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ORIGINAL ARTICLE

Rabies virus in slaughtered dogs for meat consumption in Ghana: A potential risk for rabies transmission

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Abstract

Dog-mediated rabies is responsible for approximately 60,000 human deaths annually worldwide. Although dog slaughter for human consumption and its potential risk for rabies transmission has been reported, mainly in some parts of Western Africa and South-East Asia, more information on this and factors that influence dog meat consumption is required for a better understanding from places like Ghana where the practice is common. We tested 144 brain tissues from apparently healthy dogs slaughtered for human consumption for the presence of rabies viruses using a Lyssavirus-specific real-Time RT-PCR. Positive samples were confirmed by virus genome sequencing. We also administered questionnaires to 541 dog owners from three regions in Ghana and evaluated factors that could influence dog meat consumption. We interacted with butchers and observed slaughtering and meat preparation procedures. Three out of 144 (2.1%) brain tissues from apparently healthy dogs tested positive for rabies virus RNA. Two of the viruses with complete genomes were distinct from one another, but both belonged to the Africa 2 lineage. The third virus with a partial genome fragment had high sequence identity to the other two and also belonged to the Africa 2 lineage. Almost half of the study participants practiced dog consumption [49% (265/541)]. Males were almost twice (cOR = 1.72, 95% CI (1.17–2.52), *p*-value = .006) as likely to consume dog meat compared to females. Likewise, the Frafra tribe from northern Ghana [cOR = 825.1, 95% CI (185.3–3672.9), *p*-value < .0001] and those with non-specific tribes [cOR = 47.05, 95% CI (10.18–217.41), *p*-value < .0001] presented with higher odds of dog consumption compared to Ewes. The butchers used bare hands in meat preparation. This study demonstrates the presence of rabies virus RNA in apparently healthy dogs slaughtered for human consumption in Ghana and suggests a potential risk for rabies transmission. Veterinary departments and local assemblies are recommended to monitor and regulate this practice.

KEYWORDS
dog, food handling, Ghana, rabies virus, zoonoses

1 | INTRODUCTION

Rabies is one of the most dreaded viral zoonotic diseases due to its high case fatality rate and affects multi-host mammalian species worldwide. It manifests as acute, progressive encephalitis, causing anxiety and confusion in affected persons. Death is imminent once signs and symptoms appear. Children under 15 years of age are most afflicted (Dodet et al., 2015; Gongal & Wright, 2011). An estimated 60,000 human deaths occur annually worldwide (Hampson et al., 2015). Rural settings in developing countries in Asia and Africa record approximately 56% and 43% of this figure, respectively (Hossain et al., 2012; Ngugi et al., 2018). Rabies continues to be neglected and underreported for reasons that include poor surveillance, inadequate laboratory capacity, and diverse cultural beliefs (Fooks et al., 2014). A section of people mainly in rural Africa still hold on to superstitious beliefs of witchcraft and sorcery to be responsible for rabies. Some cultures claimed that traditional medicine could cure rabies, including the use of dog parts (Ekanem et al., 2013; Gurumyen et al., 2020; Nel, 2013). This situation deprives affected areas of accurate data necessary for acting with the priority that rabies deserves.

Two critical public health measures to control rabies are mass vaccination of dogs and post-exposure prophylaxis (PEP) for exposed victims (Lavan et al., 2017; Mindekem et al., 2017). Notwithstanding, a study in Ghana revealed 76% of public health facilities did not have rabies vaccines for PEP. Furthermore, only 40% of health care providers responded they would administer PEP to dog bites victims (Kenu et al., 2018).

