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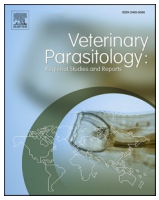

Original Article

Knowledge, attitudes and practices regarding porcine cysticercosis control among smallholder pig farmers in Kongwa and Songwe districts, Tanzania: A cross-sectional study

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ABSTRACT

Taenia solium taeniasis/cysticercosis (TSTC) is a parasitic zoonotic disease that is endemic in several developing countries, causing serious public health and economic impacts. A cross-sectional study was conducted to assess knowledge, attitudes and practices (KAP) related to porcine cysticercosis (PCC) transmission, prevention and control among smallholder pig farmers in Kongwa and Songwe Districts in Tanzania. A semi-structured questionnaire was administered to 692 smallholder pig farmers from randomly selected households. STATA software version 17 was used to analyse quantitative data, summarize farmers' KAP about PCC and calculate performance scores. Nearly half (42%) of the respondents had little knowledge regarding PCC, only 17% of the respondents had good practices towards prevention/control of PCC and 72% had a positive attitude towards PCC- prevention/control measures. The majority (73%) of smallholder pig farmers admitted deworming their pigs regularly, whereas 76% reported deworming themselves and their family members regularly. Albendazole and ivermectin are the most commonly used medications for deworming people and pigs, respectively.

According to the findings, the majority of smallholder pig farmers in Kongwa and Songwe Districts showed a good attitude towards PCC prevention/control measures but had limited knowledge of the PCC life cycle and control. In addition, only one in five farmers was engaged in good practices. The findings revealed further that farmers are engaged in risky behaviours that aid the spread and perpetuation of the *T. solium* parasite in the study area. It is recommended that farmers should be given proper health education on the *T. solium* transmission cycle and preventive/control practices to limit PCC transmission.

1. Introduction

Taenia solium taeniasis/cysticercosis (TSTC), a parasitic zoonotic disease, is reported as endemic in several developing countries in Asia, Africa and Latin America (WHO, 2015). The disease causes serious public health and economic impacts in Tanzania (Trevisan et al., 2017; Mwang'onde et al., 2018; Kayuni, 2021). The *T. solium* parasite has an indirect life cycle that consists of two mammalian hosts: pigs and humans and the environment. Ingesting the parasite's eggs from a human definitive host from a contaminated environment causes cysticercosis in both humans and pigs (Kungu et al., 2017). The parasite's life cycle is sustained in endemic areas due to unsatisfactory sanitary behaviour, free-range pig management, inadequate meat inspection, and the eating of raw or undercooked pork (Secka et al., 2008). Furthermore, the community's limited awareness of the parasite's transmission cycle facilitates the disease's endemicity (Ngowi et al.,

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2008).

In areas where *T. solium* is endemic, various strategies have been used to control its infections. These include; treatment of taeniasis-infected individuals (Haby et al., 2020), pig vaccination (Kabululu et al., 2020a), improved indoor pig rearing and sanitation, pork inspection and health education (Ngowi et al., 2017; Ngowi et al., 2019). Despite global efforts to prevent and control its infections, TSTC continues to affect many pig-raising communities worldwide, particularly in sub-Saharan Africa, Southeast Asia and Latin America. Studies in Tanzania have estimated the prevalence of porcine cysticercosis (PCC) of between 11 and over 30% using an antigen enzyme-linked immunosorbent test (Ag-ELISA) (Komba et al., 2013; Shonyela et al., 2017; Maganira et al., 2019). Importantly, more than 16% of the human population in disease-endemic communities has cysticercosis (HCC) (Ngowi et al., 2019). Neurocysticercosis (NCC), caused by the larval form of *T. solium* infecting the brain and spinal cord, in humans, is the most common medical complication, which may lead to epileptic seizures, epilepsy, and severe headaches among other neurological signs/symptoms. In Tanzania, more than 200 deaths and approximately 18,000 incident cases of epilepsy have been reported to be caused by NCC annually (Trevisan et al., 2017). The socio-economic costs in areas where TSTC is widespread are substantial. In Tanzania, economic loss from NCC-related epilepsy was estimated to cost around USD 5 million annually and PCC leads to an annual loss of up to USD 3 million due to condemnation of infected pigs or pork (Trevisan et al., 2017).

Low knowledge regarding the disease risk factors, transmission, prevention and control is the primary factor contributing to the disease's persistence in numerous pig-raising communities (Chacha et al., 2014). Poor knowledge encourages the community to adopt practices that perpetuate the life cycle of the parasite (Lescano et al., 2007; Sorvillo et al., 2011). To establish adequate measures for the prevention, control and eventual elimination of the parasite, a change in community knowledge, attitudes and practices (KAP) is required (Nyangi et al., 2022). Communities with adequate knowledge are likely to adopt managerial strategies such as improving hygienic and sanitary conditions (Shapu et al., 2021), and in-door pig management (Kajuna et al., 2023) which, in turn, reduce PCC prevalence (Ngowi et al., 2008). KAP surveys provide data on knowledge gaps, beliefs (attitudes) and practices regarding PCC transmission and prevention to enable planning control measures. However, data on KAP regarding PCC in several African countries are limited (Ngowi et al., 2008; Ngwili et al., 2022). The purpose of this study was to assess the KAP of smallholder pig farmers in PCC-endemic communities in Kongwa and Songwe Districts. The findings could help in evaluating a subsequent health education intervention targeting parasite control in smallholder pig farmers in the study areas.

2. Materials and methods

2.1. Ethical consideration

This research was approved by the Ministry of Health and the Ethics Review Board of the Tanzanian National Institute for Medical Research (NIMR) (reference number NIMR/HQ/R.8a/Vol.IX/2802) and Sokoine University of Agriculture (reference number SUA/ADM/R.1/8/352) (SUA) of the Republic of Tanzania. The study also received approval from the Ethics Committee of the Klinikum rechts der Isar, Technical University of Munich, Germany, under the number 537/18 S-KK. Permission letters were provided by the Executive Directors of Kongwa and Songwe Districts. Each respondent gave informed consent in writing before participating in the questionnaire interview. The results were pseudonymized and therefore did not reveal the identities of the respondents, and the data were kept confidential.

