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EFFECTIVENESS OF HEALTH EDUCATION INTERVENTION FOR CONTROLLING PORCINE CYSTICERCOSIS IN KONGWA AND SONGWE DISTRICTS, TANZANIA

Thesis submitted to Sokoine University of Agriculture in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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EXTENDED ABSTRACT

Taenia solium taeniasis/cysticercosis (TSTC) is a parasitic zoonotic disease that is endemic in several developing countries in sub-Saharan Africa, Latin America, and East and Southeast Asia. Tanzania is one of the developing countries where the parasite has major negative effects on the economy and public health. Based on previous reports in Tanzania, the disease is widespread in the central region,the northern and southern highland regions. Several studies on disease control have been conducted in Tanzania. Interventions for health education have been conducted with promising results. However, prior health education was characterized by limited community engagement, which could lead to limited sustainability. This study used a health education package (HEP), which was co-created with community participation to ensure knowledge uptake and sustainability for controlling porcine cysticercosis in Kongwa and Songwe Districts in the central and southern highland regions of Tanzania, respectively.

Three phases of data collection were used in the study: first, a baseline survey was conducted between June and September 2019 in 42 villages (28 in Kongwa and 14 in Songwe districts), followed by a community health education intervention between October and December 2020 in 21 villages (14 in Kongwa and 7 in Songwe district). The second survey of data collection was conducted one year after a community health education intervention between October and December 2021 in all 42 villages. A cross-sectional study was conducted in a baseline survey to assess farmers' knowledge, attitudes, and practices (KAP) related to the transmission, prevention, and control of PCC and also assess the seroprevalence of porcine cysticercosis (PCC). The survey was administered using a Kobo toolbox. The interview was conducted in the village office, followed by a household survey to evaluate and verify hygiene and sanitary practices. A total of 692 smallholder pig farmers were interviewed. To assess the seroprevalence of PCC, about 5 ml of blood samples were collected from 692 pigs through a jugular vein using a plain vacutainer tube. Later, the sera were harvested, and using a cysticercosis Ag-ELISA kit, the parasite's circulating antigens

were detected. The villages were then stratified into three strata based on the comparability of the PCC seroprevalence measured at baseline using Ag-ELISA. The first stratum consisted of 10 villages with zero seroprevalence. The second stratum consisted of 13 villages with a seroprevalence of 4.5% to 9.5%. The third stratum consisted of 19 villages with a seroprevalence of 10.5% to 33.3%. Half of the selected villages in each stratum were randomly assigned to either the intervention or control groups. Twenty-one villages with 361 households were allocated to the intervention (treatment) group, whereas the other 21 villages with 331 households were allocated to the control group.

After the baseline study, a community health education intervention trial was administered to the intervention group using leaflets, posters, and booklets. The health education was conducted in two phases. Phase one involved a two-day training of the trainers (ToT), which included village and ward leaders, livestock, and human health professionals. Phase two involved a one-day training of the pig farmers by the selected ToT. A second survey was conducted one year following the community health education intervention using the same data collection instruments as in the baseline survey.

The baseline survey showed that 72% (n = 692) of respondents had heard about porcine cysticercosis (PCC), approximately half (42% (n = 692) of the respondents had little knowledge regarding PCC, and only 34% (n = 692) were aware that pigs can acquire PCC by ingesting human faeces with *T. solium* eggs. Approximately 36% (n = 692) of the respondents could identify cyst-infected pigs. About 72% had a positive attitude toward PCC prevention and control measures. Approximately 64% (n = 692) of the respondents believed that cyst-infected pork should be outlawed. In addition, 59% of respondents (n = 692) thought that using latrines with functional doors might reduce the occurrence of PCC. The majority of smallholder pig farmers (73%) acknowledged consistently deworming their pigs; 85% of respondents admitted to deworming themselves and their family members each year. The two drugs that are frequently used to treat worms in humans and pigs are albendazole and ivermectin, respectively. In addition, 92% of households in the districts had latrines, and around

28% (n = 692) of the pigs were raised in free-range environments. Ag-ELISA results showed that 67 (9.7%) pigs had PCC. In Kongwa and Songwe districts, the seroprevalence was 7.3% and 14.0%, respectively. In addition, the baseline seroprevalence of PCC was 10.2% and 9.1% in the intervention and control groups, respectively.

Twelve months after community health education, the differences in difference analysis found that health education increased the knowledge level ($\beta = 1.779$, $p = 0.004$), attitude level ($\beta = 1.024$, $p =0.038$), and practice level ($\beta = 0.719$, $p = 0.023$) over time. In addition, the study found an increase in knowledge of the transmission of porcine cysticercosis by 41.5% ($p < 0.001$) and 11.3% ($p = 0.011$) in pig farmers in the intervention group and control group, respectively. Further, the study found improvements of 14.5% ($p < 0.001$) and 3.5% ($p = 0.034$) in farmers' desire to condemn cysticerci-infected pork in both the intervention and control groups, respectively. Furthermore, the study observed that PCC seroprevalence decreased to 0.5% and 3.9% in the control and intervention villages, respectively, although the decrease was not statistically significant in both groups. The study showed that PCC was still prevalent in the area and that farmers' knowledge about the disease was poor, and risky practices were present. The community health education intervention using the HEP has improved the knowledge, attitudes, and practices of smallholder pig farmers toward PCC transmission and control; however, the short observation period compromised the power of the study to definitively attribute the reduction of PCC seroprevalence to the interventions. Therefore, the study recommends that, future research to integrate health education interventions with treatment of human taeniosis, which could be an important step to immediately interrupt the lifecycle of *T.solium* which may have helped to see the larger short-term effects of health education interventions

IKISIRI KUU

Mnyoo tegu wa nguruwe ni ugonjwa unaoambukiza nguruwe na binadamu uliopo kwenye nchi kadhaa zinazoendelea katika Afrika ya Kusini mwa Jangwa la Sahara, Amerika ya Kusini, na Mashariki na Kusini Mashariki mwa Bara la Asia. Tanzania ni miongoni mwa nchi zinazoendelea ambazo mnyoo tegu (*T.solium*) umekua na athari kubwa. Kufuatana na taarifa zatafiti za awali zilizofanyika nchini Tanzania, ugonjwa huu umeenea sana mikoa ya nyanda za kati na nyanda za juu kaskazini na kusini. Tafiti kadhaa kuhusu udhibiti wa ugonjwa huu zimeshafanyika nchini Tanzania. Elimu ya afya shirikishi imeshafanyika na kutoa matokeo chanya. Hata hivyo, elimu ya afya shirikishi hapo awali ilinasibishwa na ushiriki mdogo wa jamii, ambayo ilipelekea kutokuwa endelevu. Tafiti hii imetumia muongozo wa elimu ya afya shirikishi, ulioundwa kwa pamoja kwa ushiriki wa jamii kuhakikisha elimu endelevu katika kudhibiti mnyoo tegu wa nguruwe katika Wilaya za Kongwa na Songwe katika mikoa ya nyanda za kati na nyanda za juu kusini mwa Tanzania.

Awamu tatu za ukusanyaji taarifa ulitumika, kwanza kulikuwa na uchunguzi wa awali uliofanyika kati ya Juni na Septemba mwaka 2019 katika vijiji 42 (28 vya Wilaya ya Kongwa na 14 vya Wilaya ya Songwe), ikifuatiwa na mafunzo ya elimu ya afya kwa jamii kati ya Octoba na Disemba 2020 katika vijiji 21 vilivyo wekwa katika kundi elimishwa (14 vya Wilaya ya Kongwa na 7 vya Wilaya ya Songwe). Awamu ya tatu ilihusisha ukusanyaji wa taarifa ulifanyika mwaka mmoja baada ya mafunzo ya elimu ya afya shirikishi kutolewa kati ya Octoba na Disemmba 2021 katika vijiji 42.

Utafiti wa awali ulifanyika ili kutathimini uelewa wa wafugaji wadogo wa nguruwe , fikra na mienendo, kuhusiana na maambukizi, kinga, na udhibiti wa mnyoo tegu kwa nguruwe. Taarifai zilikusanywa kwa njia ya mahojiano na mkuu wa kaya, ikifuatiwa na uchunguzi wa kaya kutathimini na kuhakiki mienendo ya afya na usafi. Jumla ya wafugaji wadogo 692 wa nguruwe walihojiwa. Ili kutathimini uwepo wa mnyoo tegu kwa nguruwe, sampuli za damu zilikusanywa kwa nguruwe 692 kwa uchunguzi wa viashiria vya mnyoo tegu. Kisha vijiji viligawanywa katika makundi matatu kufuatana na kushabihiana kwa uwepo wa

viashiria vya mnyoo tegu zilizobainika katika uchunguzi wa awali kwa kutumia Ag-ELISA. Kundi la kwanza lilihusisha vijiji kumi ambavyo havikubainika na uwepo wa viashiria vya mnyoo tegu kwa nguruwe waliochunguzwa. Kundi la pili lilihusisha vijiji 13 vyenye uwepo wa viashiria vya mnyoo tegu kwa asilimia 4.5 hadi 9.5. Kundi la tatu lilihusisha vijiji 19 vyenye uwepo wa viashiria vya mnyoo tegu kwa 10.5% hadi 33.3%. Nusu ya vijiji vilichukuliwa katika kila kundi na kugawanywa bila mpangilio kwenye aidha kundi elimishwa au lisilo elimishwa (kundi linganishi). Vijiji ishirini na moja vyenye kaya 361 viliwekwa katika kundi elimishwa, wakati vijiji 21vingine viliwekwa katika kundi lisilo elimishwa.