Domestic dogs are responsible for over 99% of human rabies fatalities in the world (Brunker et al., 2018; Vigilato et al., 2013; Ward, 2012). Bites from rabid dogs are the primary cause of rabies transmission in Africa (Jibat et al., 2015). In Ghana, 96.1% of all rabies cases originate from dogs, however, only 13–17% canine vaccination coverage was reported in the five-year period 2007–2011 (Lopes et al., 2018). Contamination of open wounds and mucous membranes with infectious saliva or nervous material represents a major mode of transmission (Barecha et al., 2017). Various organs could be infected posing threat for transmission to open wounds, however, the brain and cerebrospinal fluids, and secretion through the saliva which is sometimes intermittent present substantial route of transmission (Fekadu, 1993). Cases of rabies transmission through organ transplantation, although rare, have been reported (Srinivasan et al., 2005; J. Zhang et al., 2018; Zhou et al., 2016). Additionally, an important potential source often overlooked is exposure to the virus through trade, slaughter, and consumption of dog meat. Consumption of dog meat and the exposure while preparing dog meat has been reported in several parts of the world, mainly in West Africa (Ekanem et al., 2013; Garba et al., 2013; Odeh et al., 2014; Suleiman et al., 2020) and South-East Asia (Ahmed et al., 2015). A study by the Asian Canine Protection Alliance in China reported about 1.6% of non-bite rabies cases due to slaughter and dog meat consumption. Other studies have also implicated the practice of dog butchery and consumption as potential risk sources of rabies transmission in Nigeria among certain tribes through bites and exposure to infected tissues (Ekanem et al., 2013; Garba et al., 2013; Odeh et al., 2014).

As such, culture, religion, and geographical location are possible determinants of people's meat preference (Fuseini & Sulemana, 2018). In Ghana, some northern ethnic groups consider dog meat a major delicacy; however, people in southern regions abhor this practice (Ohene-Adjei & Bediako, 2017). Migration from the northern parts of Ghana to the middle and southern areas over the years has resulted in the diffusion of cultural practices with associated popularity of dog meat consumption (Lobnibe, 2016).

Slaughter of animals, including dogs, for public consumption, without veterinary inspection is in contravention of the Public Health Act 851 of 2012 and the Meat Inspection Regulations of 2020 (L.I.2405) of the Veterinary Services of Ghana. The regulations also determine slaughtering sites for livestock and game animals which are usually overseen by the local assemblies with technical support from the veterinary services directorate (FAO.org)

Although the practice of dog slaughter and consumption is patronized by certain tribes in Ghana, there is currently no study that explores its influence and the potential risk it poses for rabies virus transmission. This risk seems obvious as handling of dog meat without proper protective equipment is observed regularly (Figure 1). This study examined the presence of rabies virus RNA from apparently healthy dogs

FIGURE 1 The customary way of dog meat handling without protective gear. Picture was taken during this study

