

## Prevalence of *Taenia solium* cysticercosis in domestic pigs following albendazole deworming intervention in rural communities of Mbulu district, Tanzania

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### ABSTRACT

Taeniosis and cysticercosis are infections caused by cestodes, *Taenia solium* is among them. *T. solium* neurocysticercosis accounts for 30% of acquired epilepsy in human in developing countries. This study was carried out to determine the prevalence of cysticercosis among domestic pigs in Mbulu district following deworming intervention. The study was conducted among three rural communities monitoring community intervention in Mbulu district between March 2020 and September 2021. Live pigs were diagnosed by lingual examination for the presence of *T. solium* cysticerci, and pig-rearing practices were recorded. Logistic regression was performed to determine the role of risk factors on pig infection outcome. We conveniently sampled 510 pigs; 267 (52.4%) were sampled in the year 2020 and 243 (47.6%) in 2021. All pigs were examined by lingual examination for the presence of pork tapeworm larvae, and 43 (8.4%) pigs were found to be infected. Twenty-one (48.8%) of the infected pigs were males and 22 (51.2%) were females, and the overall annual prevalence of tapeworm larvae was 9% and 7.8% for 2020 and 2021, respectively. The pigs were twice more likely to be found infected during the rainy season compared to the dry season in 2020 (OR = 2.27, 95%CI of 1.16–7.22). The reported pig-rearing practices were free-range, penned, and tethered, 141 (52.8%), 64 (24%), and 62 (23.2%), respectively. Of the 94 visited households in 2020, 78 (83%) reported drinking water without boiling, and 59 (62.8%) household leaders reported having heard about taeniosis/cysticercosis. The prevalence of cysticercosis among domestic pigs in this study was high, with seasonal variations. Despite the ongoing national school deworming and community deworming program, there was no significant change in the prevalence of cysticercosis over two consecutive years. The reported pig infections imply fecal-oral transmission with humans tapeworm eggs released from infected humans. Most households reported consuming unboiled drinking water that might be contaminated. Integrating pig vaccination and deworming, health education and school or community deworming along with improved pig management practice and general community

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water sanitation hygiene (WASH) are recommended to reduce the burden of pork tapeworm in the study communities.

## 1. Introduction

Porcine cysticercosis is an infection of pigs with the larval stage of the pork tapeworm – *Taenia solium*. The humans are the definitive host harboring adult tapeworms in the intestine causing taeniosis. When a person is infected with the larval stage of the pork tapeworm (cysticerci), it results in cysticercosis; and when cysticerci lodge in the central nervous system, the infection is known as neurocysticercosis (NCC). Neurocysticercosis is among the major causes of epileptic seizures in humans in areas where the parasite is endemic (Assana et al., 2010; Carabin and Traoré, 2014).

Previous studies show that pork tapeworm transmission prevails in poor farming communities of developing countries worldwide (Gulelat et al., 2022; Ito et al., 2015). The main risk factors include a free-ranging practice of raising pigs, open defecation, and the consumption of undercooked pork meat (Ngowi et al., 2004; Torgerson and Macpherson, 2011).

In Africa, porcine cysticercosis prevalence by lingual examination in Eastern Africa is between 6 and 12% (Mutua et al., 2007; Ngowi et al., 2019; Pondja et al., 2010). Carcass examination is between 5 and 15% in West Africa (Melki et al., 2018; Mutua et al., 2007; Pondja et al., 2010). Antigen ELISA prevalence has been reported to be about 13–37% (Gulelat et al., 2022). Tanzania is among the pork tapeworm endemic countries in Africa, where the reported prevalence range between 6 and 17.4% based on lingual examination and 1.5–33.3% by antigen ELISA (Kabululu et al., 2020; Ngowi et al., 2019). More than 80% of the population in Tanzania live in rural areas where 65.3% of the household economic activities are on agriculture (Ministry of Agriculture, 2021). Agriculture contributes about 26.7% of the gross domestic product (GDP) and employs most of the rural population. Among the farming communities, 36% of the households are involved in livestock keeping, whereas 2.4 million pigs, which is 9% of all livestock (Tanzania Investment Center, 2018). The low livestock reproductive rates caused by poor pig management practices and high mortality rates escalated by high disease prevalence underpinning the quality, resulting in low income (Maziku et al., 2017). Mbulu district has been reported with high porcine and human cysticercosis (Mwang'onde et al., 2012; Mwang'onde et al., 2018; Ngowi et al., 2004). Despite school deworming the soil transmitted helminthes in Tanzania has been reported to be high (WHO-World Bank, 2003). This study was conducted following community treatment with albendazole as a complement to school deworming only.