2.2. Study area

The study was conducted from June to September 2019 in Kongwa and Songwe Districts. The study areas (Fig. 1) were chosen due to their popularity in small-scale pig farming and reported PCC endemicity (Maganira et al., 2019; Kabululu et al., 2020b). In 2012, the estimated pig populations were 56,498 and 33,046 in Kongwa and Songwe Districts, respectively (NBS (National Bureau of Statistics), 2012). The district covers 4041 km^2 of land and lies between 5°30 and 6°00′ S latitudes and 36° 00 and 36°15′E longitudes with an altitude of 900 to 1000 m above sea level. The mean temperature is 26.5 °C. The rainy season lasts from November to April and averages between 500 and 800 mm annually (Mkonda and He, 2017). Songwe District is located in Songwe Region in the southwestern part of Tanzania. The district covers an area of 16, 070 km^2 out of which 14,965 km^2 is occupied by land and 1105 km^2 is occupied by water. The district is located at latitudes between 8°25 and 85°65′S and longitudes of between 32°00 and 33°14′E, with an average temperature of 16 °C and altitudes of between 900 and 2750 m above sea level. The rainy season extends from November to May with an average annual rainfall of around 900 mm (URT, 2012). The major economic activities in Kongwa and Songwe Districts include livestock keeping and subsistence crop farming. In addition, gold mining, beekeeping, and fishing activities are other economic activities carried out in Songwe District.

2.3. Study design and sample size

A cross-sectional survey was conducted in 42 villages. Villages, households and participants that met the eligibility criteria were chosen using a multi-stage cluster sampling method. The probability proportional to size sampling (PPS) method was used to select the villages for the study based on the pig population (Joshi and Rajarshi, 2018). Twenty-eight (28) out of 87 and 14 out of 43 villages were selected from Kongwa and Songwe Districts, respectively. This study served as a baseline for a larger study that evaluated the effectiveness of health education intervention on the prevalence of porcine cysticercosis and KAP among smallholder pig farmers. Assuming that Health education intervention would reduce the prevalence of porcine cysticercosis to 15%, it would have an 80% power to detect a 50% drop with a 95% confidence level. The formula $n = [Z\alpha\sqrt{(2pq)} - Z\beta\sqrt{P1q1 + P2q2}]^2 / (p_1 - p_2)^2$ was used to estimate the sample size needed for this study (Dohoo et al., 2003). Where n = estimated sample size, $Z\alpha = 1.96$ Confidence interval, $Z\beta = 0.84$, p = a priori estimate of the proportion, P1, P2 prevalence estimates in the two groups (baseline and follow-up, respectively), q = 1- p, a proportion free of the factor, q1 = 1- P1, q2 = 1- P2. We assumed a PCC prevalence of 30% (Komba et al., 2013; Ngowi et al., 2014). The number of pigs sampled per village ($n = 16$) was determined by dividing the required sample size ($n = 672$) by the total number of villages ($n = 42$) for this study. Hence, 16 HHs were sampled per village. This study included 450 HH and 242 HH in Kongwa and Songwe Districts, respectively. The main criteria for a village to participate in the study were the presence of more than 20 accessible pig-keeping households and the willingness of village leaders to cooperate. The pig-keeping households were chosen at random using random numbers from Excel from a list of pig-keepers obtained from the Village Office Register. The households which met the following criteria were recruited for the study; first, the HH had to have at least one pig ≥3 months old and the second was the willingness of the HH owner to participate.

2.4. Data collection

An inception meeting was held with the selected household heads and village leaders before the beginning of the survey to explain the study's goal. The head of each selected HH was met in the village office for a questionnaire survey. Data from these households were collected by using a checklist and a questionnaire through Kobo Toolbox software. The questionnaire in Kobo Toolbox software was separately administered through face-to-face interviews with each selected HH head by a

