

Research Article

Seroprevalence and Associated Risk Factors of Porcine Cysticercosis in Ngara District, Northwestern Tanzania

Richard Simon Ngowi^{1,*} , George Isdory Makingi¹ , Justine Daudi Maganira² ,
Ernatus Martin Mkupasi¹ 

¹College of Veterinary Medicine and Biomedical Science, Sokoine University of Agriculture, Morogoro, Tanzania

²College of Natural and Applied Sciences, Sokoine University of Agriculture, Morogoro, Tanzania

Abstract

Porcine cysticercosis (PC), caused by the larval stage of *Taenia solium*, presents significant public health and economic challenges, particularly in resource-limited regions. This study determined the seroprevalence and associated risk factors of PC transmission in Ngara District, Tanzania. A cross-sectional survey was conducted, involving 342 pigs from 12 villages. Serum samples were analyzed using the cysticercosis antigen enzyme-linked immunosorbent assay (Ag-ELISA). To assess the risk factors, a semi-structured questionnaire was administered via Kobo Toolbox, along with direct observations. The overall seroprevalence of PC was 13.74%, with significant variation across villages ($p < 0.05$), although no significant differences were observed between pig age groups or sexes ($p > 0.05$). Higher prevalence rates were observed in the villages of Bukiro, Mumuhamba, Kigina, and Ntobeye. Adult pigs showed a slightly higher prevalence compared to weaners and growers. A total of 114 pig-keeping households were surveyed, and data analysis was performed using R Version 4.4.1, employing Generalized Linear Models (GLM) with a binomial logistic regression approach. The analysis identified several significant risk factors associated with PC seropositivity, including: (1) Source of feed (OR = 1.25, 95% CI: 1.18 - 1.97, $p = 0.001$), (2) Open defecation (OR = 2.12, 95% CI: 1.18 - 3.27, $p = 0.0005$), and (3) Husbandry system (Scavenging/Tethering pigs) (OR = 1.98, 95% CI: 0.72 - 2.19, $p = 0.0006$). Despite existing knowledge on PC transmission and seroprevalence in sub-Saharan Africa, there is a limited understanding of its epidemiology in specific regions like Ngara District. This gap is critical, as localized risk factors and transmission dynamics may differ significantly across regions. This study provides baseline data on the epidemiology of PC in Ngara District, emphasizing the need for targeted intervention strategies to reduce transmission risks in both pig and human populations.

Keywords

Porcine Cysticercosis, Seroprevalence, Risk Factors, Ngara, Northwest Tanzania

1. Introduction

Cysticercosis is a parasitic infection in pigs and humans caused by the larval stage of the pork tapeworm, *T. solium*, posing serious veterinary, public health, and socioeconomic challenges, particularly in developing countries [1, 4, 5, 12,

*Corresponding author: rsnnngowi@yahoo.co.uk (Richard Simon Ngowi)

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[16], and [21]. The World Health Organization (WHO) has classified *T. solium* cysticercosis as a neglected tropical disease (NTD) due to its considerable burden on human health, being a leading cause of preventable epilepsy in endemic regions. The disease, also, leads to substantial economic losses in the pig industry through meat condemnation, reduced market value, and financial setbacks for pig farmers (WHO, 2021). Beyond its economic impact, *T. solium* infection presents a significant public health risk as humans can develop neurocysticercosis (NCC), a severe neurological disorder caused by larval cysticerci in the central nervous system [16]. Infected pigs can also negatively influence consumer confidence in pork quality and safety, potentially reducing pork consumption in affected areas [15].

In recognition of the urgent need for research, control, and elimination of this zoonotic disease, the WHO added *T. solium* taeniasis and cysticercosis to its list of NTDs in 2010 (WHO, 2010). Cysticercosis was added to the list of priority research areas in Tanzania in 2013 by the National Institute for Medical Research (NIMR) to ensure food safety and minimize production problems (NIMR, 2013). *Taenia solium* cysticercosis remains endemic in Sub-Saharan Africa, Latin America, and Asia [2] and [7]. The disease is disproportionately prevalent in these regions due to inadequate sanitation, close human-pig interactions, poor hygiene practices, and limited awareness among pig farmers [19]. Despite its significant public health and economic impact, many endemic areas remain unsurveyed, particularly for the prevalence of cysticercosis in both pig and human populations. This lack of data hinders the development of targeted control strategies and effective interventions.

