiotech Inc., CA) (IgA, IgG and IgM)	KBTH, Accra	165	47.9	Ghanaian patients	[36]
Blay et al	2015	ELISA(IgG and IgM) PCR	KBTH, Accra	79 79	76.0 29.2	Pregnant women (Peripheral blood) Pregnant women (Placental tissues)	[33]
Abu et al	2016	ELISA (VEDALAB, Cerisé, France) (IgG and IgM)	Central Region	390	2.6	General population	[37]
Ayi et al	2016a	PCR	KBTH, Accra	148 149	54.7 3.4	HIV patients Healthy blood donors	[38]
Ayi et al	2016b	ELISA (IgG and IgM)	KBTH, Accra	57.6 51.2 58.0	125 125 200	HIV patients Pregnant women Children	[32]
Kwofie et al	2016	ELISA (IgG and IgM) ELISA ELISA PCR	KBTH, Accra	83 91 40 88	37.6 39.6 57.5 39.8	Mothers (Venous blood) Infants (Cord blood) Infants (peripheral blood) Mothers (Placental tissues)	[35]
Sefah-Boakye et al	2016	ELISA (Teco Diagnostics, 1268 N, Lakeview Ave., Anaheim, CA 92807, USA) (IgG and IgM)	Manhyia District Hospital, Kumasi	110	83.6	Pregnant women	[29]
Opintan et al	2017	PCR	KBTH, Accra	84	25.0	HIV patients with meningitis	[39]
Pappoe et al	2017	ELISA (IgG and IgM)	Three hospitals in the Central Region	394	74.4	HIV patients	[22]

3.3 Toxoplasmosis in HIV Patients

HIV infected individuals are at risk of multiple, opportunistic infections like toxoplasmosis owing to their immunocompromised state. As a result of low CD4+ count and reduced cytokine production, HIV patients infected with toxoplasmosis may suffer severe complications, including encephalitis, focal brain lesions, coma and even death [40]. Epidemiological surveys on prevalence of toxoplasmosis in HIV-infected patients range from 25.0% to 74.4% [22, 32, 36, 38]. A survey has shown 25% *Toxoplasma* infections in 84 HIV patients diagnosed of meningitis [39]. Another survey in HIV-infected adults showed that cerebral toxoplasmosis accounted for 27.5% of 222 patients who died during hospitalization [41]. Currently, the estimated national prevalence of HIV in Ghana is 1.7% [42], with less than half (44.1%) of infected persons receiving highly active antiretroviral therapy (HAART) [43]. This suggests that nearly 200, 000 HIV patients are at risk of mortality resulting from concurrent, opportunistic infections like toxoplasmosis. Given the wide array of opportunistic infections HIV patients suffer, it is imperative to routinely screen for microbiological aetiologies like toxoplasmosis to reduce complications and mortality.

3.4 Toxoplasmosis in Eye Patients

Toxoplasmosis can result in serious ophthalmic disorders, with at least a quarter (25%) of people infected with the parasite developing ocular toxoplasmosis [44]. Originally believed to be solely a result of congenital transmission, there is now growing evidence of ocular toxoplasmosis from acquired infections [45]. The prognosis of disease varies with the age of the patient, virulence of parasite strain, host genetic factors, as well as location, size and severity of *retinochoroiditis* [37]. Common clinical manifestations of ocular toxoplasmosis include retinochoroiditis, which may result in eye pain, blurred vision and eventually permanent vision loss [46]. A recurrence of infections in immune compromised individuals such as HIV patients, results in severe damage to the retina and choroid. An epidemiological survey on toxoplasmosis in Ghana reported toxoplasmic ocular lesions in 10 (2.6%) of 390 study subjects. *Toxoplasma retinochoroiditis* has also been reported in 11.8% of 17 patients presenting with

HIV-related ocular disorders [47]. Molecular analysis suggests that IFN- γ +874T allele exacerbates the risk of developing ocular lesions, while TNF-308A allele appears to protect against lesion development in a *T. gondii* infection [48].

3.5 Toxoplasmosis in Blood Donors

Blood transfusion is a life-saving intervention in the medical field, but could be a source of infections in the absence of proper screening for infectious agents prior to donation [49]. In Ghana, blood donation is preceded by testing for transfusion transmissible infections, namely Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human immune deficiency virus (HIV) and syphilis. Although post-natal infections of humans with *T. gondii* is possible through blood transfusion, there is no screening for this parasite in blood donors. A study among healthy blood donors in Accra revealed a prevalence of *T. gondii* DNA positivity in 3.4% (5/149) of the participants [38]. Out of the 5 who tested positive, 60.0% (3/5) were type I, while the remaining 40.0% were type II. There is also a report of 74% of healthy blood donors being seropositive for anti-*T. gondii* antibodies (unpublished data), as cited in [38]. Findings from these surveys indicate a risk of nosocomial transmission of toxoplasmosis from blood transfusion and organ transplants, thus necessitating consideration of pre-testing of blood donors for toxoplasmosis.