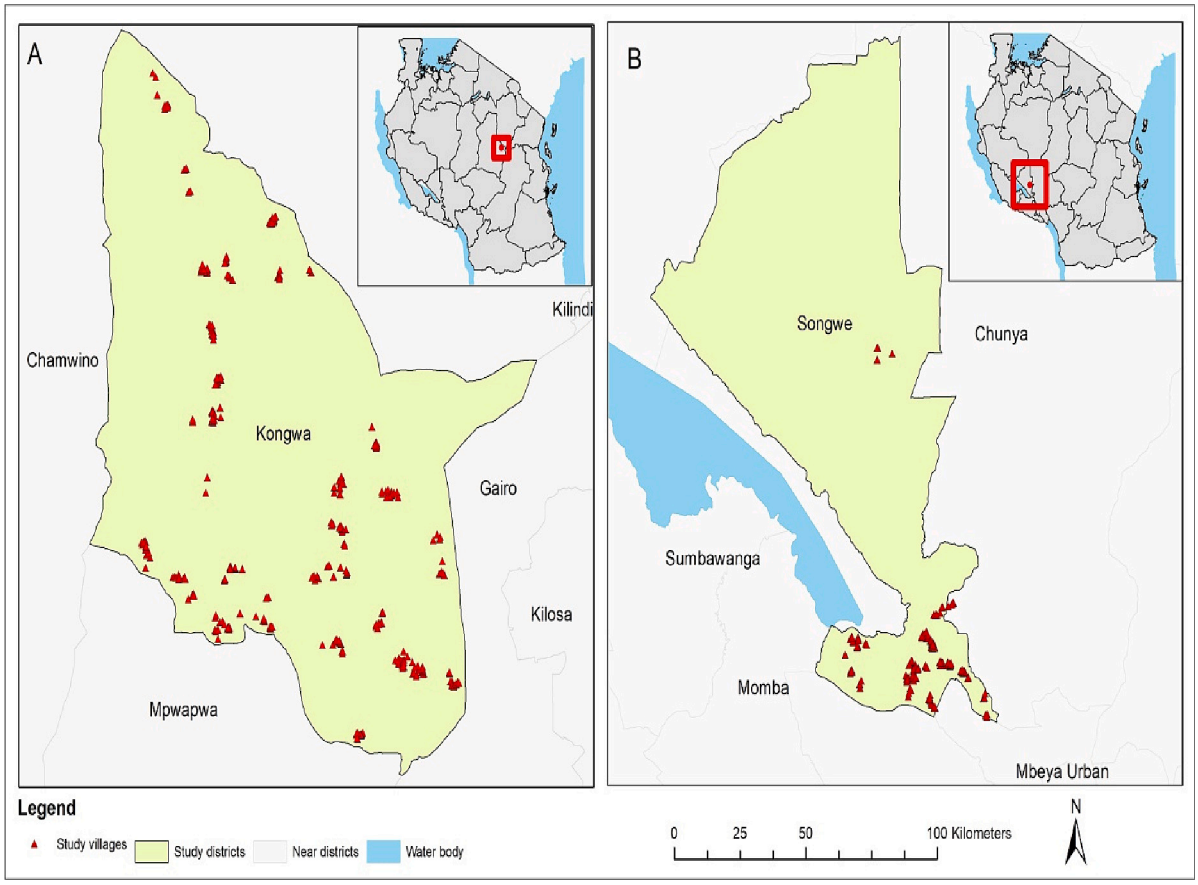

Fig. 1. The map labeled A shows Kongwa District and the insert is a map of Tanzania with a red box that indicates the relative location of the Kongwa District. The map labeled B shows the Songwe District and the insert is a map of Tanzania with a red box that indicates the relative location of the Songwe District. The red triangles mark the study households in Kongwa and Songwe Districts. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Principal Investigator and one Research Assistant. The questionnaire consisted of four sections namely; demographic factors, knowledge, attitude, and practice. The knowledge section comprised a set of questions designed to obtain information on knowledge related to PCC transmission, clinical manifestations, prevention, and control. The attitude section consisted of questions derived to measure beliefs towards PCC control, whereas the practice section consisted of a set of questions derived to determine farmers' practices towards prevention/control of PCC.

2.5. Performance score

The survey's knowledge section contained a total of 14 questions. Seven of the questions aimed to determine *T. solium* awareness and transmission and 7 others aimed to determine *T. solium* prevention and control knowledge. The questions were multiple-choice with a value of 1 for an accurate response and 0 for a false or do- not-know-response. Depending on the number of correctly selected options, a participant's total score for the 14 questions ranged from 0 to 44 points. The attitude section consisted of 8 Likert scale, questions, all of which were three points. A score of 2 was for "agree," 1 was for "not sure," and 0 was for "disagree." The ten questions on general farmer practice and the approach to disease control were multiple-choice with yes, no, or do not know responses. The score of 1 was for an accurate response and 0 was for a false or do not know response. A modified Bloom's cut-off point was used to calculate the total score for each outcome, knowledge, attitudes and practices (Yusof et al., 2018). There were three categories of knowledge level: low (less than 40%; 0–17.5 points), moderate (41 to 60%; 18–26.5 points) and high level (more than 60%; 27–44 points). On the other hand, the attitude scores were broken into three categories: a negative attitude (less than 40%; 0–6.5 points), a neutral attitude (41 to 60%; 6.6–9.7 points) and a positive attitude (61 to 100%; 9.8–16 points), The level of practice was then categorized as poor (less than 40%; 0–7.6 points), moderate (41 to 60%; 7.7–11.5 points) and good (61 to 100%; 11.6–19 points).

2.6. Statistical analysis

The questionnaire data were entered into a Microsoft Excel spread sheet for cleaning and storage. The analysis was conducted using STATA 17.0. For categorical variables, descriptive statistics in the form of frequencies and percentages were performed. Additionally, a bivariate logistic regression was used to assess the association between the independent and dependent variables. Knowledge, Attitudes and Practices (KAP) were the outcome variables, while age, sex, education level and district were the independent variables. In the first step, simple logistic models were used to fit PCC knowledge, attitudes and practices with potential predictor variables. If there was a significant association with the outcome at a significance level of 0.25, the variables were included in the multivariable logistic regression model. The significance level for the predictor variables in the multivariable logistic regression model was set at 0.05. At 95%, the confidence intervals and odds ratio (OR) were calculated.

3. Results

3.1. Demographic characteristics, pig management and sanitation situation of the study population

A total of 692 respondents participated in the study among these 66% (n = 454) were males. The majority of respondents were agro-pastoralists, the respondents' age ranged from 15 to 75 years and the highest proportion of the respondents fell between the ages of 26–45 years. The majority (65% n = 451) of the respondents had primary school education. Additionally, about 88% (n = 615) of the respondents kept between 1 and 10 pigs, while 9% (n = 59) kept between 11 and 20 pigs (Table 1). Sixty-five per cent of the respondents were practising indoor pig keeping whereby pigs were bound consistently. Maize bran, grass, vegetables and kitchen leftover were the primary feeds given to confined pigs. About 28% (n = 193 of the households were practising free-range management systems, whereby pigs were unrestricted/or grazed during the largest part of the year. The remaining percentages of the surveyed farmers were engaged in partial confinement of pigs. Pigs were partially confined in shelters or tethered during the crop production period (rain season) and left unrestricted during the dry season (after crop harvest). The study found that 92% (n = 634) of the households had latrines, though most of the latrines were lacking privacy (lacking functioning doors, well secured walls or roofs). Furthermore, 20% (n = 137) of the respondents reported their children practising open defecation. In addition, 72% (n = 500) of the surveyed households with latrines did not have hand-washing facilities. Furthermore, 15% (n = 102) of the interviewed farmers admitted slaughtering their pigs at homes where meat inspection was uncommon.

Table 1
Characteristics of the study population in Kongwa and Songwe Districts, Tanzania, 2019 (n = 692).

Independent variable	Categories	Kongwa n = 450	Songwe n = 242	Total n (%)
Age groups	15–25	48	24	72 (10.4)
	26–35	137	63	200 (28.9)
	36–45	134	65	199 (28.8)
	46–55	77	60	137 (19.8)
	56+	54	30	84 (12.1)
Sex	Male	286	168	454 (65.6)
	Female	164	74	238 (34.4)
Education level	Non-formal education	98	75	173 (25.0)
	Primary	304	147	451 (65.0)
	Secondary and above	48	20	68 (9.8)
Number of pigs owned in a household	1–10	405	210	615 (88.9)
	11–20	31	28	59 (8.5)
	≥21	14	4	18 (2.6)
Residency (year)	1–15	79	68	147 (21.2)
	16–30	158	71	229 (33.1)
	31–45	148	97	245 (35.4)
	46+	65	6	71 (10.3)

3.2. Knowledge of porcine cysticercosis transmission, prevention, and control among smallholder pig farmers

The results about the knowledge of the respondents regarding PCC transmission, symptoms, and prevention are shown in Tables 2 and 3, respectively. The respondents' overall knowledge levels were as follows: high 12% (n = 85), moderate 46% (n = 315), and low 42% (n = 292). Up to 72% (n = 496) of the respondents had heard about the disease which was locally known as "fini," "madudu," "chenga" and "mtama mweupe." However, only 34% (n = 232) of the respondents were aware that pigs contract *T. solium* cysticercosis by ingesting human feces with *T. solium* eggs. Furthermore, 10% (n = 73) of the respondents linked PCC infection to water with human feces contamination. Only 35% (n = 187) of the respondents were aware that pork infested with cysticerci poses a health risk and that they might get infected with *T. solium* cysts. Furthermore, about 36% (n = 254) of the respondents were able to identify cyst-infected pork.