Pigs serve as intermediate hosts of *T. solium*, becoming infected by ingesting eggs from contaminated environments with tapeworm carrier individuals [23]. Humans act as both definitive hosts (harbouring the adult tapeworm; leading to taeniasis) and accidental intermediate hosts (developing cysticercosis upon ingesting eggs). The disease cycle is perpetuated in settings where free-range pig farming is practiced alongside poor sanitation, allowing for easy transmission between humans and pigs.

In Tanzania, the reported prevalence of porcine cysticercosis varies significantly across regions, with estimates ranging from 6% to 33.3%. For instance, [18] reported a prevalence of 17.4% in Mbulu District, while [9] found 11.7% and 6% prevalence rates in Mbozi and Mbeya Rural Districts, respectively. A study in Nyasa District, reported a prevalence of 33.3% [25], and further studies in Ludewa, Kongwa,

and Iringa Districts documented rates of between 10% and 22% [8, 11, 12] and [30]. Most of these studies have focused on the eastern-central, northern and southern highlands of Tanzania, leaving western regions, including Ngara District in the northwest where also tradition pig rearing is practiced, unexplored.

Controlling porcine cysticercosis is essential for improving pig production, ensuring safe pork consumption, and enhancing public health in endemic regions. However, one major challenge for the disease control is lack of comprehensive data on the prevalence of porcine cysticercosis and its associated risk factors in different local settings. Understanding these aspects is crucial for developing targeted public health interventions that can mitigate the impact of *T. solium* cysticercosis.

Given the significant public health and economic implications of porcine cysticercosis, this study assessed *T. solium* porcine cysticercosis seroprevalence and associated transmission risk factors in Ngara District, northwestern Tanzania. These epidemiological data, will inform control strategies, and guide policy interventions to reduce the burden of cysticercosis and enhanced food safety in Tanzania and other endemic areas.

2. Materials and Methods

2.1. Study Area

This study was conducted in Ngara district, Kagera region, northwest Tanzania. The district lies between Latitudes: -2.5 °S to -3.0 °S and Longitudes: 29.5 °E to 30.5 °E. It is bordered to the north by Karagwe District, to the east by Bihamulo District, to the south by the Kigoma Region, to the northeast by Muleba district and to the west by the countries of Rwanda and Burundi. The district constitutes 22 wards. The area receives adequate annual rainfall reaching up to 1000 mm. The rainfall pattern is bi-modal, occurring in October to December and March to May. The main economic activities in Ngara include livestock keeping and subsistence farming. Bananas, papaya, passion fruit, groundnuts, beans, maize, cassava, and commercial farming of coffee and avocado. Most of the livestock kept by the locals include pigs, cattle, goats, and chickens. It covers an area of about 3 305 km², with a total length of 1 800 km [17].