3.6 Toxoplasmosis in Animals

Toxoplasma gondii is known to infect warm-blooded animals, including sheep, chickens, goats and pigs, with felids as the only known definitive hosts. Similar to humans, infections in these animals result from ingestion of food and/or water containing the oocysts of the parasite. Infections with this coccidian parasite in animals have been associated with abortions, stillbirths and infertility [50]. So far there are few epidemiological studies on toxoplasmosis in livestock, including pigs, chickens and small ruminants (goats and sheep) in Ghana [17-22]. Assessment of infections in these animals is of interest as they serve as food for humans and may also be useful indicators of environmental contamination with oocysts. It is estimated that nearly a quarter of food-borne toxoplasmosis are of animal origin.

Table 2. Summary of studies on *Toxoplasma* infections in Ghana highlighting the animals surveyed and key findings

Author	Year of publication	Method	Location	Number tested	Prevalence (%)	Animals surveyed	Ref. Number
Arko-Mensah et al	2000	ELISA	UW/NR, AS/BA & CR/GAR	641	39.0	Pigs	[17]
Van der Puije et al	2000	ELISA	UW/NR, AS/BA & CR/GAR	526 732	26.8 33.2	Goats Sheep	[20]
Dubey et al	2008	MAT (heart and brain tissues) PCR	Kumasi	64	64.0 2 new genotypes identified and named as TgCkGh1 and TgCkGh2	Free-ranging chickens	[21]
Pappoe et al	2017	PCR (brain tissues)	Cape Coast Cape Coast Kumasi	25 40 30	24.0 7.5 0.0	Chicken Cat Goats	[22]
Antwi et al	2018	Histology	Kumasi Abattoir	100	42.0	Goats	[19]
Bentum et al	2019	ELISA (ID Vet, France)	Kumasi Abattoir	177 170	23.7 35.9	Goats Sheep	[18]

Livestock contribute significantly to the alleviation of protein malnutrition and poverty in many rural settings in developing countries like Ghana. While livestock remains the largest source of protein supply in Ghana [51], the industry faces significant animal losses, a result of several factors, including diseases like toxoplasmosis [52]. Diseases contribute to losses of animals, a situation which further impedes efforts at bridging the glaring deficit in protein supply. To date, there are no studies assessing the direct and indirect impacts of diseases like toxoplasmosis on the livestock industry. Early detection and management of toxoplasmosis in livestock is needful to avert losses and enhance productivity. The summary of published reports of human toxoplasmosis in Ghana is presented in Table 2.

3.7 Toxoplasmosis in Pigs

Increase in pig production, particularly at the smallholder levels coupled with increasing number of free-ranging pigs heightens the risk of pig-related zoonoses, including toxoplasmosis [53]. Despite the rapid increase in pig production over the past few decades, there is paucity of current epidemiological data on zoonotic infections like toxoplasmosis [54]. Given the increasing numbers of pigs in households, contrary to by-laws prohibiting such practices, confinement of these animals is needful to avert the transmission of zoonosis. Currently, pig meat is the leading source of animal protein worldwide, thus contributing significantly to the alleviation of protein malnutrition in developing countries like Ghana. Therefore, a failure to regulate the expanding pig production industry may be of dire consequences.

One of the first records of animal toxoplasmosis in Ghana was in pigs sampled from different ecological zones [17]. An estimated seroprevalence of about 40% was reported, which is higher than the overall estimated seroprevalence of 26.0% in pigs in Africa. Risk factors of seropositivity identified included age, breed and sex of the pigs. The significantly higher *Toxoplasma* infections reported in sows are of concern owing to the increased risk of transplacental transmissions. Additionally, toxoplasmosis in sows may result in significant economic losses as the disease has been implicated in abortions and stillbirths. Seropositivity in savanna areas were significantly higher compared to the forest belt, where most pigs were kept confined. Considering that antibody levels in animals is a function of

environmental exposure to oocysts, a lack of confinement of pigs further exacerbates the risk of infections. The findings of this study suggest that consumption of raw or undercooked pork may be a source of zoonotic *Toxoplasma* transmissions in Ghana.