Table 2
Knowledge of transmission of porcine cysticercosis among smallholder pig farmers in Kongwa and Songwe Districts, Tanzania 2019 (n = 692).

Knowledge areas	Correct N (%)	Incorrect N (%)
Heard about porcine cysticercosis	496 (71.7)	196 (28.3)
Ways pigs acquire *T. solium* cysticercosis		
Eating human feces with *T. solium* eggs	232 (33.5)	460 (66.5)
Eating food contaminated with *T. solium* eggs	24 (3.5)	688 (96.5)
Eating grasses and vegetables contaminated with human feces	56 (8.1)	636 (91.9)
Drinking water containing *T. solium* eggs	73 (10.3)	619 (89.5)
Don't know	615 (88.9)	77 (11.1)
Others	305 (44.1)	387 (55.9)
Is it safe for humans to consume pork containing cysts?	542 (78.3)	150 (21.7)
If not choose the correct answer		
Might get infected with *T. solium* cysts	187 (34.5)	355 (65.5)
Might get tapeworm, taeniosis	0 (0.0)	542 (100)
The infected pork is not delicious	541 (99.8)	1 (0.2)
The infected pork is strictly prohibited	143 (26.4)	399 (73.6)
Don't know	494 (91.1)	48 (8.9)
How do you identify *T. solium* cysts in infected pigs?		
Don't know	305 (44.1)	387 (55.9)
Tongue examination	183 (26.5)	509 (73.5)
Feces examination	679 (98.1)	13 (1.9)
Hair/fur examination	589 (85.1)	103 (14.9)
How do you recognize "measly" pork?	254 (36.7)	38 (63.3)
Predilection sites for cysts in live pigs		
Skeletal muscle	71 (11.0)	573 (89.0)
Tongue	126 (19.6)	518 (80.4)
Brain	66 (10.3)	578 (89.7)
Eyes	497 (77.2)	147 (22.8)
Skin	100 (15.5)	544 (84.5)
All of the above	550 (85.4)	94 (14.6)
Don't know	331 (55.7)	263 (44.3)

N, number of respondents.

Table 3
Knowledge of prevention/control of porcine cysticercosis among smallholder pig farmers in Kongwa and Songwe Districts, Tanzania 2019 (n = 692).

Knowledge areas	Correct N (%)	Incorrect N (%)
When *T. solium* cysts are found in pigs, which steps are taken?		
Consult veterinary doctor	395 (57.1)	297 (42.9)
Use traditional medicine	680 (98.3)	12 (1.7)
No actions will be taken	496 (71.7)	196 (28.3)
Sell the pigs	684 (98.8)	8 (1.2)
Slaughter and consume the pork	689 (99.6)	3 (0.4)
Others specify	654 (94.5)	38 (5.5)
Is there any means of preventing pigs from acquiring *T. solium* cysticercosis?	299 (43.2)	393 (56.8)
If yes, mention the preventive measures		
Keeping pigs indoors all the time	290 (97.0)	9 (3.0)
To have toilets with closed doors	45 (15.1)	254 (84.9)
Proper use of toilets	9 (3.0)	290 (97.0)
People should stop open-field defecation	19 (6.4)	280 (93.6)
Do you think *T. solium* porcine cysticercosis can cause economic losses?	437 (63.2)	255 (36.8)
If yes, mention the effects:		
Lack of market for infected pigs	296 (67.7)	141 (32.3)
Condemnation of infected pork	362 (82.8)	75 (17.2)
Low price for infected pigs	54 (12.4)	383 (87.6)
Can *T. solium* cysticercosis in pigs be treated?	209 (30.2)	483 (69.8)
If yes, mention the drugs which can be used:		
Mebendazole	209 (100.0)	0 (0)
Albendazole	6 (2.9)	203 (97.1)
Ivermectin	174 (83.3)	35 (16.7)
Don't know	53 (25.4)	156 (74.6)

N, number of respondents.

3.3. Sources of information on porcine cysticercosis

The results (Fig. 2) show that friends were the most frequent source of information (70.1%) followed by Veterinary Officers (23%).

3.4. Participants' attitude towards porcine cysticercosis

The results show that the majority (73% $n = 502$) of the respondents had a favourable attitude towards PCC prevention/control efforts. About 69% ($n = 477$) agreed that PCC causes financial losses to pig producers, and 64% ($n = 444$) agreed that cyst-infected pork should be condemned. Furthermore, 59% ($n = 411$) of the respondents believed that using latrines with functioning doors can lower the occurrence of PCC (Table 4).

3.5. Practices of the respondents towards prevention/control of porcine cysticercosis

Nearly half of the respondents scored moderately on practices towards control of PCC. Meanwhile, only 17% ($n = 116$) were at the good practice level. Furthermore, most farmers (72% $n = 501$) reported deworming their pigs more than deworming themselves and their family members. Up to 43% ($n = 294$) of the respondents reported deworming their pigs every three months, while 85% ($n = 446$) reported deworming themselves and their families once a year. The majority (77% $n = 387$) of the respondents said they regularly use ivermectin to deworm their pigs, 15% ($n = 74$) did not know the type of drugs used while only 22% ($n = 114$) reported using albendazole to deworm themselves and their families. Drinking untreated water and not washing hands before preparing pig feed were common prevalent practices reported by the majority of the interviewed farmers (Table 5).

3.6. Multivariate associated with KAP scores of smallholder pig farmers ($n = 692$)

Table 6 shows the factors associated with the KAP score of smallholder pig farmers. Among these factors, education level and districts (location) were significantly associated with both KAP scores. Only the knowledge and attitudes score was significantly influenced by the age of the respondents. Compared to respondents in other age groups, those in the age range from 36 to 45 years had significantly higher odds of having adequate knowledge and positive attitudes (OR 1.7; 95% CI 1.0, 3.0; $p = 0.049$) and (OR 1.8; 95% CI 1.0,3.3; $p = 0.039$) respectively.

4. Discussion

Understanding pig farmers' knowledge, attitudes and practices (KAP) linked to *T. solium* cysticercosis transmission and prevention is critical for planning successful control interventions. A successful disease control strategy depends on community awareness. Our study found that the majority of the respondents had heard about PCC. As the majority of respondents are cognizant of the disease suggests that PCC is a challenge in the area under investigation.