Baada ya uchunguzi wa awali, mafunzo ya elimu ya afya kwa jamii yalifanyika kwa kundi elimishwa kwa kutumia vipeperushi, mabango, na vijarida. Elimu ya afya iliendeshwa kwa awamu mbili, Awamu ya kwanza ilihusisha mafunzo ya siku mbili kwa wakufunzi, iliyohusisha viongozi wa vijiji na wadi, wataalam wa afya ya mifugo na ya wanadamu. Awamu ya pili ilihusisha mafunzo ya siku moja kwa wafugaji wa nguruwe kwa kutumia wakufunzi waliochaguliwa. Uchunguzi wa pili ulifanyika mwaka mmoja kufuatia mafunzo yaelimu ya afya kwa jamii kwa kutumia nyenzo zilizotumika kwenye uchunguzi wa awali

Uchunguzi wa awali ulionesha kuwa 72% (n = 692) ya wahojiwa walisikia kuhusu mnyoo tegu wa nguruwe, takribani nusu 42% (n = 692) ya wafugaji wa nguruwe walikua na uelewa mdogo kuhusu mnyoo tegu wa nguruwe, na asilimia 34 (n = 692) tu walifahamu kuwa nguruwe anaweza kupata larva wa mnyoo tegu kwa kula kinyesi cha binadadamu chenye mayai ya mnyoo tegu (*T. solium*). Takribani asilimia 36(n = 692) ya wahojiwa waliweza kutambua nguruwe walioathiriwa na larva wa mnyoo tegu.Takribani 72 % walikuwa na fikra chanya kuhusu mbinu za kinga na uthibiti wa mnyoo tegu. Takribani asilimia 64(n = 692) ya wahojiwa waliamini kuwa nyama ya nguruwe iliyoathiriwa na larva wa mnyoo tegu yapashwa kupigwa marufuku. Pia 59% (n = 692) ya wahojiwa walidhani kutumia vyoo vyenye milango inayofanya kazi yaweza kupunguza uwepo wa mnyoo tegu kwa nguruwe. Idadi kubwa ya wafugaji wadogo wa nguruwe (73%) walikiri kuwapa nguruwe dawa ya minyoo, pia 85% walikiri kutumia dawa za minyoo wao wenyewe na familia zao kila mwaka. Aina mbili za dawa ziliripotiwa kutumika mara kwa mara kuondoa minyoo kwa binadamu na nguruwe, nazo ni albendazole na ivermectin.Vilevile 92% ya kaya za wafugaji wa nguruwe katika wilaya hizi zilikuwa na vyoo. Na takriban asilimia 28 (n = 692) ya nguruwe waliohusishwa kwenye utafiti huu walifugwa huria. Matokeo ya Ag-ELISA yalionesha kuwa nguruwe 67 (9%) walibainika kuwa na viashiria vya mnyoo. Katika wilaya za Kongwa na Songwe uwepo wa mnyoo tegu kwa nguruwe ilikuwa asilimia 7.3 na 14.0 kila mojawapo. Pia utafiti ulibaini maambukizi ya mnyoo tegu kwa nguruwe ilikuwa asilimia 10.2 na 9.1 kwenye kundi elimishwa na lile lisilo elimishwa katika uchunguzi wa awali.

Miezi kumi na mbili baada ya mafunzo ya elimu ya afya kwa wafugaji wadogo wa nguruwe, utafiti ulibaini kuwa elimu ya afya iliongeza kiwango cha uelewa (β = 1.779, p = 0.004), kiwango cha fikra (β = 1.024, p =0.038), na kiwango cha mbadiliko ya mienendo (β = 0.719, p = 0.023) kadri muda ulivyokwenda. Vilevle utafiti uligundua ongezeko la uwelewa wa wafugaji kuhusiana na maambukizi ya mnyoo tegu kwa 41.5% ($p < 0.001$) na asilimia 11.3 (p = 0.011) katika ari ya wakulima kuacha kutumia nyama ya nguruwe iliyoathiriwa na larva wa mnyoo tegu kwenye kundi elimishwa na lile lisilo elimishwa. Tafiti iligundua kuwa maambukizi ya mnyoo tegu kwa nguruwe yalipungua kwa asilimia 0.5 kwenye vijiji vya kundi linganishi na 3.9 kwa vijiji vile vya kundi elimishwa, ingawa upunguaji huo haukuwa wa kiwango kikubwa kitakwimu katika makundi yote mawili.

Utafiti ulibaini kuwa kabla ya mafunzo ya elimu ya afya kutolewa, uelewa wa wafugaji wadogo wa nguruwe kuhusu maambukizi ya mnyoo tegu kwa nguruwe ulikuwa mdogo, hususani njia za maambukizi, madhara na namna ya kujikinga. Mafunzo ya elimu ya afya kwa jamii kwa kutumia vipeperushi, vijarida, na mabango yaliboresha uelewa, fikra, na mienendo ya wafugaji wadogo wa nguruwe kuhusu maambukizi na uthbiti wa mnyoo tegu: hata hivyo, muda mfupi wa uchunguzi uliathiri ufanisi wa elimu ya afya katika kuhusisha kwa upunguaji wa uwepo wa mnyoo tegu wa nguruwe. Kwa hiyo, tafiti inashauri kuwa, mikakati ya siku zijazo ihusishe mafunzo ya elimu ya afya na tiba ya mnyoo tegu kwa binadamu (taeniosis), ambayo inaweza kuwa ni hatua muhimu ya kuzuia haraka mzunguko wa maisha ya mnyoo tegu (*T.solium*) ambayo inaweza kusaidia kuleta matokeo makubwa ya muda mfupi wa mikakati ya elimu ya afya.

DECLARATION

I, Christina Wilson, do hereby declared to the senate of the Sokoine University of Agriculture that, this thesis is my original work done within the period of my registration and that, it has never been submitted or concurrently submitted in any other institution.

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DEDICATIONS

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LIST OF ABBREVIATIONS AND SYMBOLS

° C	Degree Celsius
Ab-ELISA	Antibody-based Enzyme Linked-Immunosorbent Assay
Ag-ELISA	Antigen-based Enzyme Linked-Immunosorbent Assay
ASF	African swine fever
BMBF	German Federal Ministry of Education and Research
CDC	Centre for Disease Control and Prevention
CI	Confidence Interval
CLTS	Community-Led Total Sanitation
CNS	Central nervous system
COVID-19	Corona Virus Disease
COSTECH	Commission for Science and Technology
CSF	Cerebral Spinal Fluid
CT	Computerized Tomography
CVMBS	College of Veterinary Medicine and Biomedical Sciences (of SUA)
DALY	Disability Adjusted Life Years
DED	District Executive Director
DNA	Deoxyribonucleic Acid
DVS	Director of Veterinary Services
EITB	Enzyme Linked Immuno electrotransfer Blot
EUR	Euro (European Monetary Unit)
FAO	Food and Agriculture Organisation of the United Nations
FAOSTAT	Statistics Division of the FAO
G	Earth's Gravitational Force
GBD	Global Burden of Disease
GEE	General estimate equation
GPS	Global Positioning System
HEP	Health education intervention Package
HH	Household
IgM	Immunoglobulin M
ITFDE	International Task Force for Disease Eradication
MDA	Mass Drug Administration
MLF	Ministry of Livestock and Fisheries
MoAb	Monoclonal Antibody
NCC	Neurocysticercosis
NCL	Niclosamide
NIMR	National Institute for Medical Research

NTD	Neglected Tropical Disease
OD	Optical Density
OFZ	Oxfendazole
PCC	Porcine Cysticercosis
PCR	Polymerase Chain Reaction
PhD	Doctor of Philosophy
PZQ	Praziquantel
SSA	Sub-Saharan Africa
STATA	Statistics/Data Analysis Software
SUA	Sokoine University of Agriculture
TMDA	Tanzania Medicines and Medical Devices Authority
ToT	Training of trainer
TPP	Target Product Profile
TSTC	*Taenia solium* Taeniasis and Cysticercosis complex
URT	United Republic of Tanzania
USA	United States of America
USD	United States Dollar
WASH	Water Sanitation and Hygiene
WOAH	World Organization for Animal Health

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

Livestock production is an essential agricultural activity that ensures food security for a huge population globally. Global meat consumption is increasing with increasing human populations. Pigs significantly contribute to the overall production and output of the livestock subsector (Michael *et al.,* 2018). Pig production has increased worldwide, with Asia having the most pigs (57%), followed by Europe (19%), Latin America (9.6%), North America (9.1%), and Africa (4.4%). (FAOSTAT, 2023). In Tanzania, pig production has currently increased significantly, with the number of pigs rising from 1.6 million in 2008 (URT, 2012) to roughly 3.7 million in 2023 (URT, 2023).

The growth in pig production has been attributed to factors such as increased demand for pork; the increasing demand for pork is driven by population growth as well as the dietary transition towards more animal protein per capita (Bai *et al.,* 2018; Luis Lassaletta *et al.,* 2016).However, pig production is hampered by diseases such as African swine fever (ASF) and *Taenia solium* infection. *Taenia solium* is one of the foodborne zoonotic parasites responsible for the *T. solium* Taeniasis/Cysticercosis disease complex (TSTC). The disease causes serious public health and economic impacts in Tanzania (Kayuni, 2021; Mwang'onde *et al.,* 2018; Trevisan *et al.,* 2017). The disease has been reported in major pig-producing communities in the central zone, as well as in the northern and southern highlands of Tanzania. The southern highlands of the country produce more than 60% of the country's pigs, while the remaining proportions are kept in the central, northern highlands, and western zones (Maganira *et al.,* 2019; NBS, 2016; Wilson & Swai, 2014).

In Tanzania, pig farming is mostly practiced by smallholder farmers (Maziku *et al.,* 2019; Wilson & Swai, 2014). The small-scale pig farmers are characterized by poor pig husbandry and practice risky behaviours associated with the transmission of the parasites, such as not washing their hands after using a latrine or before eating and before preparing the pig feeds (Sithole *et al.,* 2020; Wilson *et al.,* 2023). Also, most smallholder farmers lack access to quality latrines and do practice open defaecation in the bushes (Phiri *et al.,* 2003). This allows the roaming pigs to access the faeces with *T. solium* eggs. (Maziku *et al.,* 2017; Sithole *et al.,* 2020). In addition, inadequate knowledge leads to the adoption of behaviours that support the parasite's life cycle (Lescano *et al.,* 2007; Nyangi *et al.,* 2022; Sorvillo *et al.,* 2011). A change in community knowledge, attitudes, and practices (KAP) is necessary to build effective and sustainable measures for the parasite's prevention, management, and eventual elimination (Nyangi *et al.,* 2022). Communities with sufficient knowledge are more likely to implement management practices, including increasing hygienic and sanitary conditions and indoor pig management (Kajuna *et al.,* 2023; Shapu *et al.,* 2021), which, in turn, lowers PCC prevalence (Ngowi *et al.,* 2008). Therefore, health education programs that explicitly target management practices, particularly feeding, breeding, and general management, are needed to promote the long-term profitability of smallholder pig farming and manage *T. solium* infections (Chilundo *et al.,* 2020).