3.8 Toxoplasmosis in Small Ruminants

Small ruminants can also serve as reservoirs for the coccidian parasite, *Toxoplasma gondii* [55]. Like other warm-blooded animals, infections could increase the risk of stillbirths and abortions in animals and zoonotic transmissions to humans who consume raw or undercooked meat. So far, there are only three published reports on toxoplasmosis in ruminants in Ghana [18-20]. The first report of toxoplasmosis in small ruminants was published two decades ago from animals sampled across three ecological zones in Ghana [20]. The study reported overall seroprevalence of 20.0%, 39.1% and 39.4% in Guinea Savannah, Forest and Coastal Savannah zones respectively. Sex, breed and age of the animal appeared to influence seropositivity in the small ruminants. The higher prevalence recorded in sheep (33.2%) compared to the goats (26.8%) could be a function of their feeding habits. Goats tend to browse, while sheep graze and therefore are more likely to come into contact with soil contaminated with oocysts [18]. Management practices and proximity of animals to cats, the definitive hosts of the parasite, may have also influenced seropositivity. Although nearly 4 out of 10 animals were seropositive, none of these animals was kept under the intensive system which ensures strict confinement of animals. These findings suggest an increased risk of ruminants getting into contact with sporulated oocysts in the environment.

Nearly two decades after the first report of toxoplasmosis in small ruminants, an investigation of *Toxoplasma* in goats was carried out in slaughtered goats in Kumasi (within the Forest zone). Histological examination of 100 slaughtered goats in that study revealed a prevalence of 42% [19]. The study also reported differences in prevalence according to age, breed and sex of the animals. However, that study could not be subjected to further review as the results were only published as an abstract. Following the histological examination, Bentum et al [18] also assessed the prevalence of toxoplasmosis in small ruminants by serology at the same location. The reported prevalence in goats and sheep were 23.7% and 35.9%

respectively. The seroprevalence reported in this study [18] was lower (23.7%) compared to the results of the previous sero-epidemiological study (26.8%) within the forest zone of Ghana [20]. Seroprevalence of toxoplasmosis in goats (23.7%) was also lower than the 42% recorded by histological examination within the same location. These findings suggest that consumption of improperly cooked meat from these animals may be a source of human toxoplasmosis.

3.9 Toxoplasmosis in Chickens

The poultry industry contributes substantially to protein supply worldwide, second only to pork as the leading source of animal protein. The absence of religious restrictions and competitive pricing make chicken an attractive option to consumers as compared to other animals. Efforts to increase productivity amidst the growing demand for animal protein is often met with constraints, including diseases. Although toxoplasmosis has been reported in chickens, it rarely results in disease owing to the high resistance of chickens to the parasite [56]. Free-ranging chickens are considered as the one of the best environmental sentinels for assessing contamination of soil with *T. gondii* oocysts because they feed off the ground [57]. Consumption of raw, infected tissues of chickens predisposes other animals to infections, including dogs and cats. In Ghana, there is scanty data on seroprevalence in chickens, with only two published reports [21, 22]. A report in chickens found antibodies to *T. gondii* in 41 out of 64 free-range chickens sampled from Kumasi, giving a seropositivity of 64.1%. Seropositivity in chickens in Ghana was higher than the 37.4% estimated prevalence following a systematic review and meta-analysis of toxoplasmosis in chickens in Africa [58]. The meta-analysis also showed the highest seroprevalence in chickens compared to five other animals commonly used for food. Other investigators found that chickens from Cape Coast showed *T. gondii* DNA in 24.0% of 25 animals sampled [22]. Findings from these studies provide insight on potential environmental transmission of *T. gondii* and also highlight the risk associated with consumption of raw or undercooked chicken.

3.10 Toxoplasmosis in Companion Animals

Companion animals like dogs and cats have been implicated in the spread of toxoplasmosis worldwide [59]. While pets can be found in