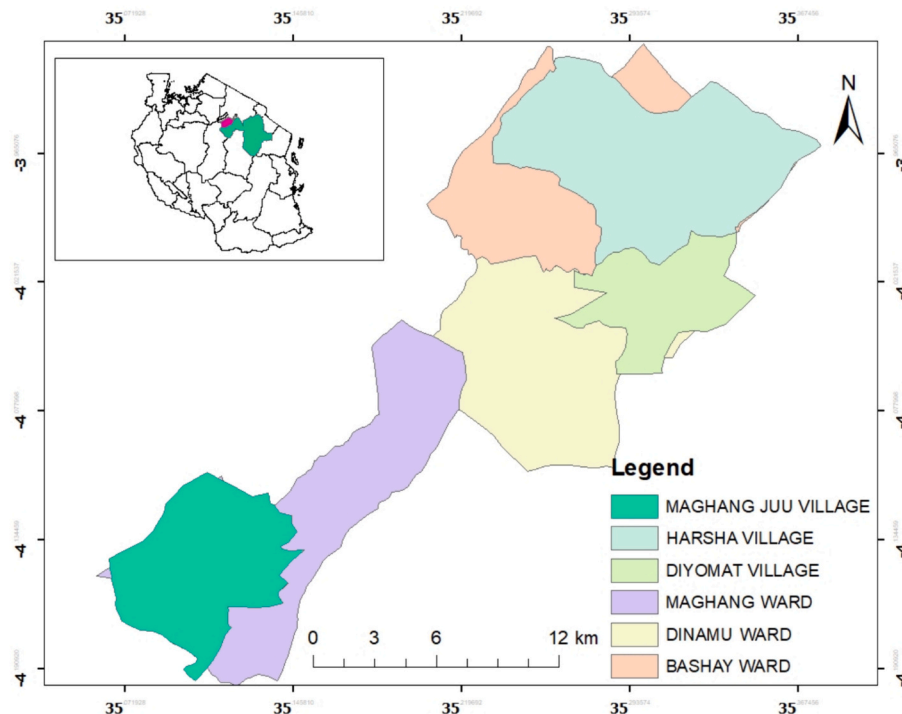


Fig. 1. Mbulu district map showing study wards and villages (courtesy of Lucas Theodori).

## 2. Materials and methods

### 2.1. Study area

Mbulu district is located on plateau of Northern Tanzania (Fig. 1). The district is comprised of 3800 km<sup>2</sup> with a population of 320,279 of which 161,548 are males and 158,731 females (Tanzania Bureau of Statistics, 2013). The indigenous are involved in agriculture and animal husbandry including pigs with free-ranging practice dominating. The study area was purposely selected due to the previously reported high prevalence of human and porcine cysticercosis (Mwang'onde et al., 2012; Ngowi et al., 2004) and preferred for monitoring albendazole intervention outcomes in pigs for pork tapeworm cysticercosis after establishing a baseline data and intervention allocation (Fig. 2). This study was conducted in the three villages namely Maghang Juu, Diyomat, and Harsha.