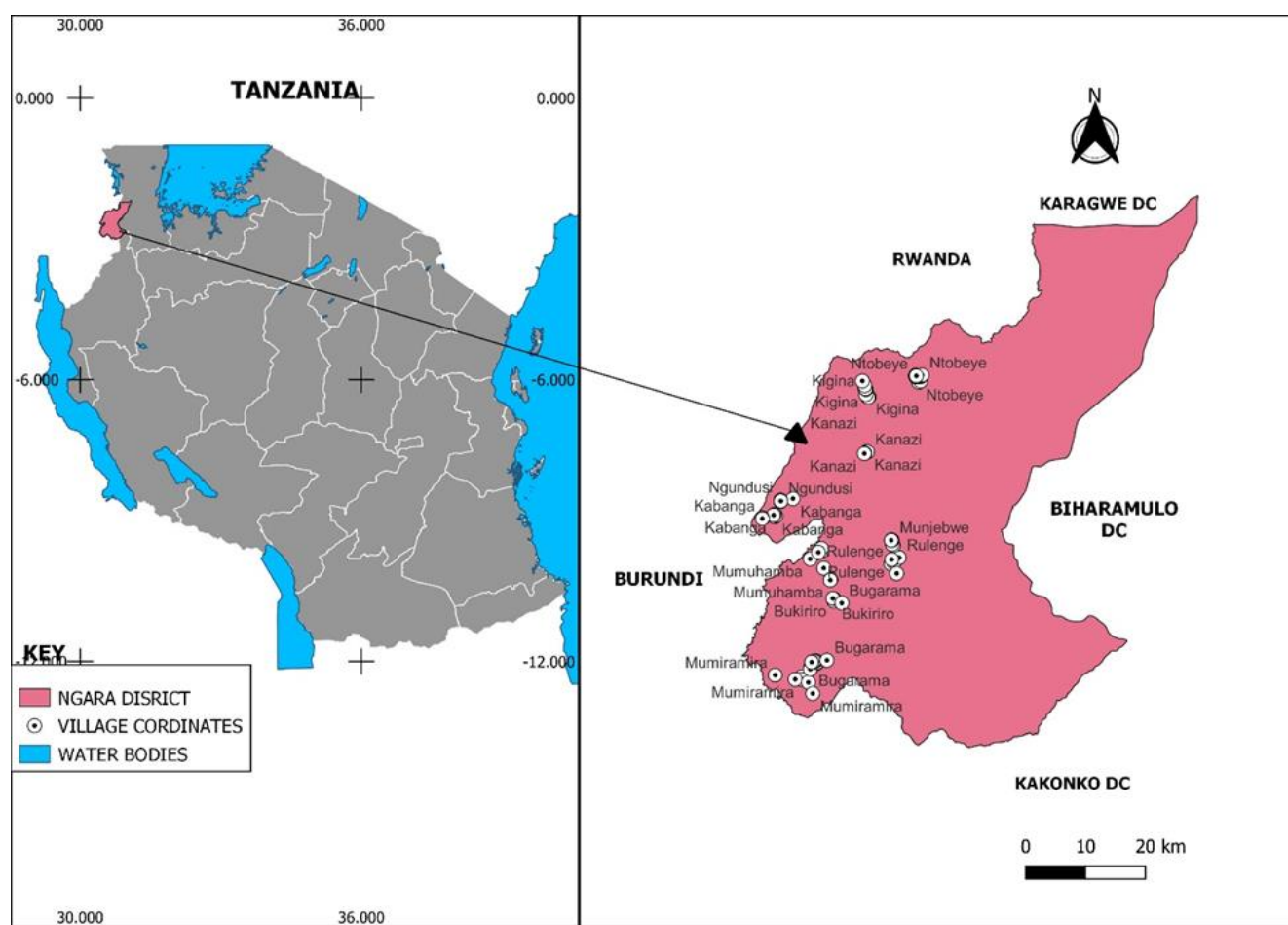


Figure 1. Map showing Ngara District.

According to the 2015-2017 NBS and Ngara District Council Sample Census of Agriculture.

The district had a population of 14,186 pigs with an average of 645 pigs per ward and rank second largest population in the Region after Kyerwa district.

2.2. Study Design and Sample Size Estimation

This study was a cross-sectional survey aims at investigating prevalence of PC in Ngara district. Twelve villages were purposively selected from six wards, with two villages chosen from each ward. The selection was based on pig population and the geographical orientation of the wards, ensuring representation from three wards in the higher highlands and three in the lower highlands. In each of the study village, eight to twelve households were selected for sample collection, the criterion for inclusion of the household was to have at least three pigs aged above three months. In each household three pigs were randomly selected for blood collection. The prevalence level of PC was determined from sera recovered from blood samples and the study was biased to different age groups of pigs and sources.

The sample size was calculated by formula $n = \frac{Z^2 PQ}{L^2}$ by [14], where n is the number of pigs to be included in this study,

P is an estimated prevalence level of PC in the study area (0.33 or 33%) [25], Z is the score of the desired confidence interval (95%), $Q = 1 - P$, and L is the permissible error of estimation (5%). Based on this formula, the estimated minimum sample size of pigs was 340, (that is $n = 1.96^2 \times 0.33 \times 0.67 / 0.05^2$). A total of 342 serum samples were collected.