This study found that the majority of the respondents had a positive attitude towards the prevention measures against PCC but had limited knowledge about PCC. Thus, PCC may persist in the study area due to limited or lack of knowledge (Jayashi et al., 2012). Likewise, public awareness of the disease has been shown to reduce the number of infected humans and pigs in endemic areas (Ngowi et al., 2008; Mwape et al., 2013).

The results of our study indicate that male respondents were more knowledgeable about PCC than their female counterparts. Further, the study found that there were no statistically significant differences between gender in their attitudes and practices. The findings of this study were comparable to the findings in a study by Kungu et al. (2017) who observed that male farmers in Uganda had significantly higher PCC knowledge than had their female counterparts. This suggests that an education strategy should pay special attention to the majority of female respondents, who in most cases do not have a formal education and are less involved in social gatherings than is the case with men.

The results of this study showed a significant knowledge gap among pig farmers on the *T. solium* life cycle, which could lead to practices that perpetuate *T. solium* infections in the community (Lescano et al., 2007; Sorvillo et al., 2011). The findings are similar to the findings from earlier studies in Tanzania (Maridadi et al., 2011; Chacha et al., 2014) and Burkina Faso (Ngowi et al., 2017). In our interviews, the majority of pig farmers admitted drinking untreated water from unhygienic sources such as open wells, rivers and ponds. This behaviour exposes the community to *T. solium* infections, (Mwanjali et al., 2013). With these observations, future interventions should focus on community health education about the *T. solium* life cycle, preventive measures and improving water, sanitation and hygiene practices.

Furthermore, the study found that the majority of the respondents were unable to distinguish between cyst-infected pork and safe pork due to a lack of knowledge, a situation that put the community's health at risk and increases the possibility of parasite transmission to humans and pigs. In the light of this, community health education about the *T. solium* parasite is advocated since studies show a clear correlation between more knowledge and the reduction of *T. solium* infections (Ngowi et al.,

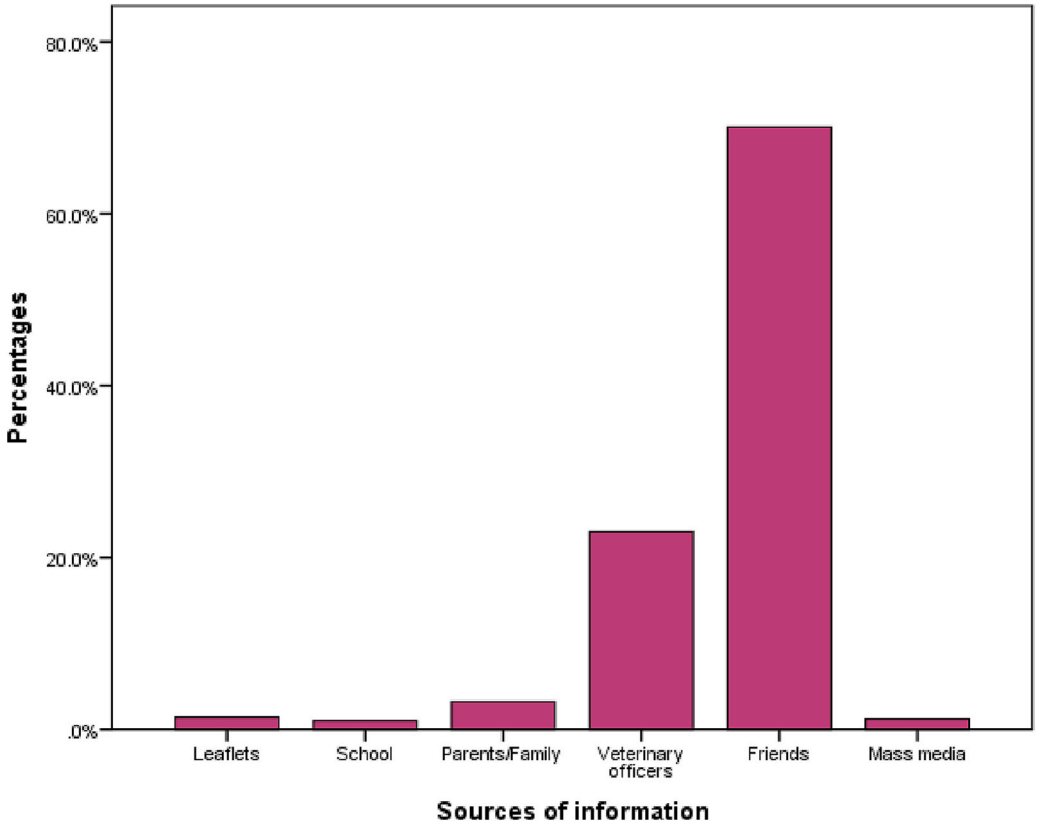

Fig. 2. Source of information about porcine cysticercosis as reported by respondents in Kongwa and Songwe districts, Tanzania $n = 692$.

Table 4
The smallholder pig farmers' attitudes towards prevention/control of porcine cysticercosis in Kongwa and Songwe Districts, Tanzania 2019. (n = 692).

Attitudes	Response		
	Agree N (%)	Neutral N (%)	Disagree N (%)
T.solium cysticercosis is a zoonotic infection that can occur in both pigs and humans.	302 (43.6)	236 (34.1)	154 (22.6)
T.solium causes great losses to pig farmers.	477 (68.9)	107 (15.5)	108 (15.6)
I know that pork infected with *T. solium* is rejected for human consumption.	424 (61.3)	138 (19.9)	130 (18.8)
I must buy/sell pork that has been slaughtered and inspected by veterinary officials.	536 (77.5)	57 (8.2)	99 (14.3)
Both humans and pigs are at risk of contracting *T. solium* cysticercosis due to poor hygiene that results in the environment being contaminated with human feces.	393 (56.8)	189 (27.3)	110 (15.9)
If I discovered that my pigs had *T. solium* cysticercosis, I would contact a veterinarian or livestock extension officer	579 (83.7)	79 (11.4)	34 (4.9)
I would condemn pork infected with *T. solium* cysts.	444 (64.2)	74 (10.7)	174 (25.1)
Using toilets/latrines and closing the toilet/ latrines door prevent pigs from accessing human feces.	411 (59.4)	90 (13.0)	191 (27.6)
The overall level of attitude	Positive 502 (72.5)	Neutral 85 (12.3)	Negative 105 (15.2)

N, number of responses.

2008; Alexander et al., 2021).