### 2.2. Study design

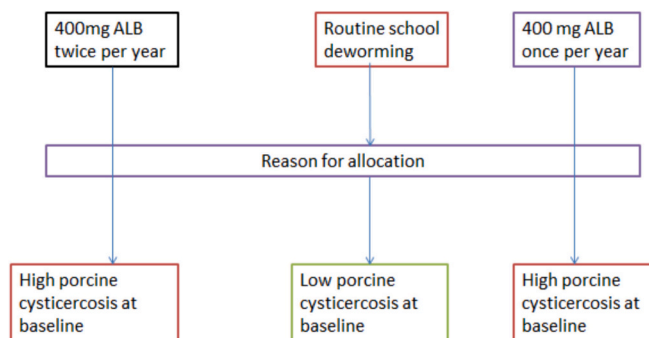
The interventional study was conducted in Mbulu district; data were collected at four different points covering rainy (March) and dry (September) seasons of the two consecutive years 2020 and 2021. The quasi experimental intervention study was conducted in three villages in Mbulu rural district council at the community level, where all eligible humans received 400 mg albendazole, June 2020 and January 2021 a six months interval; one village was a control, no albendazole treatment by study team except the routine school deworming done in entire district. The study villages were randomly selected from three randomly selected eligible wards out of 18 eligible wards as reported in the study done parallel to this study (Bandi et al., 2024). One village (Maghang Juu) had 1621 villagers and received once and the other 1892 villagers and received twice having a total of 3513 eligible humans for 400 mg albendazole. We administered a maximum of 73.67%(2588/3513) for second round at Harsha village. The human population was targeted for intervention as they harbour adult *T.solium*, thus releasing infective taeniid eggs. Treatment of entire community using minimal dose as preventive chemotherapy was recommended by NTD control program manager via oral conversation. Treatment with albendazole for three consecutive days is for diagnosed patient confirmed releasing taeniid eggs or proglotids. For preventive chemotherapy 400 mg of albendazole is recommended for three consecutive days (PAHO, 2021). In the study country the recommended preventive dose for albendazole is 400 mg and the new released treatment guideline was not adopted and allowed. We monitored the effect of albendazole intervention on pigs. Pigs are usually sold at six months of age otherwise left for breeding purposes, thus pigs are good estimate of effect of intervention for short term outcome of porcine cysticercosis as it reflects the presence of taeniid eggs in feces because they consume as they are freely ranged. This study monitored the effect of increasing coverage of albendazole intervention in human population at Maghang Juu and Harsha villages; Diyomat was a control village (Fig. 2). The schematic diagram describes elimination approach (Fig. 3). Apart from this intervention the primary school children have been treated with albendazole and praziquantel under school deworming program conducted in the country, we had previous data from District Medical officer from the year 2018 to 2020 as shown in Fig. 4.

### 2.3. Study population

The study district is estimated to have 72,000 pigs (oral communication with the veterinarian in charge) about twice the previously reported pig population (Ngowi et al., 2010). The pigs aged 2 months and above were included in the study. Three study villages were randomly selected from fifteen eligible wards. Three wards were excluded as the residents were rarely involved in pig husbandry. The pigs were conveniently sampled upon acceptance by the pig owner and a maximum of five pigs per household were examined considering age and sex differences. The questionnaires were administered to the head of household visited upon consent.

### 2.4. Data collection

Data collection was conducted between March 2020 and September 2021. With owners' consent, a maximum of five live pigs per



**Fig. 2.** The criteria for community allocation to albendazole intervention in two villages and the control village receiving routine annual intervention among school children in the district.