several Ghanaian homes, there is scanty data on the role these pets play in the transmission of zoonoses [54]. Cats act as the definitive hosts of the parasite, while dogs, like other non-felid mammals, may serve as intermediate hosts. Zoonotic transmission of toxoplasmosis from dogs is possible in three main ways. Dogs, through coprophagy, may ingest cat faeces containing sporulated oocysts and subsequently aid in environmental transmission by shedding intact oocysts as they defecate [60]. Secondly, dogs which tend to roll in soils infested with oocysts may harbour these oocysts in their fur which can be transmitted to humans through petting [61]. Consumption of raw or undercooked dog meat containing tachyzoites, the tissue form of the parasite, may also be a source of infections [62]. The high number of free-ranging dogs which tend to feed off raw meat products may play an active role in the transmission of the disease in Ghana [63]. On the other hand, cats get infected from consumption of viscera of animals such as rodents infected with the tissue form of the parasites. Stray cats in particular may introduce oocysts into the food chain by shedding sporulated oocysts into the environment. In a study of pregnant women, ownership and/or handling of cat litter boxes appeared to influence transmission of the disease [30]. The only available study on toxoplasmosis in cats reported positive *T. gondii* DNA in 7.5% of 40 cats sampled [22]. With the population of pets increasing in homes amidst security concerns [64], more epidemiological surveys in these companion animals are needed to inform management of the disease.

3.11 Toxoplasmosis in Other Food Animals

Cattle and grasscutters (*Thryonomys swinderianus*) also contribute to the protein supply in Ghana. So far, there are no documented reports of toxoplasmosis in these animals in Ghana. Consequently, reference is made to reports from Nigeria, a neighbouring West African country, from which animals like cattle are brought into the country [54]. Epidemiological surveys in Nigeria have revealed anti-*Toxoplasma* antibodies in cattle [65, 66]. Therefore, the frequent movement of animals across the borders without proper screening may introduce infections into the country. Nomadic herding of cattle also increases the chances of these animals ingesting oocysts as they graze. A meta-analysis of meat from animals in Africa revealed that cattle had the lowest, overall

estimated prevalence of toxoplasmosis of 12% (range – (8-17%)) as compared to other animals [58]. This could be attributed to the high natural resistance of cattle to the parasite [67]. Like cattle, grass cutters serve as a delicacy for many, particularly in the rural settings. While there are no surveys on toxoplasmosis in grass cutters in Ghana, it is noteworthy that a report in Nigeria revealed a seroprevalence of 100% in 104 grass cutters sampled [68]. Epidemiological surveys are needed to clarify the role these animals play in the distribution of toxoplasmosis in Ghana.

4. GENOTYPING OF STRAINS OF *T. gondii* IN GHANA

The severity of disease varies with the strain of the parasite responsible for the infection. Genotyping of isolates of *T. gondii* has revealed three major clonal lineages, type I, II and III as responsible for human toxoplasmosis [69]. Genotyping in Ghana revealed clonal types I, II and mixed types (I and II) in human subjects, with 93.8% of positive samples being clonal type II [38]. Genotyping of *T. gondii* in chickens in Ghana also revealed two unique genotypes - TgCkGh1 and TgCkGh2 [21]. Another genotype, TgCtGh1, not previously reported elsewhere was found in cats sampled from Kumasi, Ghana [22]. So far, there are few reports on genotyping of *T. gondii* in Ghana. Further molecular investigations are needed to gain a better understanding of the epidemiology of the disease.

4.1 Environmental Transmission of Toxoplasmosis

Environmental transmission of toxoplasmosis is possible through soil, water and food [7]. The detection of *Toxoplasma gondii* oocysts in environmental matrices has, however, proven a daunting task for researchers owing to the lack of standardized procedures [70]. An infected cat can shed millions of environmentally-robust oocysts with long-term persistence into the soil. Meanwhile, the ingestion of a single oocyst through contaminated soil, water, fruits or vegetables can cause severe infections in both animals and humans. As such, control of transmission through the environment is crucial in the management of the disease. To date, there is no documented study on *Toxoplasma gondii* in environmental matrices in Ghana, despite the importance of the parasite in food safety. Fruits and vegetables which are mostly eaten raw, with washing as the main method of processing prior

to consumption could aid in the transmission of the parasite. The recovery of multiple animal parasites from farm soils and irrigation water, as well as fresh vegetables and salads sold on Ghanaian markets [71-73], highlights the possibility of environmental transmission of *T. gondii* in Ghana. Toxoplasmosis is an important protozoan food and water-borne zoonosis [74], therefore there is the need to improve the poor food hygiene practices among vendors in Ghana.

5. CONCLUSION

Toxoplasmosis is a neglected, tropical disease in Ghana. So far, literature on the disease in humans abounds, with scanty information on animals. These serological and molecular surveys have revealed high prevalence of toxoplasmosis in humans and animals in Ghana. Detection of infections in pregnant women and blood donors necessitate policies which recommend screening in these groups. There is a dearth on information in the Northern part of the country, with most surveys concentrated in Greater Accra Region. Nationwide surveys under a One-Health concept are therefore recommended to inform management strategies on the disease.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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