In addition, the study found that more than half of the farmers dewormed their pigs with ivermectin every three months. The findings of this study were comparable to the findings in a study by Shongwe et al. (2020) in South Africa, who revealed that farmers frequently used ivermectin to deworm their pigs. The routine deworming of pigs demonstrates that farmers are aware of the importance of helminthic control. This is despite that they might not be well-informed on which anthelmintic to use when targeting PCC control. Oxfendazole is the drug of choice for effective PCC treatment, however, it is currently unavailable in the country (Mkupasi et al., 2013; Kabululu et al., 2020a). For proper treatment and control of PCC in Tanzania, the veterinary authority should facilitate the importation of oxfendazole, and pig farmers should be advised accordingly.

Washing hands before preparing pig feeds helps to minimize the chances of contaminating the feeds with the eggs of *T. solium*. Our study revealed that the majority of the interviewed pig farmers reported not washing their hands before making pig feeds. This behaviour is linked to a lack of understanding of *T. solium* transmission among farmers. The findings of this study supports the findings of studies by Mwendia and Notenbaert (2018) and Sibongiseni et al. (2016), who found a link between a low understanding of *T. solium* infections and farmers' hygienic practices. According to the World Health Organization, hygienic practices such as hand washing with soap and clean water reduce the burden of infectious diseases such as *T. solium* taeniasis and cysticercosis (Aiello and Larson, 2002).

This study found good coverage of latrines in the study areas, although the majority of them were inappropriate since they had no doors, insecure walls, roofless structures and lacked water and soap for hand washing. Furthermore, a proportion of the respondents reported to have children that practice open defecation for fear of falling into a pit latrine. Inappropriate latrine still presents a risk for PCC transmission. Previous studies highlighted a lack of or limited use of latrines as an important factor for *T. solium* transmission (Ngowi et al., 2004; Krecek et al., 2012). Therefore, the findings of the current study reaffirm the significance of not only having and using latrines but also of using latrines with functioning doors. In addition, it is important to emphasize

Table 5
Practices associated with control of *T. solium* cysticercosis in smallholder pig farmers in Kongwa and Songwe Districts, Tanzania 2019 (n = 692).

Practices	Frequency	Percent	Total
Wash hands before preparing pigs feed			692
Yes	148	21.4	
Sometimes	31	4.5	
Never	513	74.1	
Disadvantages of free-range pig management			428
Pigs may contract African swine fever	94	22.0	
Pigs may acquire *T. solium* cysticercosis	355	82.9	
A pig may acquire mange	222	51.9	
This may lead to quarrels with neighbours	350	81.8	
Frequency of deworming pigs			692
Once after every three months	294	42.5	
After six Months	34	4.9	
Once per year	173	25.0	
Not deworming	191	27.6	
Drugs used to deworm pigs			501
Albendazole	40	8.0	
Ivermectin	387	77.2	
Don't Know	74	14.8	
Treatment of water before drinking			692
Boil	69	10.0	
Filter	5	0.7	
No treatment	613	88.6	
Others	6	0.9	
Family members dewormed			692
Yes	528	76.3	
No	164	23.7	
Frequency of Family members dewormed			528
Three months interval	45	8.5	
Six months interval	37	7.0	
Once per year	446	84.5	
Drug commonly used for deworming family members			528
Albendazole	114	21.6	
Don't know	210	39.8	
The overall level of Practice			692
Poor	272	39.3	
Moderate	304	43.9	
Good	116	16.8	

washing hands (with soap) after using a latrine for controlling *T. solium* and other hygienic-related diseases.

5. Conclusions and recommendations

The majority of pig farmers in Kongwa and Songwe Districts were aware of porcine cysticercosis. However, they lacked adequate knowledge of PCC transmission and prevention. Farmers were also engaged in risky behaviours that aid in the spread and perpetuation of the *T. solium* parasite. To effectively prevent/control *T. solium* infections in pig-producing endemic areas, farmers should receive proper health education on the *T. solium* transmission cycle and preventive actions to limit PCC transmission.

The strengths and limitations of the study

The study's strength lies in the large sample size of 692 households, which allowed for a comprehensive evaluation of farmers' knowledge, attitude, and practices towards PCC control. This study focused on smallholder pig farmers; thus, the findings may not reflect community understanding, attitudes, or actions towards PCC control. Additionally, the study used a questionnaire to gather knowledge data. It did not use specimens or photographs to acquire information from pig producers about the *T. solium* parasite. The accuracy and truthfulness of the participants' responses were critical to the study's outcomes.

Authors' contributions

Christina Wilson: research design, field data collection, writing original draft, data analysis; Hezron Nonga: supervision, review of the manuscript for publication, Helena Ngowi: funding acquisition, design of the study, management of the project, review, and editing of the manuscript; Ayubu J. Churi: review, editing of the manuscript, Robinson Mdegela: supervision, review, and editing of the manuscript; Ernatus Mkupasi: supervision, project administration, review, editing of the manuscript; Andrea S Winkler: funding acquisition, designing the study, review, editing the manuscript; the final version of manuscript was approved by all authors.

Table 6
Multivariate logistic regression of factors associated with knowledge, attitudes, and practices towards porcine cysticercosis in smallholder pig farmers in Kongwa and Songwe Districts, Tanzania 2019 (n = 692).

Factors	Knowledge			Attitudes			Practices		
	Adequate N (%)	OR (95% CI)	*P*-value	Positive N (%)	OR (95%CI)	P-value	Positive N (%)	OR (95%CI)	P-value
Sex									
Male	280(61.7)	Reference	0.005 **	371(82.4)	Reference	0.404	171(37.7)	Reference	0.222
Female	120(50.4)	0.6(0.5,0.9)		131(54.1)	0.3(0.2,0.4)		101(42.4)	0.1(0.1,0.2)	
Age									
15–25	36(50.0)	Reference		45(62.5)	Reference		31(43.1)	Reference	
26–35	110(55.0)	1.2(0.7,2.1)	0.466	142(71.0)	1.5(0.8,2.6)	0.183	76(38.0)	1.2(0.7,2.1)	0.452
36–45	126(63.3)	1.7(1.0,3.0)	0.049*	150(75.4)	1.8(1.0,3.3)	0.039*	72(36.2)	1.3(0.8,2.3)	0.304
46–55	80(58.4)	1.4(0.8,2.5)	0.247	103(75.2)	1.8(1.0,3.4)	0.057	60(43.8)	1.0(0.6,1.7)	0.918
56+	48(57.1)	1.3(0.7,2.5)	0.373	62(73.8)	1.7(0.9,3.3)	0.131	33(39.3)	1.2(0.6,2.2)	0.633
Education level									
No formal education	65(37.6)	Reference		99(57.2)	Reference		106(61.3)	Reference	
Primary Education	289(64.7)	2.9(2.1,4.5)	<0.001 **	349(77.4)	2.6(1.8,3.7)	<0.001 **	156(34.6)	3.0(2.1,4.3)	<0.001 **
Secondary and Above	46(67.7)	3.5(1.9,6.3)	<0.001 **	54(79.4)	2.9(1.5,5.6)	0.002 **	10(14.7)	9.2(4.4,19.2)	<0.001 **
District									
Kongwa	299(66.4)			371(82.4)	Reference		105(23.3)	Reference	
Songwe	101(41.7)	0.4(0.3,0.5)	<0.001 **	131(54.1)	0.3(0.2,0.4)	<0.001 **	167(69.0)	0.1(0.1,0.2)	<0.001 **

N, number of respondents; OR: Odds ratio.
*Significant ($p < 0.05$).
**Significant ($p < 0.01$).