2.3. Data Collection

Pigs were restrained using a pig snare and, about 3-4 ml blood sample was drawn from auricular vein of pigs using 5 ml Becton Dickinson (BD) vacutainer tubes and disposable vacutainer needles. Blood samples were temporarily stored at 4°C in a cooler box during data collection. The collected blood was centrifuged at 3200 rpm for 10 minutes to get a clear serum. Serum was then harvested into micro vials using a micro pipette and stored in -20°C freezer before shipping to SUA Laboratories, Department of Veterinary Medicine and Public Health for further analysis.

2.4. Laboratory Analysis

The apDia cysticercosis antigen enzyme-linked immunosorbent assay (apDia cysticercosis Ag-ELISA) was employed

in the laboratory to qualitatively assess serum samples for PC seropositivity, following the manufacturer's protocol. Briefly, pretreated serum and control samples were introduced into microtiter wells coated with the monoclonal antibody B158C11A10 and incubated at 37 °C for 15 minutes while shaking at 800 rpm. This process facilitated the binding of circulating antigens from viable cysticerci to the wells. Subsequently, unbound antigens were eliminated by washing the wells with phosphate-buffered saline. The antigen-antibody complexes formed were then detected using B60H8A4 monoclonal antibodies. The enzymatic reaction was terminated by adding 0.5 M sulphuric acid (H_2SO_4) solution and followed by reading the optical density (OD) at 450 nm in a microplate reader. Then, the cut off was calculated by multiplying mean OD_{neg} × 3.5, and the antigen index (Ag-index) of each sample was calculated by dividing OD value by cut-off value. The results were designated as positive if the Ag-index was ≥ 1.3 , negative if Ag-index was ≤ 0.8 and doubtful if $0.8 < \text{Ag-index} < 1.3$.

2.5. Data Analysis

R software version 4.4.1 was used for statistical data analysis. Descriptive statistics were used to compute the prevalence while associations between the potential risk factors for Ag ELISA results were assessed using the chi-square statistic, a generalized linear regression model was then used to determine the association between cysticercosis seropositivity and significant variables from the chi-squared test. As such, to

determine the association between cysticercosis seropositivity and significant variables, a GLM was employed.

2.6. Ethical Approvals

The Sokoine University of Agriculture Research Ethics Committee approved this study DPRTC/186/49. Research clearances were sought from the SUA, Kagera Regional Authority, Ngara District and specific ward and village authorities. In addition, heads or household representative of each household involved in this study provided informed consent before data collection.

3. Results

3.1. Characteristics of Study Pigs

A total of 342-pigs from selected households across twelve villages in the Ngara District were enrolled in this study (Table 1). The distribution of pigs among the villages indicated that Bugarama and Ntobeye had the highest number of pigs ($n=36$, 10.59%), while Bukiriro village had the lowest ($n=15$, 4.41%). Of the total serum samples analyzed, 108 (31.76%, 95% C.I. 26.60-36.70) were from weaners, 96 (27.65%, 95% C.I. 23.30-33.08) from growers, and 138 (40.59%, 95% C.I. 35.35-46.03) from adult pigs. Also, the distribution of pigs with respect to sex was 65.88% for female and 34.12 for male.

Table 1. Showing number of sampled pigs in each village.

Variable	Categories	Number of Pigs in each category	Percentage of pigs per category (%)
Villages	Bugarama	36	10.52
	Bukiriro	15	4.39
	Kabanga	21	6.14
	Kanazi	33	9.49
	Kigina	33	9.49
	Mukibogoye	33	9.49
	Mumiramira	21	6.14
	Mumuhamba	27	7.89
	Munjebwe	27	7.89
	Ngundusi	33	9.49
	Ntobeye	36	10.52
	Rulenge	27	7.89
	Weaner	108	31.57
Age	Grower	96	28.07
	Adult	138	40.35

Variable	Categories	Number of Pigs in each category	Percentage of pigs per category (%)
Sex	Female	225	65.88
	Male	117	34.11

3.2. Prevalence of Porcine Cysticercosis in Ngara District

The overall seroprevalence of PC in Ngara district was 13.74% (n=47/342; 95% CI: 0.1033-0.1796), a significant difference in the prevalence of porcine cysticercosis was observed between villages χ^2 (11, N=342) = 34.18 p<0.01). However, no significant differences were noted between the categories of weaners, growers, and adult pigs. The highest prevalence was recorded among female pigs at 225 (15.20%,