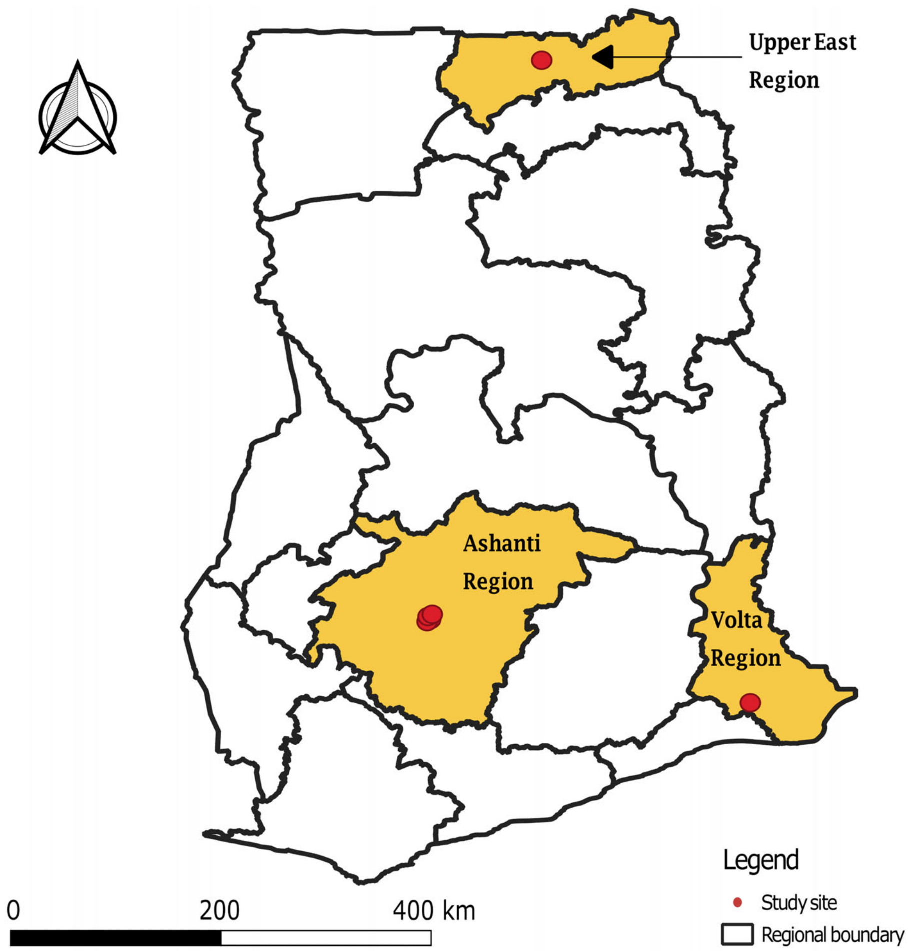

FIGURE 2 Map of Ghana showing study sites. The distribution of sites visited during the study. Yellow areas depict the administrative regions, and the red dots indicate the districts in which the study was conducted

slaughtered for human consumption and evaluated factors that could potentially influence dog meat consumption across the southern, middle, and northern zones of Ghana.

2 | MATERIALS AND METHODS

2.1 | Study area

The study was conducted in October–November 2018, and April–May 2019. The districts included as study sites were located in three different administrative regions of Ghana. The selected districts were Adidome in the Volta region which is in the South-Eastern part of Ghana sharing borders with the republic of Togo, Agogo in the Ashanti region also in the Southern part of Ghana and Bolgatanga in the Upper East region located in the Northern part of the country (Figure 2). These regions are dominated by their main tribes: Volta, Ashanti and Upper East are predominated by the Ewes, Ashantis, and Frafras, respectively. All other tribes encountered other than these were classified as non-specific for the purposes of this study. The study sites were geo-referenced and mapped as seen in Figure 2.

2.2 | Study method

The three regions and their corresponding districts were purposely selected based on reports of high dog slaughter obtained from veterinary staff. Insider information from persons involved in the dog trade and consumption was used in locating slaughter sites for this study. Five slaughter sites were found in the Ashanti region but only three were actively slaughtering during our sampling period. In Bolgatanga in the Upper East region, two sites were found, however insider information indicated dog slaughter in individual homes was a common practice. Due to higher demand and prices, slaughtered dogs in the Volta region were transported to neighbouring country Togo for sale and sampling was therefore not possible during the study period. Five slaughter sites comprising three in the Ashanti region and two in the Upper East region were therefore visited in this study. All slaughter sites were found in communities that could be considered rural to semi-urban denoting strong attachment to traditional customs. Prior visits indicated that approximately 250–300 dogs were slaughtered each month from the five selected dog slaughter sites combined, mainly on Fridays, Saturdays and Sundays when the demand was highest. Initial interactions with butchers revealed some hesitancy in selling solely dog heads to persons they deemed 'outsiders' of the business. Taking this hesitancy into account, we aimed to purchase approximately 20% of the monthly slaughter which translated into at least 60 dog heads for sampling per month for 3 months from all five sites. All available dog heads were considered for purchase. On average 48 brain tissues were obtained (range 40–60) per month, totalling 144 from Ashanti and Upper East regions.

Dog brain tissue samples were taken by a trained veterinarian, using a glass pipette through the foramen magnum (Yale et al., 2019). Brain tissues were stored in labelled tubes containing RNAlater in an −80°C freezer prior to shipment to the Institute of Virology, Charité, Berlin, Germany, for laboratory investigations.