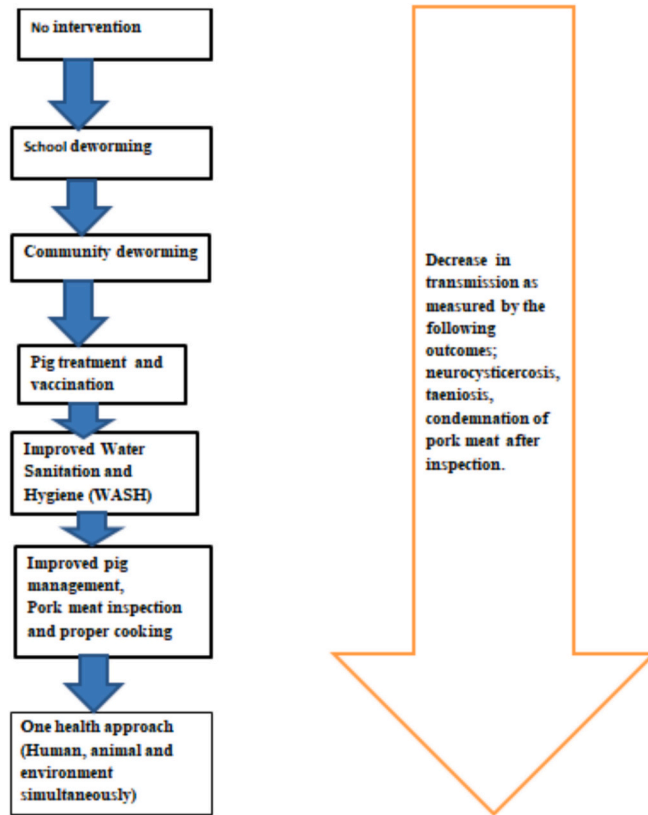


Fig. 3. Approach to elimination of *Taenia solium* from no intervention to one health intervention.

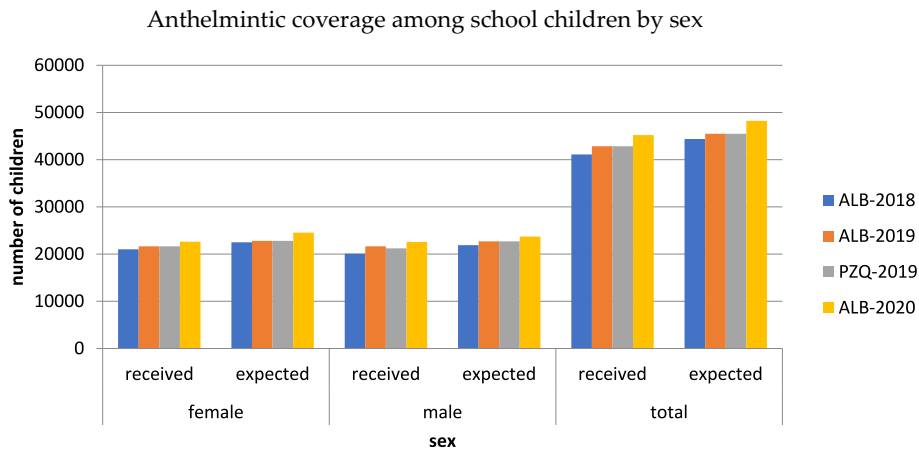


Fig. 4. Recorded anthelmintic coverage among school children in Mbulu district. The trend shows increasing coverage from the year 2018 to 2020 with albendazole being the most administered drug in the district.

household were conveniently sampled and examined for the presence of cysticercosis by the lingual examination method. The pig management practices were recorded for each pig examined. The whitish mass on the underside of the tongue set the decision on cysticercosis infection (Mutua et al., 2007; Ngowi et al., 2008). This was done by a veterinarian. The head of household upon consent was requested to respond to questionnaires on disease knowledge and sanitation and responses recorded electronically.

2.5. Data analysis

Data were analysed using SPSS version 20 software. Categorical variables were summarized by frequencies and proportions.

Logistic regression was performed to determine the influence of risk factors on the outcome. A  $p$ -value of less than 5% was considered significant. Wilson's method was used to calculate the confidence interval (Dunnigan, 2008).

## 2.6. Ethical consideration

Ethical clearances were obtained from the National Health Research Ethics Committee (NatHREC) of the National Institute for Medical Research (NIMR/HQ/R8a/Vol.IX3301). The study also received approval from the Tanzania Medicines and Medical Devices Authority (TMDA) with reference number TMDA0019/CTR/0017/02.

## 3. Results

A total of 510 pigs were conveniently sampled, of these 267 (52.4%) were sampled during the rainy (March) and dry (September) seasons of the year 2020 while 243 (47.6%) were sampled in the year 2021 for rainy and dry season. Of the 510, 237 (46.5%) were male pigs. Out of 510 pigs 43 (8.4%) pigs were infected with *T.solium* metacestode, among them, 21 (48.8%) were males and 22 (51.2%) females. There was no statistical significant difference in infection between male and female pigs ( $p = 0.7451$ ). The pigs aged four months and above are likely to be detected with the lingual examination methods as shown in Table 1. Overall, the annual prevalence of the infection between the two consecutive years for rainy and dry seasons was 24 (9%) and 19(7.8%) in 2020 and 2021, respectively ( $p = 0.6348$ ) with observed seasonal variations (Table 2). A significant seasonal difference in infection was observed for the year 2020 where the pigs were more than two times infected during the rainy season compared to the dry season (OR 2.27 (95% CI of 1.16–7.22) (Table 3).