1.2 Aetiology and the life cycle of *T. solium*

The pork tapeworm, *T. solium*, is a member of the genus *Taenia*, the cyclophyllid cestode family *Taeniidae,* and the phylum Platyhelminthes. Because pigs are involved in its transmission, it is frequently referred to as a "pork tapeworm. Morphologically, the *T. solium* tapeworm has three body parts, namely the head, neck, and body (Flisser, 2013a). The big body (strobila) measures between 2 and 4 meters and is made up of several hundred proglottids. The proglottids are divided into three groups: immature, mature, and gravid. These groups vary in size, form, developmental stage, internal reproductive organ, and egg composition. Initially tiny and brief, immature proglottids later develop into adult proglottids. Proglottids eventually mature into gravid proglottids and are larger, nearly rectangular organisms. The elongated gravid proglottids are roughly 12 mm long and 6 mm broad. Each gravid proglottid can contain up to 50, 000 to 60, 000 eggs, and each worm carries roughly 800 to 1,000 proglottids (Flisser, 2013b; Sathe *et al.,* 2011). The tapeworm also possesses a scolex with four suckers and a double crown of hooks that are utilized to attach to the host's intestinal mucosa (Flisser, 2013a). The scolex is spherical in form, one millimeter in diameter.

The embryonated eggs are spherical with a diameter of 26 to 36 millimeters, have a double-walled striated membrane protecting an embryophore, and are indistinguishable from those of other *Taenia* species (Schantz, 1996). The embryophore contains an oncosphere armed with six typical embryonic hooklets, hence the name hexacanth embryo.

The cysticerci (larvae) are ovoid and vesicular in shape, while they can sometimes take on irregular (racemose) shapes, especially in the brain (White, 2000). Up to 2 cm in diameter, a fully grown live cysticercus possesses a white, transparent membrane with a single spherical, invaginated protoscolex floating in a clear fluid (Sciutto *et al.,* 2000). When a cyst is not viable, it degenerates, the fluid becomes opaque and thick, it shrinks, and its form changes. A calcified cyst is a fully deteriorated cyst that is visible as a white, spherical nodule that contains calcified material (García *et al.,* 2010).

The life cycle of *T. solium* involves two different hosts—humans and pigs—and the environment (Fig. 1). Humans, as a definitive host, acquire taeniasis by ingestion of pork with viable *T. solium* cysts (Flisser, 2013a; Okamoto & Ito 2013; Sathe *et al.,* 2011). The scolex evaginates and attaches to the gut wall with its hooks and suckers when it comes into contact with bile inside the human alimentary canal. Through progressive strobilation, the larva turns into an adult worm. In two to three months, the worm reaches sexual maturity and begins to lay eggs, which are subsequently expelled out with the gravid segments (Flisser 2013b; Sathe *et al.,* 2011). Pigs become infected with cysticercosis when they consume eggs or gravid proglottids contained in human faeces (Okamoto & Ito 2013; Johansen *et al.,* 2014). The oncospheres emerge from the eggs in the pig's gut. They use hooks to attach to the intestinal mucosa, pierce the gut wall, and enter the portal veins or mesenteric lymphatic system before reaching the systemic circulation. The oncospheres go through the portal vein and eventually get into the liver, right side of the heart, lungs, left side of the heart, brain, or any other tissue with a high blood perfusion (Flisser 2013a; Schantz *et al.,* 2014). The flowing blood filters the bare oncospheres into the muscle tissue, where they eventually settle and continue to grow. Within a time frame of 9–10 weeks, they grow and transform into fluid-filled cysts (DelBrutto *et al.,* 1988).

Humans may potentially become intermediate dead-end hosts if they accidentally consume *Taenia* eggs in infected food or drink, self-infect their mouths with faeces if they have taeniasis, or come into direct contact with a tapeworm carrier (Soulsby, 1982). The oncospheres are released from the eggs in the colon after consumption. Invading the intestinal mucosa, these larvae are subsequently transported by the bloodstream to various tissues, where they mature into cysts. The central nervous system (CNS) skeletal muscles, eye, and subcutaneous tissue of humans harbour the majority of cysts, which results in a disease known as cysticercosis. (Torgerson & Macpherson, 2011; White, 2000).

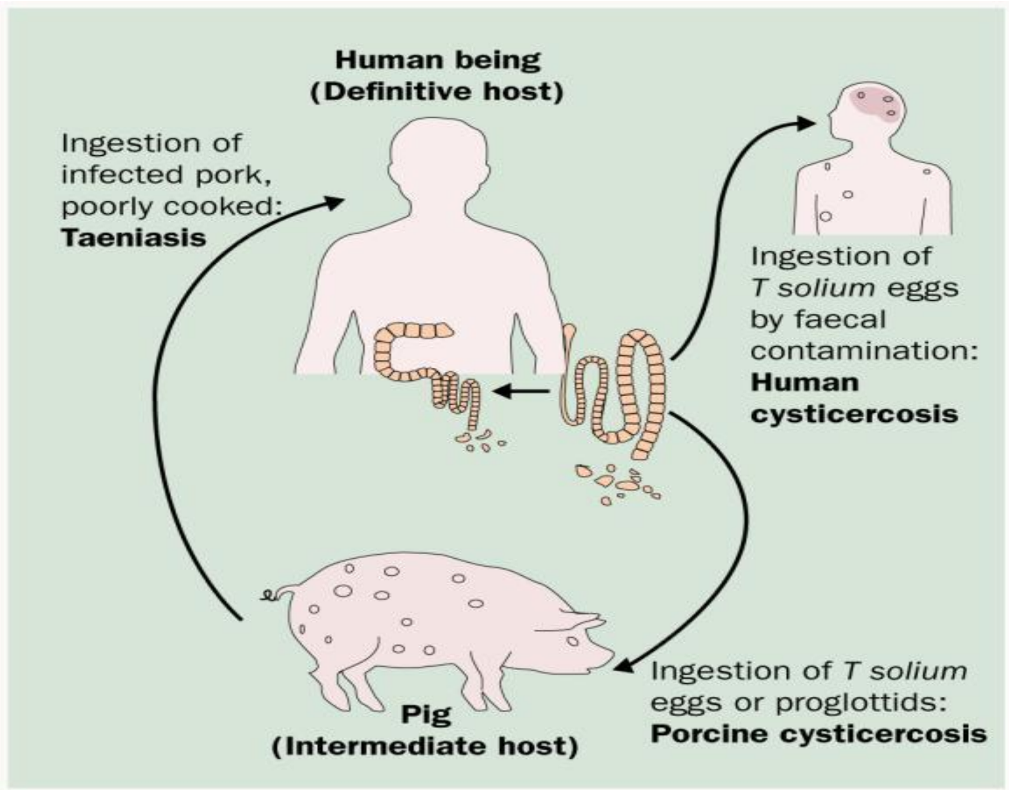

Figure 1: The life cycle of *Taenia solium* parasite (Source García *et al.,* 2003)

1.3 Distribution and burden of *T. solium* taeniasis/cysticercosis

1.3.1 Distribution of *T. solium* taeniasis/cysticercosis

Taenia solium taeniasis/cysticercosis (TSTC) has a worldwide distribution (Fig.2), but is most prevalent in many developing countries in sub-Saharan Africa (Braae *et al.,* 2015a; Phiri *et al.,* 2003) South and Southeast Asia (Braae *et al.,* 2018; Rajshekhar *et al.,* 2003) and Latin America (Braae *et al.,* 2017a). It has been established that *T. solium* is prevalent in 31 of 54 African countries (Braae *et al.,* 2015b), 16 of 41 Central American and Caribbean countries (Braae *et al.,* 2017b) and 8 of 16 countries across East and Southeast Asia (Braae *et al.,* 2018)

The parasite's life cycle is sustained in endemic areas due to unsatisfactory sanitary behaviour, free-range pig management, inadequate meat inspection, and eating of raw or undercooked pork (Secka *et al.,* 2010).The parasite has been declared eradicable by the International Task Force for Disease Eradication (ITFDE) since 1993 (Schantz *et al.,* 1993).The parasite has likely been eradicated in the majority of European and North American countries (Gonzalez *et al.,* 2003). However, in recent years, more cases of neurocysticercosis (NCC) have been reported in these countries, mostly due to the disease's reintroduction as a result of an increase in the migration of people from endemic regions and vice versa.

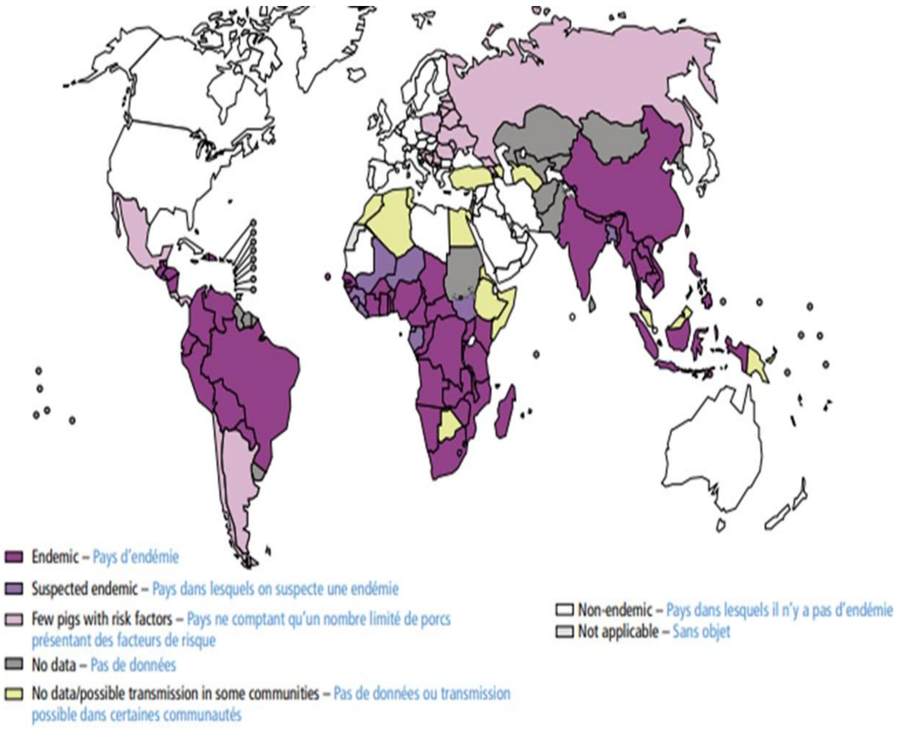

Figure 2: Global distribution of *T. solium*, 2022 Source WHO 2022

In the 1980s, Tanzania experienced an increase in PCC-related problems. In those years, pigs from Mbulu district were exported to Kenya, and after they were slaughtered, it was discovered that they had a severe parasite infection (Phiri *et al.,* 2003). The frequency of PCC was shown to have increased from 0.4% to 5% between 1985 and 1989 in the Mbulu district, according to a retrospective review of slaughter slab data (Phiri *et al.,* 2003). A post-mortem examination of pigs in northern highlands revealed a prevalence of 5% to 38% (Boa *et al.,* 1995). Several other studies conducted in central, northern and southern Tanzania (Fig. 3) reported prevalence of PCC of up to 33% (Boa *et al.,* 2006; Kabululu *et al.,* 2015; Maganira *et al.,* 2019; Shonyela *et al.,* 2017; Braae *et al.,* 2017a; Mwanjali *et al.,* 2013; Mwang'onde *et al.,* 2018).