Ethical consideration

The Ministry of Health and the ethics review board of the Tanzanian National Institute for Medical Research (NIMR) gave their approval (reference number NIMR/HQ/R.8a/Vol.IX/2802). The Sokoine University of Agriculture granted research authorization (reference number SUA/ADM/R.1/8/352) (SUA). The study also received approval from the ethics committee of the Klinikum rechts der Isar, Technical University of Munich, Germany, under the number 537/18 S-KK. Permission letters were provided by the Kongwa and Songwe districts' executive directors. Each respondent gave his/her informed consent in writing before participating in the questionnaire, which was completely voluntary and offered no incentives.

Declaration of Competing Interest

There was no mention of a conflict of interest.

Data availability

The data used to support the results of this study are available from the corresponding author upon request.

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References

Aiello, A.E., Larson, E.L., 2002. What is the evidence for a causal link between hygiene and infections? Lancet Infect. Dis. 198, 284–291.

Alexander, A.M., Mohana, V.R., Muliyila, J., Dorny, P., Rajshekhard, V., 2021. Changes in knowledge and practices related to taeniasis/cysticercosis after health education in a south Indian community. Int. Health 4, 164–169.

Chacha, M., Yohana, C., Nkwengulila, G., 2014. Indigenous knowledge, practices, beliefs and social impacts of porcine cysticercosis and epilepsy in Iringa rural. Health. 6 (21), 2894–2903.

Dohoo, I.R., Martin, W., Stryhn, H., 2003. Veterinary Epidemiologic Research. National Library of Canada, Canada, pp. 47–61.

Haby, M.M., Leon, L.A.S., Luciañez, A., Nicholls, R.S., Reveiz, L., Donadeu, M., 2020. A systematic review of the effectiveness of selected drugs for preventive chemotherapy for *Taenia solium* taeniasis. PLoS Negl. Trop. Dis. 14 (1), e0007873.

Jayashi, C.M., Arroyo, G., Lightowlers, M.W., García, H.H., Rodríguez, S., Gonzalez, A.E., 2012. Seroprevalence and risk factors for *Taenia solium* Cysticercosis in rural pigs of northern Peru. PLoS Negl. Trop. Dis. 6, e1733.

Joshi, K., Rajarshi, M.B., 2018. Modified probability proportional to size sampling. Commun. Stat. - Theory Methods 47 (4), 805–815.

Kabululu, M.L., Ngowi, H.A., Mlangwa, J.E.D., Mkupasi, E.M., Braae, U.C., Colston, A., Cordel, C., Poole, E.J., Strunke, K., Johansen, M.V., 2020a. TSOL18 vaccine and oxfendazole for control of *Taenia solium* cysticercosis in pigs: a field trial in endemic areas of Tanzania. PLoS Negl. Trop. Dis. 14 (10), e0008785.

Kabululu, M.L., Ngowi, H.A., Mlangwa, J.E.D., Mkupasi, E.M., Braae, U.C., Trevisan, C., Colston, A., Cordel, C., Johansen, M.V., 2020b. Endemicity of *Taenia solium* cysticercosis in pigs from Mbeya rural and Mbozi districts, Tanzania. BMC Vet. Res. 16, 325.

Kajuna, F., Mwang'onde, B., Holst, C., Ngowi, B., Sukums, F., Noll, J., Winkler, A.S., Ngowi, H., 2023. Effects of a Digital Health Literacy Intervention on Porcine Cysticercosis Prevalence and Associated Household Practices in Iringa District, Tanzania.Pathogens.,12,107.

Kayuni, E.N., 2021. Social-economic and health cost of porcine/human cysticercosis, neurocysticercosis and epilepsy to small-scale pig producers in Tanzania. Bull. Natl. Res. Cent. 45, 217.

Komba, E.V.G., Kimbi, E.C., Ngowi, H.A., Kimera, S.I., Mlangwa, J.E., Lekule, F.P., Sikasunge, C.S., Willingham, A.L., Johansen, M.V., Thamsborg, S.M., 2013. Prevalence of porcine cysticercosis and associated risk factors in smallholder pig production systems in Mbeya region, southern highlands of Tanzania. Vet. Parasitol. 198, 284–291.

Krecek, R.C., Mohammed, H., Michael, L.M., Schantz, P.M., Ntanjana, L., 2012. Risk factors of porcine cysticercosis in the Eastern Cape Province, South Africa. PLoS One 7 (5), e37718.

Kungu, J.M., Dione, M.M., Ejobi, F., Ocaido, M., Grace, D., 2017. Risk factors, perceptions and practices associated with Taenia solium Cysticercosis and its control in the smallholder pig production Systems in Uganda: a cross-sectional survey. BMC Infect. Dis. 17 (1), 1–9.

Lescano, A.G., Garcia, H.H., Gilman, R.H., Guezala, M.C., Tsang, V.C., Gavidia, C.M., Rodriguez, S., Moulton, L.H., Green, J.A., Gonzalez, A.E., Cysticercosis working group in Peru, 2007. Swine cysticercosis hotspots surrounding *Taenia solium* tapeworm carriers. Am. J. Trop. Med. Hyg. 76 (2), 376–383.

Maganira, J.D., Mwang'onde, B.J., Kidima, W., Mwita, C.J., Höglund, J., 2019. Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district, Tanzania. Parasite Epidemiol. Control. 7, e00123.

Maridadi, A.F., Lwelamira, J., Simime, F.G., 2011. Knowledge and practices related to *Taenia solium* cysticercosis-Taeniosis among smallholder farmers in selected villages in Kilolo District in Iringa region in the southern highland of Tanzania. Int. J. Anim. Vet. Adv. 3 (3), 196–201.