Based on a similar study from Nigeria (Ameh et al., 2014), we aimed to obtain demographic and dog consumption practice data from 600 people in the 3 regions. Assembly members in the respective study communities were visited, informed on the purpose of the study and their assistance solicited. They in turn assisted by advocating the cooperation and participation of their community members. A day before questionnaire administration in each community, gong-gong beating, a local resonating percussion which calls the attention of the community members prior to announcements were used to convey reminders to the community on the arrival of the research team and the impending questionnaire administration the following day. In each of the selected districts, the bus station, which is usually central was purposely chosen as a reference point. A starting street was chosen randomly by spinning a bottle and the direction where the mouth of the bottle pointed was picked. The first household on the selected street was considered the starting point of questionnaire administration. Every other household having a dog was then selected as previously done in a study with similar settings and conditions in Nigeria (Ameh et al., 2014). A total of 541 persons consented and participated in the study. Structured questionnaires which collected data on sex, religion, cultural group, and dog consumption practices were administered to dog owners by trained veterinary technical staff who could speak the local languages. The veterinary technical staff provided guidance to the participants who could not fill out the questionnaires independently due to their inability to read the English language or felt more comfortable in their native languages. Questionnaire data from dog owners on dog meat consumption was taken to assess the factors that influence dog consumption. A nonparticipant observation approach was used to evaluate the slaughter process, assessing risk behaviours pertaining to the use of personal protective equipment (PPE) such as gloves, face shields and overcoats at all five dog slaughter sites.

2.3 | Laboratory investigation

Viral RNA was extracted using the RNeasy mini kit (Qiagen, Hilden, Germany) according to the manufacturer's instructions. Briefly, approximately 30 mg of brain tissue was lysed in 600 μl of RLT buffer containing 6 μl of 14.3 M β-mercaptoethanol. Tissue homogenization was performed using steel beads for 3 minutes in a tissue lyser (Qiagen, Hilden, Germany), and elution was done in a 100 μl of RNAse-free water. Real-Time PCR was performed using Roche LightMix® Modular Rabies (Lyssa) virus kit (TIBMolbiol, Berlin, Germany) according to manufacturer's instructions. RT-PCR positive samples were also processed by a High-Throughput Sequencing (HTS) approach or tested by a conventional RT-PCR followed by amplicon sequencing for confirmation and virus typing (Heaton et al., 1997). For HTS, library preparation was performed using the KAPA RNA Hyper Prep Kit (Roche Molecular Diagnostics, Basel, Switzerland) according to manufacturer's instructions. DNA libraries were sequenced on Illumina MiSeq and NextSeq machines (MiSeq Reagent Kit v3; 600-cycle, NextSeq Reagent Kit v3, 150-cycle) aiming at >5–50 Million reads per sample. HTS sequencing reads were mapped against reference strains from GenBank.

2.4 | Statistical and phylogenetic analysis

Statistical analysis was performed using GraphPad Prism 8, version 8.02. Data were presented as frequencies (percentages) and proportions. To determine potential factors associated with the dog consumption, we first employed univariate logistic regression analysis to determine crude odds ratios (cOR), followed by multivariate logistic regression to determine adjusted odds ratios (aOR), using the enter method for variables with p-values $< .05$ after univariate analysis, to identify independent risk factors. All tests were two-sided and a p-value $< .05$ was considered statistically significant. Phylogenetic analysis was done by maximum likelihood reconstruction using a general time reversible model with a gamma distribution and proportion of invariable sites (GTR+G+I) with the PHYML (Guindon et al., 2010) plugin in Geneious prime and 500 bootstrap replicates. Comparison of the full nucleoprotein coding region to those of a representative subset of African rabies viruses of various lineages inclusive of the whole diversity of available rabies viruses on the continent was performed (Sadeuh-Mba et al., 2017; Troupin et al., 2016).