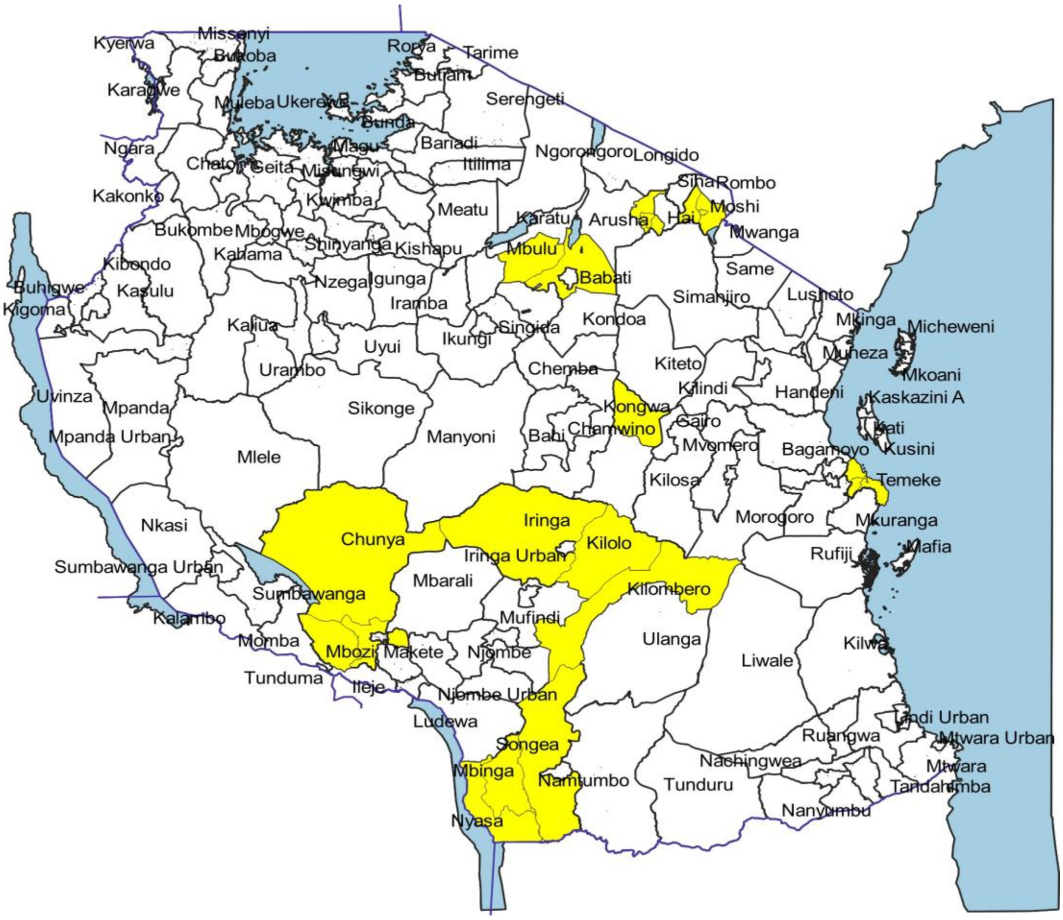

Figure 3: **Locations (yellow) of prior research in Tanzania on *Taenia solium* taeniasis/cysticercosis from 1995 to 2018. Source Ngowi et al. (2019)**

1.3.2 The burden of *T. solium* taeniasis-cysticercosis

T. solium poses a significant burden due to the health effects of neurocysticercosis (NCC) and the financial losses caused by PCC. Neurocysticercosis is the leading parasite disease of the central nervous system. *T. solium* was identified as the most significant foodborne parasite, as NCC is the leading cause of foodborne disease mortality (WHO/FAO, 2014). WHO (2006) reports that *T. solium* infections affect at least 50 million individuals globally, leading to around 50,000 deaths annually. In 2013, the Global Burden of Disease (GBD) reported that there were 1,030,800 instances of human cysticercosis globally (GBD, 2015). Recent years have seen an increase in reported instances in developed countries. In the USA, cysticercosis affects between 41,000 and 169,000 people annually (Hotez *et al.,* 2008). In SSA, about 1.9 to 6.2 million persons are infected with *T. solium*, and 0.76 to 2.46 million may have NCC-associated epilepsy (Winkler, 2012).

NCC is responsible for the major health burden associated with *T. solium*, causing approximately one third of epilepsy/seizure disorders in endemic settings (Gripper & Welburn, 2017). Limited access to health treatments has been linked to up to six times greater mortality rates from NCC compared to the general population (WHO, 2015).The average seroprevalence of human cysticercosis was recently estimated to be 4% in Asia and 7% in Latin America and Africa (Coral-Almeida *et al.,* 2015). In low and middle income countries 2.8 million disability-adjusted life-years (DALYs) related to human cysticercosis was reported (WHO, 2015). In Tanzania human cysticercosis prevalence is estimated at 17% (Mwanjali *et al.,* 2013), NCC has also been linked to more than 200 deaths and approximately 18,000 incident cases of epilepsy per year (Trevisan *et al.,* 2017). According to recent research in sub-Saharan Africa (SSA), the prevalence of PCC ranges from 2% to 41.2%, depending on the location and diagnostic method used. However, in certain places of SSA, prevalence has been reported as high as 64% (Mwape *et al.,* 2012). Tanzania reports a prevalence of up to 17.4%, 18.2%, and 33.3% based on tongue examination, routine meat inspection, and Ag-ELISA (Ngowi *et al.,* 2019).

PCC estimated to cause annual losses of up to 25 million USD in 10 West and Central African countries (Zoli *et al.,* 2003) while 5 million USD in the Eastern Cape Province of South Africa in 2004 (Carabin *et al.,* 2006) and 3 million USD in Tanzania attributed to condemnation of infected pigs or pork (Trevisan *et al.,* 2017). A study by Boa et al. (2006) established that pigs with cysticercosis are sold at discounts of up to 65% off the price of a healthy pig.

The prevalence of *T. solium* taeniasis in endemic regions ranges from 1% to 3% (Coral-Almeida et al., 2015). Hyper-endemic foci of infections have been observed in SSA, with prevalence ranging from 6% to 12% (Mwape *et al.,* 2012; 2013), whereas Asia has a prevalence of 19% to 26% (Prasad *et al.,* 2007; Okello *et al.,* 2014). In Latin America, the prevalence typically ranges between 1% and 4% (Sarti *et al.,* 2000). In Tanzania, the prevalence of *T. solium* taeniasis ranges between 0.4% and 5.2% (Mwanjali et al., 2013; Braae et al., 2017a).

1.4 Risk factors associated with *T. solium* transmission

The presence of adult *T. solium* human carriers and open-field defecations are the main risk factors associated with acquiring cysticercosis in both pigs and humans, whereas the main risk factor for obtaining adult *T. solium* in people is the consumption of infected pork (Khaing *et al.,* 2015; Okello *et al.,* 2015;). The absence, irregular usage, or incorrect use of latrines and free-range pig rearing are the main risk factors for the parasite transmission (Komba *et al.,* 2013; Shonyela *et al.,* 2017). Also lack/limited knowledge of the community regarding PCC is an important risk factors contributing to the practices that perpetuates the persistence of the disease (Chacha *et al.,* 2014; Maridadi *et al.,* 2011; Ngowi *et al.,* 2017). Other risk factors include cultural taboos and contaminated feed or water (Komba *et al.,* 2013; Pondja *et al.,* 2010). According to a study conducted in Zambia, several cultural taboos encouraged open defecation. In particular, males were shown to be less likely to use latrines than the rest members of the family (Thys *et al.,* 2015).

1.5 Diagnosis of porcine cysticercosis

PCC in live pigs is diagnosed using serology and tongue examination. Tongue examination includes visual examination and palpation throughout the whole length of the tongue's ventral surface (Thomas *et al.,* 2016; Chembensofu *et al.,* 2017). The technique is rapid, easy to use, and reasonably affordable, making it particularly suitable for PCC screening in field situations. Pig farmers and dealers frequently employ this technique to inspect pigs before purchasing, selling, or transporting them for slaughter. However, the approach is claimed to have poor sensitivity, often ranging from 16% to 70%, depending on the severity of the infection (Dorny *et al.,* 2004; Phiri *et al.,* 2006). This is because not all infected pigs will have cysticerci in the tongue.

PCC can be diagnosed using a variety of immunodiagnostic procedures, including methods for identifying certain antibodies or parasite antigens in blood or cerebrospinal fluid (Dorny *et al.,* 2004; Lightowlers *et al.,* 2016). The serological tests commonly used for diagnosis of PCC are enzyme-linked immunoelectro transfer blot assay (EITB) and enzyme-linked immunosorbent assay (ELISA). Antigen detection techniques have been developed and provide a useful tool in identifying individuals with active infections and therefore a tool for serological monitoring of anti-parasitic therapy. The commonly used serological method is Antigen–ELISA which was reported to be high sensitive but the test had limited by the lack of species specificity when performed in pigs (Akoko *et al.,* 2019). For example, currently, most assays cannot differentiate *T. solium* from other taeniid species such as *T. hydatigena and T. asiatica* (Akoko *et al.,* 2019; Dermauw *et al.,* 2016; Kabululu *et al.,* 2020a) Ag-ELISA has been shown to have a high sensitivity for detecting a pig with even a single cyst (Nguekam *et al.,* 2003).