The pig-keeping styles recorded in the study area for the year 2020 include; 141 (52.8%) with no tethering, 64 (24%) penned and 62 (23.2%) tethered. Human feces were often observed on footpaths as the research team moved from one household to another. The difference in pig infection outcomes in the study villages was not statistically significant regardless of the pig-keeping style (Table 4).

In this study, 94 households were visited for the year 2020 with the household members ranging from two to ten. Of these household heads, 78 (83%) reported drinking water without boiling; and only 16 (17%) households reported using boiled water. Fifty-nine (62.7%) household heads reported having heard taeniosis/cysticercosis in vernacular called 'gilgiri' for tapeworm segments and 'fini' for cysticercus as observed in pork meat.

## 4. Discussion

The study results show persistent porcine cysticercosis for two consecutive years and observed significant seasonal variations in porcine cysticercosis prevalence for the year 2020. Porcine cysticercosis prevalence did not vary significantly based on the pig-keeping style. The observed difference between the rainy and dry seasons of the year 2020 may be explained by the long rainy season observed compared to the year 2021 where the rain was moderate. The persistent prevalence of porcine cysticercosis is an indicator of fecal contamination of soil and water with infective pork tapeworm eggs from human excreta as feces were observed along the footpath as the team moved from one household to another and the smell of feces in the mouth of pigs was detected during the lingual examination. This has implication of poor health education.

This study recorded four different points to have a trend of infection in the community; the varied trends may be a result of school deworming interventions conducted annually or a result of discouraged pig farmers due to the loss experienced from previous year infected pigs, resulting in the household with a tapeworm carrier unknowingly avoiding to keep pigs as a consequence of a loss experienced. Second the results show no statistical significance in pig management practices; this may be due to the free-roaming of young pigs thus being infected at the first two months of life and become easily detected by lingual examination from fourth month of life if infected as pig buyers inspect before buying as shown in Table 2; above four months of life cysticerci are easily detected in tongue. Third, may also be attributed to the community treatment with albendazole in households conducted in this study. The results of this study are similar to the results of studies conducted in Kenya, Mozambique, and Zambia where the prevalence of lingual

**Table 1**  
Domestic pig infection trend by age for 2020 and 2021.

Age (month)	infected 2020	infected 2021	Total infected
2	3	0	3
3	1	0	1
4	1	3	4
5	4	1	5
6	3	7	10
7	1	2	3
8	4	0	4
9	4	2	6
10	0	1	1
12	2	3	5
14	1	0	1
Total	24	19	43

**Table 2**

Porcine cysticercosis prevalence among three villages in Mbulu district for two consecutive years.

Year	Village	Total	positive	Prevalence	Fisher's exact test
2020	Diyomat	101	5	4.95 (2.13–11.07)	reference
	Maghang Juu	62	4	6.45 (2.54–15.45)	0.7319
	Harsha	104	15	14.42 (8.94–22.44)	0.0323
	Overall communities	267	24	8.99 (6.11–13.03)	0.2781
2021	Diyomat	75	5	6.67 (2.88–14.68)	reference
	Maghang Juu	101	7	6.93 (3.4–13.62)	1.0000
	Harsha	67	7	10.45 (5.15–20.03)	0.5488
	Overall communities	243	19	7.82 (5.06–11.89)	1.0000

**Table 3**

The seasonal prevalence of porcine cysticercosis in Mbulu district, Tanzania.

Year	Month(Season)	Positive n (%)	Negative n (%)	Total	odds ratio(95CI)	z statistic (P value)
2020	March(rainy)	17 (13.3)	111 (86.7)	128	2.27 (1.16–7.22)	2.270 (0.0232)
	September(dry)	7 (5.0)	132 (94.9)	139		
	Sub-Total	24 (9.0)	243 (91.0)	267		
2021	March(rainy)	7 (8.1)	79 (91.8)	86	1.07 (0.40–2.82)	0.138(0.8904)
	September(dry)	12 (7.6)	145 (92.3)	157		
	Sub-Total	19 (7.8)	224 (100)	243		
	Total	43(8.4)	467(91.6)	510		

**Table 4**

Prevalence and risk factors of porcine cysticercosis (N = 267).