3 | RESULTS

3.1 | PCR testing

Of the 144 apparently healthy domestic dogs slaughtered for human consumption, 2.1% (3/144) tested positive for rabies virus using Real-Time RT-PCR. Two of the three were confirmed to be rabies RNA positive using the HTS approach (Table S1). The third real-time RT-PCR positive sample could not be confirmed by HTS likely due to a lower viral RNA concentration compared to the other two samples, as indicated by a much higher PCR ct-value (35.75 vs. 25.58 and 21.97, Table S1). However, repeated RNA extraction followed by real-time RT-PCR testing targeting the nucleocapsid and polymerase region, followed by conventional PCR testing with a different assay also targeting the nucleocapsid region and amplicon sequencing confirmed the presence of Rabies RNA in this sample. The final genome coverage was 100% for two sequences. The HTS approach and sequence comparison

FIGURE 3 Phylogenetic comparison of African rabies viruses. The tree was based on complete nucleoprotein sequences and rooted with the Africa 4 lineage branch. All lineage branches apart from the Africa 2 lineage were collapsed and represented by blue for Africa 1, green for Africa 3 and purple for Africa 4. Tips are labelled with accession numbers and country of origin in brackets. The sequences obtained in this study are depicted in red and a bold type font. Bootstrap support values greater than 90 are represented with black dots

confirmed the presence of 2 distinct but related viruses showing 96.1 % nucleotide identity in a pairwise comparison. Both sequences belonged to the Africa 2 lineage in different monophyletic groups by phylogenetic comparison of the nucleocapsid region and were most closely related to dog-derived sequences from Côte d'Ivoire, Niger, Nigeria, and Burkina Faso (Figure 3). Sequencing of the conventional PCR product of the third sample with the highest ct-value resulted in the detection of a sequence closely related to the other two complete genomes with nucleotide sequence identities of 97.1 and 100% and belonging to the Africa 2 lineage, with up to 16 different nucleotide positions in the available 547 bp nucleotide PCR-fragment. All three sequences were submitted to GenBank and assigned accession numbers MW057694-MW057696.

3.2 | Administered questionnaires, observations and informal interactions

From the planned 600 participants, 541 persons consented to the study and completed questionnaires. A higher proportion of the participants were males [72% (391/541)], and Christian [74.7% (404/541)]. People from the Frafra cultural background were the most represented with 46.8% (253/541) while the Ewe and Ashanti cultural groups represented approximately even proportions. Almost half of the study participants practiced dog meat consumption [49% (265/541)]. Between the districts, 86.8% of the people from Bolgatanga consumed dog meat, however, 0.8% and 12.5% of people from Adidome and Agogo utilized dog meat as a diet respectively (Table 1).

TABLE 1 Baseline characteristics of the respondents

Variable	Location			
	Total	Adidome	Agogo	Bolgatanga
Sex of respondent				
Male	391 (72.3)	83 (21.2)	126 (32.2)	182 (46.5)
Female	150 (27.7)	26 (17.3)	63 (42.0)	61 (40.7)
Religion				
Christian	404 (74.7)	85 (21.0)	178 (44.1)	141 (34.9)
Muslim	19 (3.5)	1 (5.3)	9 (47.4)	9 (47.4)
Traditional African	118 (21.8)	23 (19.5)	2 (1.7)	93 (78.8)
Cultural group				
Ewe	106 (19.6)	106 (100.0)	0 (0.0)	0 (0.0)
Ashanti	142 (26.2)	0 (0.0)	142 (100.0)	0 (0.0)
Frafra	253 (46.8)	0 (0.0)	10 (4.0)	243 (96.0)
Others	40 (7.4)	3 (7.5)	37 (92.5)	0 (0.0)
Do you eat dog meat?				
Yes	265 (49.0)	2 (0.8)	33 (12.5)	230 (86.8)
No	276 (51.0)	107 (38.8)	156 (56.5)	13 (4.7)