In abattoirs and slaughter slabs, post-mortem meat inspection is regularly carried out by visual inspection and slicing of certain preference spots. The psoas, triceps brachii, tongue, internal and external masseters, diaphragm, and heart muscles were identified as predilection locations for *Cysticercus cellulosae* (Chembensofu *et al.,* 2017).

1.6 Methods for control porcine cysticercosis

For the prevention of *T. solium* infections in endemic areas, many methods have been suggested. These include public health education, general enhanced sanitation, pig vaccination, treatment of infected pigs, efficient pork inspection, and enclosed pig rearing practices, as well as the treatment of infected people. (Verastegui *et al.,* 2003).

1.6.1 Health education

Studies show that transmission of *T.solium* infections can be decreased by public health education (Kolaczinski *et al.,* 2010; Ngowi *et al.,* 2008; Sarti *et al.,* 1997). The goal of health education is to increase information of *T. solium*, which is anticipated to impact behaviour and practice changes and, ultimately, result in a decrease in the prevalence and incidence of *T. solium* infections. Health education is crucial for the prevention of *T. solium* infections, as shown by several research studies (Alexander *et al.,* 2021; Carabin *et al.,* 2018; Mwidunda *et al.,* 2015; Ngowi *et al.,* 2008; 2011).

In addition, health education can be employed alone or in conjunction with other management techniques to reduce the prevalence of other diseases linked to poor hygiene, such as cholera and typhoid fever. Significant improvements in knowledge and some practices linked to transmission of *T. solium* have resulted to several educational programs (Ngowi *et al.,* 2008; Sarti *et al.,* 1997). Community collaboration and full engagement are crucial for any intervention to be successful (WHO/FAO/OIE, 2004). The transmission of *T. solium* is significantly influenced by community knowledge, behaviour, and customs. For instance, research conducted in China showed a substantial correlation between the frequency of human cysticercosis and inadequate pig rearing techniques, the inability to identify diseased pork, and a limited understanding of the transmission of *T. solium* (Cao *et al.,* 1997).

As measured by Ag-ELISA using sentinel pigs, Ngowi et al. (2008) showed a reduction in the incidence of PCC around 12 months following a health education intervention. Also, Sarti et al. (1997) study in Mexico revealed that health education can dramatically lower PCC prevalence as indicated by the EITB one year following the intervention. A community-based educational intervention was successful in lowering the incidence and prevalence of cysticercosis in Burkina Faso, as demonstrated by Carabin et al. (2018). These investigations found that the knowledge gained did not significantly alter the observed behaviour, which might have an impact on the treatments' durability. Limited resources to put the information into practice have been cited as one of the causes for a less dramatic change in behaviour after an improvement in knowledge (Sarti *et al.,* 1997). In order to have a sustainable long-term benefit, this implies that health education should be included and put into practice with other treatments (Murrell *et al.,* 2005). More research is needed, especially when it is delivered as a specialized tool, to determine the effect of health education on the transmission of *T. solium*.

1.6.2 General improved sanitation

The interaction of intermediate hosts (pigs), which ingest infective eggs, from infected human faeces is essential for completion of the *T. solium* life cycle. The use of well-built latrines, the management of waste water and sludge and best practices in animal husbandry are all hygiene measures that help to avoid the infection of the intermediate host. Effective meat inspection and adequate cooking methods can also minimize the spread of the human taeniasis. There has been evidence linking poor hand hygiene to a higher chance of contracting swine cysticercosis, such as failing to wash hands with soap after defecation (Vora *et al.,* 2008). Pigs that are managed under free- range system are predisposed to *T. solium* infection (Komba *et al.,*2013; Maganira *et al.,* 2019; Shonyela *et al.,* 2017).

It has been noted that a rise in the demand for free-range pork in Europe may result in a rise in the incidence of swine cysticercosis (Zammarchi *et al.,* 2013). The need to supply confined pigs with clean and safe feed and water should be highlighted. Nevertheless, some studies have indicated the possibility of transmission inside the confinement as a result of giving pigs contaminated feeds and water (Braae *et al.,* 2015c; Komba *et al.,* 2013). To prevent indiscriminate defecation, latrines must be accessible and used correctly in *T. solium* endemic areas. A study in Mbulu district of Tanzania found that the frequency of cysticercosis was significantly greater in pigs raised in households without latrines than in those raised in households with latrines (Ngowi *et al.,* 2004). Zero open defecation should be successful in reducing the likelihood of cysticercosis infection in pigs, and human. In developing countries, like Tanzania, have prioritized the building of latrines in every rural household through a campaign called “nyumba ni choo” (literally, “house is toilet”) that was launched in 2018. The campaign focused on encouraging households to build and use latrines hygienically in an effort to combat infectious diseases. Limited resources hinders the adoption of such measures in some households. The effectiveness of the sanitary facilities may also be influenced by existence and enforcement of local by-laws.

1.6.3 Vaccination and treatments of pigs

Worldwide, vaccination programs have been utilized extensively to combat several infectious diseases. Vaccination targeting pigs appears to be a suitable preventive approach given that pigs are the primary intermediate hosts of *T. solium*. Different vaccine candidates have been developed and evaluated for their ability to prevent *T. solium* cysticercosis in pigs. These include SP3Vac, TSOL45, and TSOL18, among which SP3Vac and TSOL18 appear to have the potential to control cysticercosis since they offer a high level of protection (Flisser *et al.,* 2004; Huerta *et al.,* 2002; Sciutto *et al.,* 2007).

In field trials in Mexico, the synthetic vaccine SP3Vac, which contains protective peptides, significantly reduced the prevalence of PCC (Huerta *et al.,* 2002; Morales *et al.,* 2008, 2011). However, a recombinant protein called TSOL18 that is expressed during the oncospheres stage of the life cycle has been found to be the most efficient, offering full protection in both controlled laboratory trials (Flisser *et al.,* 2004; Gonzalez *et al.,* 2005; Lightowlers, 2006) and field trials (Assana *et al.,* 2010; Poudel *et al.,* 2019). Considering how well-protected they are, they have the ability to control cysticercosis. Before implementing a commercial vaccination that is effective against *T. solium* as a control approach, it is crucial to take into account a number of factors. For smallholder pig farmers in low-income countries to afford the vaccination, it must be inexpensive or subsidized. The vaccine must also provide long-lasting protection and be simple to deliver in a broad intervention program (Sarti & Rajshekhar, 2003).

On the other hand, treatment of PCC-diseased pigs ensures that, the infected pork is kept out of the food chain. Numerous drugs, including albendazole, fenbendazole, flubendazole, oxfendazole, and praziquantel, have been studied with variable degrees of efficacy *(*Gonzalez *et al.,*2012*;* Mkupasi *et al.,* 2013a; Pondja *et al.,* 2012). A single oral dosage of 30 mg/kg of oxfendazole (OFZ), has been shown to be the most effective treatment for *T. solium* cysticerci, with effectiveness also being observed against other gastrointestinal parasites (Garcia *et al.,* 2016; Mkupasi *et al.,* 2013a; Pondja *et al.,* 2012). For example, in the study by Kabululu et al. (2020b), the concurrent administration of TSOL18 and OFZ eradicated viable cysticerci in the examined pigs, when tested 3.5 months following treatment. Pigs treated either at four or nine months of age showed a substantial decrease in the incidence of PCC in a randomized controlled experiment in Mozambique (Pondja *et al.,* 2012). Pigs that have been treated are also shielded from re-infection for up to four months (Gonzalez *et al.,* 2003). According to Lightowlers (2010), the parasite is thought to have triggered the protection. Although the blood-brain barrier certainly plays a role in OFZ's reduced effectiveness against brain cysticerci (Gonzalez *et al.,* 2012; Mkupasi *et al.,* 2013b; Sikasunge *et al.,* 2008), transmission may not be affected by this as brain consumption is uncommon. The effectiveness of anthelminthic against PCC certainly needs more investigation. Meanwhile, it's critical to protect pigs from infections in endemic areas in order to safeguard the public health

1.6.4 Meat inspection

Meat inspection is the sole diagnostic tool used in abattoirs and slaughter slabs to detect pig cysticercosis post-mortem. The method involves visual inspection and slicing of specified predilection areas (Chembensofu *et al.,* 2017). Pig carcass examination is widely used to accurately diagnose cysticerci in pigs. Postmortem examination of carcasses varies by country, but often involves examining the masseter, ham, lingual, and cardiac muscles (Taylor *et al.,* 2007). Carcass examinations are commonly used to assess the quality of pigs entering the food chain. While specific, it lacks sensitivity for low cysticerci infection levels (Dorny *et al.,* 2004; Phiri *et al.,* 2006; Taylor *et al.,* 2007). In a Zambian investigation, meat inspection failed to detect infection 61% of infected pigs, (Phiri *et al.,* 2006). Using Bayesian estimation, Dorny et al. (2004) estimated sensitivity of meat inspection to be 22.1%. By using 24 naturally infected finished pigs, Boa et al. (2002) found that about 10.6% of all cysticerci would be located at inspected/sliced sites by using the available pork inspection guidelines. Apart from the low sensitivity of meat inspection, informal pig trade and slaughter are common in endemic areas, circumventing official meat inspection and allowing uninspected pork into the food chain (Boa *et al.,* 2006; Kagira *et al.,* 2010a; Nsadha *et al.,* 2014). This results in gross underestimation of prevalence of PCC hence undermining the validity of the method for epidemiological surveys. Also, protocols on pork inspection vary between countries hence comparison across studies may not be valid.

1.6.5 Treatment of human taeniasis

Taeniasis treatment is one of the methods that may be used to execute *T. solium* cysticercosis control in pigs and humans, a strategy to reduce the burden of parasite in a specific population. Regardless of clinical state, mass drug administration (MDA) is the routine treatment of the whole population within a predetermined geographic region. Selective chemotherapy, in contrast, screens patients and then administers treatment in accordance with clinical status, whereas targeted chemotherapy only administers treatment to particular risk groups on a regular basis. (Gabrielli *et al.,* 2011).

The common anthelmintic medications includes niclosamide (2 g/person as a single dose), praziquantel (5 - 10 mg/kg as a single dose), (Pearson & Guerrant, 1983 ; Pearson & Hewlett, 1985) tribendimidine (200 mg per 15 years old child or 400 mg per adult single oral dose), (Steinmann *et al.,* 2008) and albendazole (3400 mg/person for three consecutive days), are effective against infections with the adult stage of *Taenia* spp. (Steinmann *et al.,* 2011). Niclosamide and praziquantel are only effective in 85% and 95% of *Taenia* spp. Praziquantel has been used to treat humans at dosages greater than 10 mg/kg with great success, however there is a chance that the drug may cause seizures (Sarti *et al.,* 2000).