95% C.I. 10.70-20.60), while the lowest prevalence was observed in male pigs at 117 (11.2%, 95% C.I. 6.10-18.40); however, this difference was not statistically significant χ^2 (1, N=342) = 0.71, p=0.401). Among adult animals, a higher prevalence of cysticercosis was noted at 138 (15.20%, 95% C.I. 9.67-22.30), followed by growers at 96 (13.70%, 95% C.I. 7.49-22.30), with weaners showing the lowest prevalence at 108 (15.2%, 95% C.I. 6.63-19.90). Again, this observed difference was not statistically significant χ^2 (2, N=342) = 0.48, p=0.787) (Table 2).

Table 2. Prevalence of porcine cysticercosis by village, age, and sex, Ngara District.

Variable	Categories	Number of Pigs examined	Number of positive pigs	Prevalence	Chi-Squared P value
Villages	Bugarama	36	2	5.00	p<0.01
	Bukiro	15	5	33.33	
	Kabanga	21	4	19.05	
	Kanazi	33	2	6.06	
	Kigina	33	8	24.24	
	Mukibogoye	33	1	3.03	
	Mumiramira	21	0	0.00	
	Mumuhamba	27	8	29.63	
	Munjebwe	27	2	7.41	
	Ngundusi	33	2	6.06	
	Ntobeye	36	10	27.80	
	Rulenge	27	3	11.10	
Age	Weaner	108	13	12.04	P=0.787
	Grower	96	13	13.54	
	Adult	138	21	15.11	
Sex	Female	225	34	15.11	P=0.407
	Male	117	13	11.11	

3.3. Risk Factors Associated with Porcine Cysticercosis Transmission in Ngara

The presence of toilets in households was found to be inversely associated with the likelihood of pigs harboring *T. solium* cysts. Specifically, pigs from households with available toilets had a significantly lower probability of infection, with an OR of 0.079 (95% CI: 0.067 - 0.094, $p > 0.05$). The method of pig rearing significantly influenced the likelihood of *T. solium* cyst infection. Pigs raised under a scavenging system exhibited a 1.98-fold increased likelihood of infection compared to those raised using other methods (OR = 1.98, 95% CI: 0.72 - 2.19, $p < 0.01$). Households practicing open defecation were found to have a significantly higher risk of *T. solium* cyst infection in pigs, with an OR of 2.12 (95% CI: 1.18 - 3.27, $p < 0.01$). This indicates that pigs in households with open defecation practices are twice likely to be infected with cysts than those in households with proper sanitation facilities. Pigs fed primarily on plant-based feed were 1.25 times more likely to harbor *T. solium* cysts compared to those fed alternative diets (OR = 1.25, 95% CI: 1.18 - 1.97, $p < 0.01$) (Table 3).

Table 3. Showing risk factors and likelihood of transmission in Ngara.

Risk factor	Odds Ratio	P-Value
Toilet availability	7.90E-02	> 0.05
Husbandry practices	1.98E+00	< 0.01
Open defecation	2.12E+00	< 0.01
Feed source	1.25E+00	< 0.01

4. Discussion

This study examined the seroprevalence of porcine cysticercosis in Ngara District, Tanzania, using the Antigen Enzyme-Linked Immunosorbent Assay (Ag-ELISA). The presence of these antigens strongly suggests that pigs in Ngara are actively exposed to *T. solium* eggs, indicating ongoing transmission of the parasite within the local environment. This study provides compelling evidence of the conditions in Ngara that facilitate the survival and transmission of *T. solium*, the causative agent of porcine cysticercosis.

The overall seroprevalence recorded in this study was 13.74%, which is comparable to previously reported prevalences varying from 2% to 43% using various assays (Eg. Tongue Palpation) but 37% was seroprevalence using Ag ELISA and in connection with prevalence of Neuro Cysticercosis in neighboring country of Rwanda [24] and [26], but higher than the 8.5% observed in southern Uganda, which borders the Kagera region [27]. The difference in prevalence between studies could be attributed to factors such as geo-

graphical location, sampling strategies, sample sizes, and the diagnostic assays used.