TABLE 2 Odds ratio of factors associated with dog consumption

Variable	Don't consume	Consume	cOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Sex of respondent						
Female	91 (60.7)	59 (39.3)	1		1	
Male	185 (47.3)	206 (52.7)	1.72 (1.17–2.52)	.006	4.23 (1.86–9.61)	0.001
Religion						
Traditional African	27 (22.9)	91 (77.1)	1		1	
Muslim	7 (36.8)	12 (63.2)	0.51 (0.18–1.42)	.197	3.07 (0.12–79.08)	0.499
Christian	242 (59.9)	162 (40.1)	0.20 (0.12–0.32)	<.0001	4.47 (0.45–44.28)	0.201
Tribal origin						
Ewe	104 (98.1)	2 (1.9)	1		1	
Ashanti	136 (95.8)	6 (4.2)	2.29 (0.45–11.60)	.315	0.63 (0.04–10.19)	0.744
Frafra	15 (5.9)	238 (94.1)	825.1 (185.3–3672.9)	<.0001	263.73 (16.64–4180.71)	<0.0001
Others	21 (52.5)	19 (47.5)	47.05 (10.18–217.41)	<.0001	14.65 (1.10–200.39)	0.044

Abbreviations: aOR: adjusted odds ratio.; cOR: crude odds ratio.

Demographic data of respondents was assessed in relation to dog consumption practice. Males were almost twice (cOR = 1.72, 95% CI (1.17–2.52), *p*-value = .006) as likely to consume dog meat compared to females. Likewise, people from the Frafra tribal group [cOR = 825.1, 95% CI (185.3–3672.9), *p*-value < .0001] and those with non-specific tribes [cOR = 47.05, 95% CI (10.18–217.41), *p*-value < .0001] presented with higher odds of consuming dog meat compared to Ewes. Similar observations were made after adjustment of possible confounders in multivariate regression analysis. People who professed the Christian faith had significantly lower odds of consuming dogs [cOR = 0.20, 95% CI (0.12–0.32, *p*-value < .0001] compared to those with traditional beliefs, however this was not confirmed after multivariate analysis. (Table 2).

During visitation to the five slaughter sites, dogs brought alive were immediately clubbed to death. Majority of the dogs were brought dead in sacks with their mouths bound. A portion of the dead dogs were roasted wholly to remove fur using open flames, while the heads of others were cut off with machetes before roasting. The carcasses were then eviscerated in readiness for cooking. Dog meat consumers bought their preferred body parts including internal organs, and whole head for preparation in their homes. The meat was mainly roasted by butchers and their assistants for sale in nearby markets where some of the meat was prepared in soups. Specifically, in Bolgatanga in the Upper East region where the only officially known dog market was situated, dogs were purchased alive, tied with ropes, and transported on bicycles or motorbikes for slaughter and meat preparation for home use. None of the butchers were observed to be using any form of PPE in the form of gloves, face shields or overcoats during the slaughtering and meat preparation process.

4 | DISCUSSION

This study explores the potential presence of rabies virus in apparently healthy dogs slaughtered for human consumption and evaluates transmission risks during the process and factors that could influence consumption of dog meat in Ghana. Understanding the intricacies of this practice and the potential role in the transmission of rabies is important for the development of strategies aimed at rabies elimination in Ghana and beyond. The 2.1% rabies virus RNA detection rate in apparently healthy dogs was considerably higher than expected, posing a risk of rabies infection in humans and animals (Hu et al., 2008; Isek et al., 2013; Nguyen et al., 2011; H.-L. Zhang et al., 2014), taking into account the high fatality rate, lack of knowledge in affected communities, and lack of post exposure prophylaxis (Susilawathi et al., 2012). Males constituted most of the dog owners in this study. In Ghana and most parts of Africa, dogs are owned by males and used predominantly for guarding and hunting, and less frequently as pets (Ebuy et al., 2019; Mshelbwala et al., 2018). This finding coincides with similar studies in rural settings of Ghana and Cameroon that reported 71.5% and 68.3% dog owner respondents to be male (Awuni et al., 2019; Costa et al., 2018). Several persons involved in the dog trade face potential risks of exposure at various points along this chain, including the community level where dogs are bought, captured by force, slaughtered, and transported to sites for processing. Furthermore, observed occasions where consumers purchased raw meat from butchers for processing and consumption with a preference for the head which may harbour infected brains and saliva constitutes a high risk of transmission to unsuspecting clients during processing through potential exposure.