Additionally, niclosamide has a long shelf life and does not require cold storage (Sarti & Rajshekhar, 2003). As a result, many low-income nations should choose this medication. However, it is suggested that in order to significantly reduce the taeniasis burden in the target group, mass treatment should be given twice a year for five or more years.

A study in Guatemala demonstrated high efficiency of niclosamide in reduction of both taeniasis and PCC (Allan *et al.,* 1997). Taeniasis prevalence (measured by copro-Ag-ELISA) was significantly reduced in Tanzania from 2.3% to 0.3% and maintained at below 0.1% as a result of annual MDA with praziquantel given to school-aged children primarily for controlling schistosomiasis and "track and treat" of taeniasis cases (Braae *et al.,* 2017a)

1.7 Problem statement and Justification of the Study

1.7.1 Problem statement

Porcine cysticercosis caused by *T. solium* is still prevalent in endemic areas, leading to significant economic loss and public health consequences. In Tanzania, the prevalence of porcine cysticercosis has been estimated to be high, ranging from 11% to above 30% using Ag-ELISA, (Komba *et al.,* 2013; Maganira *et al.,* 2019; Shonyela *et al.,* 2017).The disease has high public health and economic importance due to reduced value of pigs and condemnation of infected carcasses, resulting in serious economic losses in the pork industry (Trevisan *et al.,* 2017; Ngowi *et al.,* 2019).

The occurrence of *T. solium* PCC is associated with poor environmental sanitation, inadequate hygiene practices, economic constraints, free-range pig management, and a lack of knowledge on the transmission of the parasite in endemic areas. Limited knowledge and education are major risk factors for the spread and persistence of porcine cysticercosis. The lack of knowledge on the epidemiology of the disease leads to practices that support its transmission and persistence (Lescano *et al.,* 2007; Sorvillo *et al.,* 2011). Substantial evidence has been gathered to inform about the magnitude and burden of the *T. solium* PCC in the country and this justifies investment for control of the parasite (Ngowi *et al.,* 2019).

Although the zoonotic TSTC has been declared as possibly eradicable (WHO, 2006), its control still remains a challenge. Different strategies, such as treatment of infected humans, vaccination of pigs, improved sanitation, indoor pig rearing, pork inspection, and public health education, have been implemented for the control of *T. solium* infections, they have not been effective in current PCC endemic areas. Drugs and vaccines for the control of the disease are expensive, inaccessible, or not registered in some countries (Bulaya *et al.,* 2015). Limited studies conducted in Tanzania and elsewhere on health education focusing on TSTC control, has been reported to have been limited to minimal community engagement and lacked changes in practices towards transmission, prevention and control of PCC, hence had short-term sustainability (Ngowi *et al.,* 2008; Mwidunda *et al.,* 2015; Chilundo *et al.,* 2020). Additionally, communities in endemic areas have inadequate knowledge on porcine cysticercosis transmission and prevention, and therefore do not adopt behaviours that prevent disease transmission. Therefore, the control of PCC remains a challenge despite efforts to implement various strategies, and there is a need for effective and sustainable interventions that address knowledge gaps and behavioural practices in endemic areas.

1.7.2 Study Justification

Health educational interventions if properly designed and delivered have shown to be effective towards control *T. solium* taeniosis cysticercosis (TSTC) infections. Community-engaged participatory interventions in Tanzania and elsewhere had resulted to reduction of incidence and prevalence of PCC in some low-resource settings (Carabin *et al.,* 2018; Ngowi *et al.,* 2008), and also had led to the improvement in knowledge (Alexander *et al.,* 2021; Chilundo *et al.,* 2020; Mwidunda *et al.,* 2015; Ngowi *et al.,* 2011). Effective health communication strategies require not only information on disease epidemiology and the characteristics of the technical intervention being promoted, but also social, cultural, behavioural, and economic data about the target communities (Nyangi *et al.,* 2022). However, its effectiveness depends on the proper design that requires careful planning, consideration of the local context and One Health approach in collaboration with the local communities from the start to the finish. This study used TSTC community-based health education package (CHEP) which was co-created with community participation to ensure knowledge uptake and translation to changes in practices (Nyangi *et* *al.,* 2022). Hence, first this study intended to present an update of the status of PCC and risk factors for *T. solium* PCC transmission, secondly, the study assess farmers' knowledge, attitudes and practices which may influence transmission of the parasite in the area. Thirdly, this study aimed to determine one-year effectiveness of the health education intervention in reducing, prevalence of PCC through improving the smallholder pig farmers' knowledge, attitudes and practices in Songwe and Kongwa districts in Tanzania

1. 8 Objectives of the study

1.8.1 Main objective

The overall objective of this study was to evaluate the effectiveness of community-based health education intervention for controlling of *T. solium* porcine cysticercosis in Kongwa and Songwe Districts, Tanzania.

1.8.2 Specific objectives

(i) To determine knowledge, attitude and practices (KAPs) regarding *T.solium* porcine cysticercosis prevention and control among small holder pig farmers in Kongwa and Songwe districts

(ii) To determine sero-prevalence of *T. solium* porcine cysticercosis and its associated risk factors in Kongwa and Songwe Districts

(iii) To evaluate the effectiveness of community-based health education intervention in improving knowledge, attitude and practices (KAPs) in Kongwa and Songwe districts

(iv) To evaluate the effectiveness of community-based health education intervention in reducing the sero prevalence of *T. solium* porcine cysticercosis in Kongwa and Songwe districts.

1.9 Research Questions

(i) What is the status of knowledge, attitude and practices (KAPs) regarding *T. solium* porcine cysticercosis control among small holder pig farmers in Kongwa and Songwe Districts?

(ii) What is the sero prevalence of *T. solium* porcine cysticercosis in Kongwa and Songwe districts?

(iii) What is the effectiveness of the community-based health education intervention in improvement of the knowledge, attitudes and practices in Kongwa and Songwe districts?

(iv) What is the effectiveness of the community-based health education intervention in reducing the sero prevalence of *T. solium* porcine cysticercosis in Kongwa and Songwe districts?

1.10 Organization of the thesis

This thesis is structured into five chapters, preceded by an extended abstract which summarizes the objectives, materials and methods, main findings and conclusion of the study. Chapter one covers an introduction, problem statement, study justification, objectives, and research questions. Chapter two to four represents results obtained in each specific objectives which are synthesized into papers. Two of these papers have already been published to peer review journals (papers I and II), and one has been submitted to peer review journal (paper III).Chapter five covers general discussion, conclusion and recommendations based on the findings of the study. A list of the papers originating from this study as described above is provided below:

I. Wilson, C., Nonga, H.E., Mdegela, R.H., Churi, A.J., Mkupasi, E.M., Winkler, A.S., Ngowi, H.A., 2023. Knowledge, attitudes and practices regarding porcine cysticercosis control among smallholder pig farmers in Kongwa and Songwe districts, Tanzania: A cross-sectional study. Veterinary Parasitology Regional Studies and Report, 44, 100912. **https://doi.org/10.1016/j.vprsr.2023.100912**

II. Christina Wilson, Robinson Hammerthon Mdegela, Hezron Emmanuel Nonga, George Makingi, Ayubu Jacob Churi, Stelzle Dominik, Ernatus Martin Mkupasi, Veronika Schmidt, Hélène Carabin, Andrea Sylvia Winkler, Helena Aminiel Ngowi., 2023. Seroprevalence and risk factors for *Taenia spp* infection in pigs in Kongwa and Songwe districts, Tanzania: A cross-sectional study. Food and Waterborne Parasitology, 33, e00215. **https://doi.org/10.1016/j.fawpar.2023.e00215**

III. Christina Wilson, Hezron Emmanuel Nonga, Robinson Hammerthon Mdegela, George Makingi, Ernatus Martin Mkupasi, Andrea Sylvia Winkler, Helena Aminiel Ngowi. 2023. Effect of community health education intervention on prevalence and pig farmers' knowledge, attitudes and practices related to porcine cysticercosis in Tanzania. Acta Tropica (submitted)

CHAPTER TWO

PAPER ONE

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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A.S. Winkler, H.A. Ngowi

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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

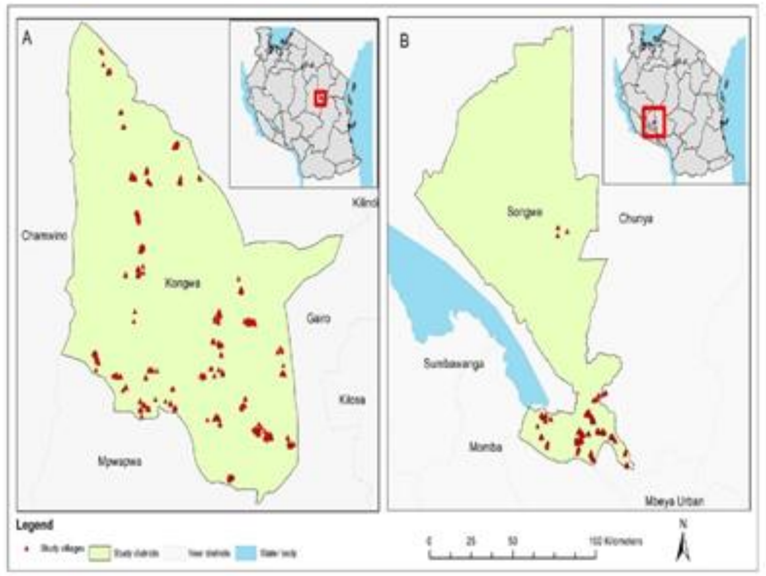

Fig. 1. The map labeled A shows Kongwa District and the insert is a map of Tanzania with a red box that indicates the relative location of the Kongwa District. The map labeled B shows the Songwe District and the insert is a map of Tanzania with a red box that indicates the relative location of the Songwe 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.,

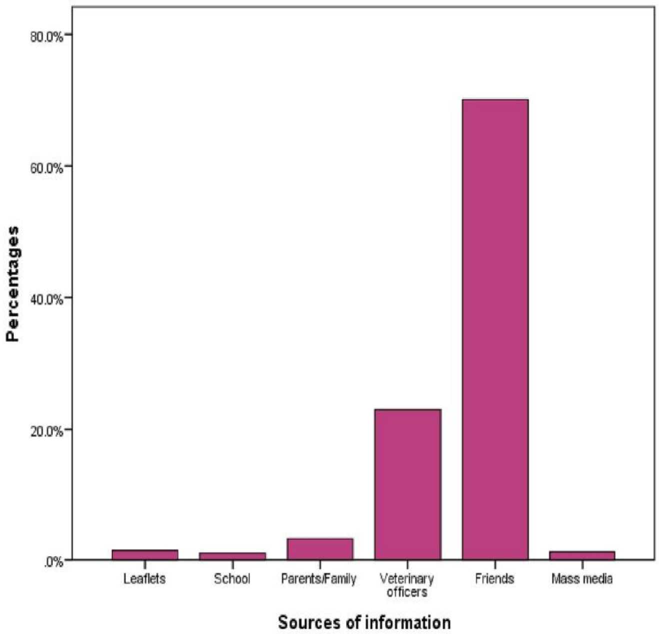

Fig. 2. Source of information about porcine cysticercosis as reported by respondents in Kongwa and Songwe districts, Tanzania $n = 692$.