Findings also highlighted significant variations in prevalence across villages within Ngara, with higher rates observed in Bukiriro, Mumuhamba, Ntobeye, and Kigina. These variations are likely due to differences in local pig management practices, environmental sanitation, and socio-economic factors, such as household access to sanitation facilities and the level of interaction between pigs and human populations. This is consistent with earlier studies indicating that poor sanitation and close interactions between humans and pigs increase the risk of transmission [29]. Furthermore, the high seroprevalence in certain villages suggests that transmission dynamics are localized, possibly due to inadequate control measures or environmental factors conducive to *T. solium* survival.

The presence of household toilets showed a strong protective effect against porcine cysticercosis (PC) seropositivity. This aligns with evidence that improved latrine coverage reduces environmental contamination by *T. solium* eggs through proper fecal disposal [3] and [13]. However, one Tanzanian study found no significant difference in human cysticercosis rates between households with/without toilets, suggesting protective effects may depend on proper toilet usage and maintenance to prevent pigs accessing human waste [13].

Free-range pig rearing nearly doubled infection risk (OR=1.98) as roaming pigs can directly consume human feces containing tapeworm eggs. This highlights the critical role of confined pig management systems in breaking the parasite lifecycle. The tight confidence interval and highly significant p-value emphasize the reliability of this finding [10] and [20].

Open defecation showed the strongest association with PC, creating environmental reservoirs of infectious eggs. Studies in Tanzania documented children's feces being disposed directly into pigpens [13], while Kenyan interventions demonstrated reduced cysticercosis prevalence after latrine improvements [3]. Plant-based feeding showed modest increased risk, likely because forage-fed pigs encounter contaminated vegetation. This association may reflect broader system deficiencies - free-roaming pigs typically subsist on scavenged plant matter near defecation sites, rather than inherent risks of plant feed itself [10].

While the study did not find significant differences in prevalence across age groups or between male and female pigs, adult pigs exhibited slightly higher prevalence rates, which may be attributed to cumulative exposure over time. This observation is consistent with previous studies that noted adult pigs are at greater risk due to prolonged exposure to contaminated environments [22]. The lack of variation between male and female pigs in Ngara suggests that factors such as roaming behavior or sex-related physiological differences may not significantly influence the risk of infection in this context, although this contrasts with findings from other regions, such as Nigeria, where male pigs had higher

seroprevalence due to more extensive roaming [28].

The overall seroprevalence of 13.74% in Ngara District is consistent with the levels found in other endemic regions of sub-Saharan Africa and highlights the significant public health implications of porcine cysticercosis [6]. This study underscores the need for targeted intervention strategies, including improving pig management practices, enhancing community education on hygiene and sanitation, and implementing control programs to reduce *T. solium* infections in both pigs and humans. By addressing risk factors such as inadequate sanitation, open defecation, and scavenging husbandry practices, it is possible to reduce the transmission of *T. solium* and improve the health of both pigs and humans in Ngara District.

5. Conclusion and Recommendation

This study established 13.74% seroprevalence of porcine cysticercosis in Ngara District, revealing significant variability across villages. The variability in prevalence across villages suggests that localized conditions, such as sanitation infrastructure and farming practices, play a key role in the spread of the disease.

Targeted intervention strategies should be developed based on these findings, with a focus on improving sanitation, reducing human-pig interactions, and enhancing pig management practices, such as preventing scavenging and ensuring safer feed sources.

Abbreviations

Ag ELISA	Antigen Enzyme-Linked Immuno Sorbent Assay
BD	Becton Dickinson
CI	Confidence Interval
DPRTC	Director Postgraduate Research Technology Transfer and Consultancy
GLM	Generalized Linear Modal
NBS	National Bureau of Statistics
NCC	Neural Cysticercosis
NIMR	National Institute for Medical Research
NTD	Neglected Tropical Disease
OD	Optical Density
OR	Odds Ratio
PC	Porcine Cysticercosis
SUA	Sokoine University of Agriculture
WHO	World Health Organization

Conflicts of Interest

The authors declare no conflicts of interest.

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