Majority of dogs in Africa lack rabies vaccination (Knobel et al., 2005; Ogundare et al., 2017) hence an exposure of any kind be it bite, saliva contamination of wounds or neural tissues constitute plausible sources of rabies transmission (Okeme et al., 2020). In effect, a single rabies infected dog destined for human consumption could potentially expose various persons across the unconventional capture-slaughter-preparation process by butchers and consumers alike.

Sequences from this study belonging to the Africa 2 lineage were unsurprising given this is the major lineage circulating in West Africa (Sadeuh-Mba et al., 2017). As observed in a previous study in South-East Asia, movement of dogs within the West African subregion fuelled by dog trade for consumption could account for the predominance and spread of this lineage in the region (Ekanem et al., 2013; Mey et al., 2016).

Our findings are similar to results obtained from previous studies indicating 0.7–2% prevalence of rabies virus RNA in samples of apparently healthy dogs slaughtered for human consumption in Nigeria (Kia et al., 2018; Suleiman et al., 2020). However, these studies also reported higher prevalence of 6–17% using fluorescence antigen detection (Kia et al., 2018; Suleiman et al., 2020). The higher prevalence reported by the studies using the fluorescence antigen detection method may be as a result of differences in clinical sensitivities between the two assay types, especially in resource limited-settings, where RT-PCR is not routinely performed. In theory, Rabies RT-PCR assays may have lower clinical sensitivities compared to fluorescence antigen detection due to the genetic diversity that exists among these viruses which can hinder binding between oligonucleotides and templates (Hughes et al., 2004; Mani & Madhusudana, 2013). In contrast, there are highly conserved antigenic sites in the Nucleoprotein region of rabies viruses, which is the main target for direct antigen detection assays (Goto et al., 2000; Kouznetzoff et al., 1998).

The presence of rabies virus in saliva and brains of apparently healthy dogs has been reported in parts of Africa and Asia. These reports posit some of these dogs could be asymptomatic carriers or infected with specific rabies strains adapted to dogs (Ajayi et al., 2006; Asian Canine Protection Alliance, 2013; Danbirni et al., 2010; Mshelbwala et al., 2013). A more probable explanation could be due to difficulty in recognizing symptoms of the paralytic form of rabies in some populations given the common association of rabies with madness and aggression as previously reported (Digafe et al., 2015; Turkson & Wi-Afedzi, 2020). Lack of previous knowledge of the past disposition of dogs may also make it difficult for people who purchase them for slaughter to notice subtle changes in behaviour.

In Africa, bites from domestic dogs are mainly responsible for rabies transmission in humans (Brunker et al., 2018; Jibat et al., 2015). One important source which is often neglected is exposure to the virus through trade, slaughter, and consumption of dog meat. The practice of dog meat consumption is known in parts of West Africa (Daniel et al., 2017; Ohene-Adjei & Bediako, 2017) and Asia (Lee et al., 2018; Sorenson, 2019). Across the three study regions of which Volta and Ashanti regions are not known culturally for dog slaughter and consumption, the high prevalence of dog meat consumption, some of which could be infected with the rabies virus, likely increased the demand for slaughter. This was also likely to bring about a corresponding increase in the risk to people involved in the preparation process, a situation that could hamper efforts for reducing human rabies.