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

CHAPTER THREE

PAPER TWO

Seroprevalence and risk factors for *Taenia spp* infection in pigs in Kongwa and Songwe districts, Tanzania: A cross-sectional study

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Seroprevalence and risk factors for *Taenia spp* infection in pigs in Kongwa and Songwe districts, Tanzania: A cross-sectional study

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ABSTRACT

Taenia solium porcine cysticercosis (PCC) is widespread in many low- and middle-income countries (LMICs) where free-range pig rearing is common and hygienic standards are subpar. A cross-sectional survey was conducted in 42 villages between June and September 2019 (14 in Songwe district, southwest Tanzania, and 28 in Kongwa district, central Tanzania). Using a commercial Ag-ELISA kit (apDia, Belgium), circulating antigens of *Taenia spp* in pig serum were identified and used to calculate the PCC seroprevalence. The study recruited 692 randomly selected households, sampling one pig per household. The relationship between each risk factor and the seroprevalence of PCC at the household and village levels was analysed using mixed logistic regression models. The findings showed that approximately 28% of the pigs were reared in free-range settings, the proportion of households with latrines across the districts was 92%. Twenty-seven percent of households with latrines had water and soap available for hand washing. Sixty-seven (9.7%) tested positive for PCC based on Ag-ELISA. The overall seroprevalence in Kongwa and Songwe districts was 7.3% and 14.0% respectively. In addition, the overall village Ag-ELISA positivity was 9.3%, with an interquartile range (IQR) of 4.6% – 14.1%. Increasing the age of the pig (OR = 3.13 95% CI = 1.48 – 6.60; $p = 0.003$), pig originating from outside the household (OR = 0.5 95% CI = 0.25 – 0.99; $p = 0.05$), and pigs kept in a household that practised deworming (OR = 2.23 95% CI = 1.08 – 4.61; $p = 0.03$) were important risk factors associated with PCC positivity. Therefore, the high seroprevalence of PCC, up to 14%, calls for rapid and effective control actions such as vaccination and treatment of pigs against PCC, and public health education emphasises on indoor

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pig rearing, hygienic practices and regular use of latrines. Our findings also point to a potential danger of *Taenia. spp* infection indicating the possibility of people carrying the adult parasite *Taenia solium* not only in the rural communities of Kongwa and Songwe districts but also in the urban areas of Tanzania, where pigs from these areas are transported for consumption. To develop effective management measures, further research on taeniasis and cysticercosis in the human population is required.

1. Introduction

Small-scale farmers, particularly in low and middle-income countries (LMICs) of Africa, Latin America, and Southeast Asia, greatly benefit from pig farming (Costales et al., 2007; Huynh et al., 2007). Pig production has fundamentally expanded recently in numerous provincial areas of Tanzania, where the pig population has increased by >30% in 10 years from an estimated 1.6 million in 2008 (URT, 2012) to nearly 2.1 million in 2020 (URT, 2020). The growth in pig production has been attributed to factors such as increased demand for pork in both urban and rural areas, the high fecundity and growth rate of pigs, and the low investment cost for farmers. These factors lead to quick economic returns from the pig business (Ngowi et al., 2004a; Phiri et al., 2003). However, a difficulty faced by Tanzanian pig farmers is the existence of parasitic zoonosis such as the tapeworm *T. solium*. Pigs can contract the parasite's larval stage, which can also infect humans. After consuming eggs released in faeces from a *T. solium* human carrier, which serves as the parasite's only host, pigs and humans develop cysticercosis (Del Brutto, 2014). Cysticercosis is normally prevalent in pig farming communities with poor sanitation, free-range pig rearing, limited knowledge of the disease, inadequate meat inspection, eating undercooked pork, and the presence of humans carrying the adult form of *T. solium* (Sikasunge et al., 2008; Gweba et al., 2010).

Tanzania is endemic for *T.solium* infection with porcine cysticercosis (PCC) prevalence ranging from 11% to over 30% (assessed by antigen enzyme-linked immunosorbent assay (Ag-ELISA) (Shonyela et al., 2017; Maganira et al., 2019; Kajuna et al., 2022), human cysticercosis (HCC) between 16.7% using Ag-ELISA and 45.3% using an antibody (Ab)-ELISA and human taeniasis between 0.4% to 1.1% and 0.3% to 5.2% using copro-antigen-enzyme linked immunosorbent assay (copro-Ag-ELISA) (Mwanjali et al., 2013; Braae et al., 2017). Previous studies have also shown a great burden of HCC and neurocysticercosis (NCC) in rural areas of Tanzania among people with epilepsy (Winkler, 2012; Mwang'onde et al., 2018; Stelzle et al., 2022a, 2022b). PCC can lead to significant economic loss to the pig industry due to the reduced value of pigs and the condemnation of infected carcasses when inspected (Trevisan et al., 2017; Kayuni, 2021). Controlling PCC is essential for improving human and porcine health, safe pork consumption, and smallholder pig production in Tanzania and other *T. solium*-endemic African nations (Komba et al., 2013).

Previous studies in Tanzania and elsewhere have shown that knowledge about *T. solium* and practices toward infection prevention is suboptimal (Nyangi et al., 2022). In addition, health education can considerably improve knowledge and possibly reduce the prevalence of PCC (Ngowi et al., 2008; Mwidunda et al., 2015). Health education packages need to be adapted to context, and the effective sensitization of the education requires knowledge about the epidemiology, and risk factors associated with PCC/HCC. Understanding the risk factors associated with disease prevalence is critical for PCC control. Several studies on the risk factors for PCC or HCC in Tanzania have been conducted; however, some social, economic, geographic, and environmental traits are unique to certain places; thus, risk factors may vary among groups in different regions. This paper reports on the baseline seroprevalence of PCC and associated factors in the context of testing a community-based health education intervention on PCC in Kongwa and Songwe districts in Tanzania.

2. Materials and methods

2.1. Ethics statement

The Ministry of Health 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) in the Republic of Tanzania, have all approved this research. In addition, the Klinikum rechts der Isar Ethics Committee at the Technical University of Munich in Germany approved the study under study approval number 537/18 S-KK. The executive directors of the Kongwa and Songwe districts provided letters of consent. After explaining the purpose of the study and the procedure, informed consent was obtained from each farmer. Farmers were given the chance to inquire and choose whether or not to participate. Only pigs aged three months and above were included. Late pregnant and suckling sows were excluded.

2.2. Study area

The study was conducted between June and September 2019 in Kongwa and Songwe districts. The study areas were selected on the basis of previous reports of PCC and pig-keeping popularity (Ngowi et al., 2014; Maganira et al., 2019; Kabululu et al., 2020b). Tanzania's eastern-central Dodoma region consists of the Kongwa district. The district experiences a mean annual temperature of 26.5 °C, 500–800 mm of rain on average, and a rainy season from November to April (Mkonda and He, 2017). The district comprises 87 villages, is located on 4041 km^2 of land, and is situated between latitudes 5°30 and 6°00′ S and longitudes 36° 00 and 36°15′ E. In 2012, the estimated pig population was 56,498. In the southwest of Tanzania, in the Songwe Region, is the Songwe district. The district has

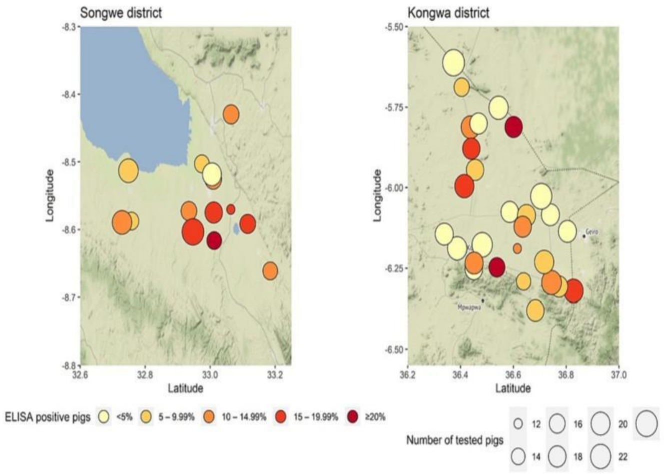

Fig. 1. Map of Songwe and Kongwa districts showing seroprevalence of porcine cysticercosis by village (colour) and number of pigs tested per village (bubble): The bubble's size is determined by the number of pigs screened.

an average annual temperature of 16 °C and is situated between 900 and 2750 m above sea level, with latitudes between 8°25 and 85°65′S and longitudes between 32°00 and 33°14′E. It has a total area of 16, 070 km^2, of which 1105 km^2 is covered by water and 14,965 km^2 by land. The rainy season runs from November through May with an average annual rainfall of approximately 900 mm (URT, 2012). The district had an estimated 33,046 pig population.