Mkonda, M., He, X., 2017. Are rainfall and temperature really changing? Farmer's perceptions, meteorological data, and policy implications in the Tanzanian semi-arid zone. Sustainability 9, 1–16.

Mkupasi, E.M., Ngowi, H.A., Sikasunge, C.S., Leifsson, P.S., Johansen, M.V., 2013. Efficacy of ivermectin and oxfendazole against *Taenia solium* cysticercosis and other parasitoses in naturally infected pigs. Acta Trop. 128 (1), 48–53.

Mwang'onde, B.J., Chacha, M.J., Nkwengulila, G., 2018. The status and health burden of neurocysticercosis in Mbulu district, northern Tanzania. BMC Res. Notes 11, 890.

Mwanjali, G., Kihamia, C., Kakoko, D.V.C., Lekule, F., Ngowi, H., Johansen, M.V., Thamsborg, S.M., Willingham, A.L., 2013. Prevalence and risk factors associated with human *Taenia Solium* infections in Mbozi District, Mbeya region, Tanzania. PLoS Negl. Trop. Dis. 7, e2102.

Mwape, K.E., Phiri, I.K., Praet, N., Speybroeck, N., Muma, J.B., Dorny, P., Gabrie, S., 2013. The incidence of human cysticercosis in a rural community of eastern Zambia. PLoS Negl. Trop. Dis. 7 (3), e2142.

Mwendia, S., Notenbaert, A.N., 2018. Review of Livestock Production in Kakamega, Busia, and Bungoma Counties in Western Kenya. International Center for Tropical Agriculture (CIAT), Nairobi, Kenya, p. 5.

NBS (National Bureau of Statistics), 2012. National Sample Census of Agriculture: Socio-Economic Profile of Dodoma Region. http://www.nbs.go.tz.

Ngowi, H.A., Kassuku, A.A., Maeda, G.E.M., Boa, M.E., Carabin, H., Willingham, A.L., 2004. Risk factors for the prevalence of porcine cysticercosis in Mbulu District, Tanzania. Vet. Parasitol. 120, 275–283.

Ngowi, H.A., Carabin, H., Kassuku, A.A., Mlozi, M.R.S., Mlangwa, J.E.D., Willingham, A. L., 2008. A health-education intervention trial to reduce porcine cysticercosis in Mbulu District, Tanzania. Prev. Vet. Med. 85, 52–67.

Ngowi, H.A., Chenyambuga, S., Sambuta, A., Mkupasi, E., Chibunda, R., 2014. Co-endemicity of cysticercosis and gastrointestinal parasites in rural pigs: a need for integrated control measures for porcine cysticercosis. Sci. Parasitol. 15, 1–4.

Ngowi, H., Ozbolt, I., Milogo, A., Dermauw, V., Some, T., Spicer, P., Jervis, L.J., Ganaba, R., Gabriel, S., Dorny, P., Carabin, H., 2017. Development of a health education intervention strategy using an implementation research method to control taeniasis and cysticercosis in Burkina Faso. Infect. Dis. Poverty 6 (1), 1–15.

Ngowi, H.A., Winkler, A.S., Braae, U.C., Mdegela, R.H., Mkupasi, E.M., Kabululu, M.L., Lekule, F.P., Johansen, M.V., 2019. Taenia solium taeniosis and cysticercosis literature in Tanzania provides research evidence justification for control: a systematic scoping review. PLoS One 14 (6), e0217420.

Ngwili, N., Thomas, L., Githigia, S., Johnson, N., Wahome, R., Roesel, K., 2022. Stakeholders' knowledge, attitude, and perceptions on the control of Taenia solium in Kamuli and Hoima districts, Uganda. Front. Vet. Sci. 9, 833721.

Nyangi, C., Stelze, D., Mkupasi, E.M., Ngowi, H.A., Churi, A.J., Schmidt, V., Mahonge, C., Winkler, A.S., 2022. Knowledge, attitudes and practices related to Taenia solium cysticercosis and taeniosis in Tanzania. BMC Infect. Dis. 22, 534.

Secka, A.T., Marcotty, R., De Deken, V.M., Stanny, E.S., 2008. Porcine cysticercosis and risk factors in the Gambia and Senegal. J. Parasitol. Res. 2010, 1–6.

Shapu, C.R., Ismail, S., Ying Lim, P., Ahmad, N., Abubakar Njodi, I., 2021. Effectiveness of health education intervention on water sanitation and hygiene practice among adolescent girls in Maiduguri metropolitan council, Borno state, Nigeria: a cluster randomised control trial. Water. 13, 987.

Shongwe, N.A., Byaruhanga, C., Dorny, P., Dermauw, V., Qekwana, D.N., 2020. Knowledge practices and seroprevalence of Taenia species in smallholder farms in Gauteng, South Africa. PLoSOne. 15 (12), e0244055.

Shonyela, S.M., Mkupasi, E.M., Sikalizyo, S.C., Kabemba, E.M., Ngowi, H.A., Phiri, I., 2017. An epidemiological survey of porcine cysticercosis in Nyasa District, Ruvuma region, Tanzania. Parasite Epidemiol. Control. 2, 35–41.

Sibongiseni, T.G., Oguttu, J.W., Masafu, M.M., 2016. Pig farming in rural South Africa a case study of uThukela district in KwaZulu-Natal. Indian J. Anim. Res. 50 (4), 614–620.

Sorvillo, F.J., Patricia, W., Shira, S., Mark, E., 2011. Public health implications of Cysticercosis acquired in the United States. Emerg. Infect. Dis. 17, 1–6.

Trevisan, C., Devleesschauwer, B., Schimidt, V., Winkler, A.S., Harrison, W., Johansen, M.V., 2017. The societal cost of Taenia solium cysticercosis in Tanzania. ActaTrop 165, 141–154.

URT, 2012. United Republic of Tanzania National sample census of agriculture 2007/2008. Smallholder agriculture. In: Livestock Sector National Report, vol. III. http://www.nbs.go.tz.

WHO, 2015. Investing to Overcome the Global Impact of Neglected Tropical Diseases: Third WHO Report on the Neglected Disease. World Health Organization, Geneva. http://apps.who.int/iris/bitstream/10665/152781/1/978924156486.

Yusof, A.M.M., Rahman, N.A., Haque, M., 2018. Knowledge, attitude, and practice toward food poisoning among food handlers and dietetic students in a public university in Malaysia. J. Pharm. Bioallied Sci. 10 (4), 232–993.