The association between gender and dog consumption revealed males were significantly more likely to consume dog meat compared to females. The high demand for dog meat by men has previously been asserted by them to be because of its palatable taste (Garba et al., 2013) and for prevention and treatment of diseases (Oh & Jackson, 2011; Podberscek, 2009). This finding is in consonance with dog consumption in certain parts of Asia where the practice is also considered to be male dominated (Cawthorn & Hoffman, 2016). Some reasons previously ascribed to dog consumption by men included its palatable taste and for prevention of diseases. Part of the reason for male dominance in dog consumption may also be attributed to the fact the practice is considered a taboo for women in some African cultures (Simoons, 1996). Furthermore, some cultural groups from the

Philippines consider dog meat as a delicacy to be eaten with alcoholic drinks associated more to men and they consider the meat as a recipe for male virility (Lassiter et al., 2002). Tribal origin played a major role in dog meat consumption. The people of the Frafra tribal group, known to eat dog meat as part of their culture, were overwhelmingly likely to ascribe to this practice. People from non-specified tribes showed significantly higher odds of consuming dog meat compared to people from the Ewe tribe. Over the years, culture and traditions of people have played important roles in disease prevalence. Although some of these practices and ways of life could be protective, others constitute root causes of disease emergence and transmission within individuals and communities (Murray & Schaller, 2010). In sub-Saharan Africa, cultural beliefs are strongly grounded and would sometimes take precedence to state laws (Adelman, 1998). Despite the multiplicity of languages, norms and beliefs across Sub-Saharan Africa, people remain attached culturally and live communally, especially in rural areas where urbanization is less felt (Millar & Haverkort, 2006). One of such cases is the emergence and transmission of Ebola virus by particular ethnic groupings through bushmeat gathering and handling (Alexander et al., 2015; Johnson et al., 1993). In Ghana, tribes and ethnic groupings in the northern sector are commonly associated with dog meat consumption. Work-related migration of these northern ethnic tribes, bringing traditions with them may lead to new mechanisms of disease spread in urban centres (Lobnibe, 2016). Immediate, and direct engagement of butchers to sensitize them on the risks of possible rabies transmission, application of pre-exposure prophylaxis and use of PPEs could reduce the risk of rabies transmission through this practice.

5 | CONCLUSION

This study demonstrated the presence of rabies virus RNA in dogs slaughtered for human consumption in parts of Ghana. Three out of 144 dogs sampled tested positive for rabies virus. The detection of rabies virus in slaughtered dogs processed without protective gear, sold, and consumed by the public, represented a potential source of rabies transmission and a threat to the fight against human rabies, thereby calling for this practice to be included in the epidemiology of rabies transmission in Ghana. Approximately 50% of respondents across three regions of Ghana were engaged in dog meat consumption, thus, we recommend that the veterinary department and the local assemblies should monitor and regulate this practice while more research is needed to understand the status of butchers. Education of butchers on the risks of rabies transmission could help reduce this potential source of exposure.

6 | LIMITATIONS

The questionnaire data was administered to dog owners in areas where dog trade, slaughter, and consumption occur but not to those engaged in the trade. We could not generate specific data on the individual dogs slaughtered because the butchers were reluctant to be interviewed formally for fear of losing their livelihood from this unregulated trade.

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ETHICAL CLEARANCE

Ethical clearance was obtained from the Animal Research Ethics Committee of the Faculty of Pharmacy and Pharmaceutical Sciences, Kwame Nkrumah University of Science and Technology. The study was approved by the Director of Veterinary Services Department of Ghana. Purpose of the study was explained to all participants.

CONFLICT OF INTEREST

We declare no conflict of interests.

AUTHOR CONTRIBUTIONS

William Tasiame, Victor Max Corman, Christian Drosten and Philip El-Duah conceived the paper. William Tasiame, Philip El-Duah, Tobias Bleicker, Talitha Veith, and Julia Schneider did PCR screening and HTS. Sherry A. M Johnson, Eddie-Williams Owiredu, Ernest Akyereko, Benjamin Emikpe and Raphael D. Folitse participated in data interpretation and revision of manuscript. All authors read, reviewed, and approved the final version.

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