Variable	n	Rainy season		Odds ratio (95% CI)	n	Dry season		Odds ratio (95% CI)
		Infected n (%)	Non-Infected n (%)			Infected n (%)	Non-Infected n (%)	
	128				139			
Village								
Harsha	50	12(24.0)	38(76.0)	Ref	54	3(5.56)	51(94.44)	Ref
Diyomat	52	1(1.92)	51(98.08)	0.06(0.01–0.49)	49	4(8.16)	45(91.84)	1.51(0.32–7.12)
Maghang Juu	26	4(15.38)	22(84.62)	0.58(0.17–2.01)	36	0(0.00)	36(100.0)	~
Rearing style								
caged	32	3(9.38)	29(90.63)	0.81(0.19–3.49)	32	0(0.00)	32(100.0)	~
free	43	8(18.60)	35(81.40)	1.79(0.57–5.63)	98	5(5.10)	93(94.90)	0.19(0.03–1.15)
mixed	53	6(11.32)	47(88.68)	Ref	9	2(22.22)	7(77.78)	Ref
Total	128	17(13.28)	111(86.72)		139	7(5.04)	132(94.96)	

examination ranged from 6 to 15% (Mutua et al., 2007; Pondja et al., 2010; Sikasunge et al., 2007). The pork tapeworm risks of free-roaming and tethering sometimes were observed and similar to other studies conducted in Tanzania, Mozambique, and Zambia (Kabululu et al., 2015; Pondja et al., 2010; Sikasunge et al., 2007). The high prevalence of porcine cysticercosis suggests the presence of tapeworm carriers in communities while drinking unsafe water in endemic communities presents risks to human cysticercosis in these communities. Pig vaccination and treatment for pork tapeworm are not in operation in Mbulu district. The deworming program is for humans only and is at primary school and it is reflected that younger age groups are protected from infection by 28% though protection was not significant (Bandi et al., 2024). The school deworming program may have contributed to the observed decrease in porcine cysticercosis compared to the prevalence (17.4%) reported twenty years back in the same study area using the same –lingual- examination diagnostic method (Ngowi et al., 2004). The porcine cysticercosis incidence after health education in the same area fifteen years ago showed a decrease of 13% (95% CI: 12–14) per 100 pig-years, a halfway drop from the baseline (Ngowi et al., 2008). This implies health education intervention is powerful as it combines pig management practices, personal sanitation and hygiene, proper cooking of pork meat and treatment of infected pigs.

This study suffered short time of intervention, we did not employ carcass examination of slaughtered pigs in communities, furthermore antigen and antibody diagnostic methods were not employed thus underestimating the prevalence. In this study intervention scaled up to adult with a single dose of albendazole administered at six month interval for one community so as to abide to present preventive treatment guideline in the country. The triple dose at 24 h interval as preventive chemotherapy was not adopted in the country (PAHO, 2021). The last limitation is seasonal prevalence was assessed at March and September only which are considered

as mid-points for rainy and dry seasons respectively. Thus, integrating pig vaccination and deworming, community health education, and school or community deworming may be the future solution to porcine cysticercosis (Fig. 3).

## 5. Conclusion

The study has shown that porcine cysticercosis prevalence fluctuates. The decrease in the subsequent year with little rain needs further research as there was community deworming apart from school deworming as conducted for entire human population in the study sites. Thus it is not conclusive that the decrease was attributed to low rain or other study in community deworming programs in human. The observed porcine cysticercosis prevalence and a large proportion of households drinking unsafe water imply a high prevalence of taeniosis and human cysticercosis in these communities.

## CRedit authorship contribution statement

**Vedasto Bandi:** Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Bernard Ngowi:** Supervision, Methodology, Investigation, Conceptualization. **Emmanuel Mpolya:** Supervision, Methodology, Conceptualization. **Andrew Martin Kilale:** Writing – review & editing. **John-Mary Vianney:** Supervision, Methodology, Conceptualization.

## Declaration of competing interest

The authors declare no conflict of interest.

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