2.3. Study design, and sample size

In a cross-sectional survey, pigs, households and villages were selected using multistage cluster sampling. According to Joshi and Rajarshi (2018), the probability proportional to population size (PPS) technique was used to select the research villages. From Kongwa and Songwe districts, 28 out of 87 (32%) and 14 out of 43 villages (33%) were chosen. Using random numbers from Excel, pig-keeping households were chosen randomly from a list of pig keepers collected from the village register in each village. The formula $n = [Z\alpha\sqrt{(2pq)} - Z\beta\sqrt{P1q1 + P2q2}]^2 / (p1 - p2)^2$, was used to estimate the number of pigs needed for the investigation (Dohoo et al., 2003). We assumed a PCC prevalence of 30% (Komba et al., 2013; Ngowi et al., 2014), which yielded an estimated sample size of 672 pigs. A village sample size of 16 pigs was produced by dividing the necessary sample size by the number of villages (672/42). One pig was randomly selected and examined from each household to avoid clustering at the household level. Hence, a range of 8 to 24 pigs were sampled per village (Fig. 1). The criteria for inclusion included three months old and above, excluding late pregnant and suckling sows for ethical reasons. This resulted in 450 and 242households samples in the Kongwa and Songwe districts, respectively.

2.4. Surveys of households and in-person observations

Data at the households were gathered through a structured questionnaire and checklists. The questionnaire was administered using the KOBO toolbox software through face-to-face interviews. The interviews were conducted with the household head or permanent adult resident, information was provided in Kiswahili, and the questions were worded to reflect local conditions. Global Positioning System (GPS) coordinates were recorded using GPS for each household for mapping. The data collected included demographic characteristics, general pig management practices, presence and reported use of latrines by household members, pig feeding system, pig slaughter facilities, water sources, and experience of PCC in the pig herd. In addition, a checklist for direct observation of items was used to evaluate and verify hygiene and sanitary practices, such as the presence and conditions of latrines and toilets, the availability of facilities for hand washing, and open defecation. Other pig welfare factors, such as drinking water in the pig pen, were also considered.

2.5. Determination of cysticercosis antigen positivity in study pigs

Based on the farmer's experience and observations, the studied pigs were classified as young (3 –4 months old), growers (5 - 8 months old), or adults ($\geq$ 9 months). Before sampling, the breed, origin, and sex of the pigs were noted. Blood samples (5 ml) were drawn from the jugular vein and placed into a plain vacutainer tube using a sterile vacutainer needle or sterile syringe. The serum samples were recovered by centrifuging the blood at 1500g for 10 min after the blood samples were pre-stored on ice in a cold box within 3 – 8 h of blood collection. Before further analysis, the serum samples were added to 1.8 ml cryogenic vials and kept in the lab at -20 °C. Samples were analysed at the Sokoine University of Agriculture (SUA) CYSTINET-Africa Project laboratory and tested for circulating PCC antigens (Ag) using a commercial cysticercosis antigen enzyme-linked immunosorbent assay (Ag-ELISA) kit (apDia, REF 650501, Belgium). In brief, serum samples were prepared according to the manufacturer's instructions using duplicates of the pre-treated controls. Trichloroacetic acid (TCA) was used to pre-treat the blood samples, and the samples and controls were then added to the wells coated with the monoclonal antibody B158C11A10. Circulating antigens from living cysticerci were selectively bound to the wells during this incubation stage. The antigen-antibody complex in each well was identified using peroxidase-conjugated B60H8A4 monoclonal antibodies after the unbound serum proteins had been removed using a washing technique. Fifteen minutes later, the reaction was stopped with 0.5 M H2SO4, and the absorbance values/optical densities (OD) were calculated at 450 nm. The cut-off value was determined by multiplying the mean OD of the negative controls by 3.5, and the antigen index (Ag Index) of each sample was established by dividing the OD value of the sample (OD sample) by the cut-off value. A positive Ag index was >1.3, whereas a negative Ag index was <0.8. Samples with Ag indices between 0.8 and 1.3 were not conclusive and were therefore re-tested.(Dorny et al., 2004).

2.6. Statistical analysis

Baseline characteristics of households, pigs, and respondents and antigen positivity by the variables above were determined using STATA version 15 and R version 4.1.1. The relationship between each risk factor and the prevalence of porcine cysticercosis (as measured by antigen ELISA positivity) at the households, village, and district levels was analysed using logistic regression models. Correlations between village-level antigen positivity and the village-level proportion of households with unprotected water sources, people who practice open defecation, dewormed pigs, and households without latrines were visualized using scatter plots. Antigen ELISA-positive pigs were geolocated by village and district. Factors associated with antigen positivity were analysed using mixed logistic regression models including fixed and random effects. Fixed effects were the age group of the pigs, pig sex, origin of the pig, pig management, village proportions of households with unprotected water sources, households without latrines, the proportion of dewormed pigs, and the proportion of people practicing open defecation. The district and village levels were included as random intercepts.

3. Results

3.1. Questionnaire survey results

Of the 692 questionnaire respondents, 454 (66%) were men, and most respondents were between 26 and 45 years old. The majority of respondents 451 (65%) had attended primary school, 10% had attended secondary school and above, and 173 (25%) had not received any formal education. Approximately 28% of the households practised free-range management systems, in which pigs were unrestricted/ grazed during most periods of the year. The proportion of households with latrines across the district was 92%, with 97% and 81% in Kongwa and Songwe districts, respectively. Overall, 27% of the households had water and soap available for hand washing near the latrines. In Kongwa district, the median proportion of households with unprotected water sources was 13% with an interquartile range (IQR) of 0% – 66%, whereas in Songwe district, it was 23% with an IQR of 7% – 35% (Table 1).

3.2. Seroprevalence of porcine cysticercosis

Of the 692 pigs examined, 97 (14%) were young, 311 (45%) were growers, and 284 (41%) were adults. Almost all 667 pigs (96%) were crossbreeds of Large White, Landrace, Hampshire, and Duroc, with 415 (60%) being females. Of the 692 serum samples from the included pigs, 67 (9.7%) tested positive for PCC based on Ag-ELISA. The overall seroprevalence in Kongwa and Songwe districts was 7.3% and 14.0%, respectively (Table 2). In addition, the overall village Ag positivity was 9.3% with an interquartile range (IQR) of 4.6% – 14.1%. The prevalence of PCC in pigs varied among villages. In Songwe district the village median seroprevalence was 12.9% with an interquartile range (IQR) of 10.1 – 16.7%. On the other hand, in Kongwa district the village median seroprevalence was 6.7% with an IQR of 0% – 12.5%. Of the total number of household's visits, 29% (21% to 32%) had at least one infected pig (Table 2). Antigen ELISA positivity was higher in Songwe district than in Kongwa district. In both districts, positivity was somewhat uniformly distributed (Fig. 2) (there were no clusters of several villages that had a notably higher positivity).

3.3. Risk factors for PCC seropositivity

The following factors were significantly associated with PCC infection in the mixed logistic model. PCC positivity increased with the age of pigs, as older pigs ($\geq$ 9 months) had higher risks of acquiring infection (OR = 3.13 95% CI = 1.48 – 6.60; $p = 0.003$) than younger ones; pigs originating from outside the household had a higher risk of being infected (OR = 0.5 95% CI = 0.25 – 0.99; $p = 0.05$) than pigs originating within the household. In addition, pigs reared in households that practised deworming were more at risk of PCC infection (OR = 2.23 95% CI = 1.08 – 4.61; $p = 0.03$) than those reared in households with no deworming (Table 3).

3.4. Factors associated with village-level Ag-ELISA positivity

The findings show that village-level Ag ELISA positivity was positively associated with several village-level factors, including the

Table 1
Pig management and sanitation conditions in Kongwa and Songwe Districts based on a questionnaire survey combined with direct observations, Tanzania, 2019 ($n = 692$).

Variable	Categories	Kongwa District ($n = 450$)	Songwe District ($n = 242$)	Total (n = 692)
Household with a latrine	Yes	437 (97)	197 (81)	634 (92)
	No	13 (3)	45 (19)	58 (8)
Village proportion of households without latrine	Median (IQR)	0% (0-6%)	18% (2-29%)	0% (0-13%)
The presence of water and soap for hand washing near the latrine	Yes	158 (35)	34 (14)	192 (27)
	No	292 (65)	208 (86)	500 (73)
Water source	Protected	170(38)	186 (77)	356 (51)
	Unprotected	280 (62)	56 (23)	336 (49)
Village proportion of unprotected water source	Median (IQR)	13% (0-66%)	23% (7-38%)	20 % (0-44%)
Pig rearing system	Indoor	356 (79)	93 (38)	449 (65)
	Free range	54 (12)	139 (57)	193 (28)
	Semi-intensive	40 (9)	10 (4)	50 (7)
Deworming of pigs	Yes	268 (60)	234 (97)	502 (73)
	No	182 (40)	8 (3)	190 (28)
Village proportion of dewormed pigs	Median (IQR)	36% (10-74%)	0% (0-92%)	34% (0-87%)
Slaughter pigs at home	Yes	53 (12)	49 (20)	102 (15)
	No	397 (88)	193 (80)	590 (85)
Pork inspection	Yes	41 (9)	48 (20)	89 (13)
	No	409 (91)	194 (80)	603 (87)
Open defecation by children	Yes	90 (20)	47 (19)	137 (20)
	No	360 (80)	195 (81)	555 (80)
Village proportion of people practicing open defecation	Median (IQR)	13% (6-28%)	7% (1-34%)	13% (6-30%)

N: number of households, IQR: interquartile range.

Table 2
Seroprevalence of porcine cysticercosis in Kongwa and Songwe districts in Tanzania (n = 692).

		Songwe District (n = 242 pigs; *n* = 14 villages)	Kongwa District (n = 450 pigs; *n* = 28 villages)	Total (n = 692 pigs; *n* = 42 villages)
		n (%)	n (%)	n (%)
Number of pigs screened per village	Median	16	16	16
	(range)	(12 to 25)	(8 to 23)	(8 to 25)
Number of antigen ELISA-positive pigs	None	0 (0)	10 (36)	10 (24)
	One	3 (21)	9 (32)	12 (29)
	Two	6 (43)	4 (14)	10 (24)
	More than two	5 (36)	5 (18)	10 (24)
Antigen ELISA-positive pigs	n/N (mean)	34/242 (14.0)	33/450 (7.3)	67/692 (9.7)
Antigen ELISA positivity by village	Median (IQR)	12.9%	6.7%	9.3%
		(10.1 to 16.7%)	(0 to 12.5%)	(4.6 to 14.1%)
	range	5 to 33.3%	0 to 26.7%	0 to 33.3%

N: number of pigs, village, IQR: interquartile range, Ag- ELISA: Antigen based Enzyme Linked-Immunosorbent Assay.

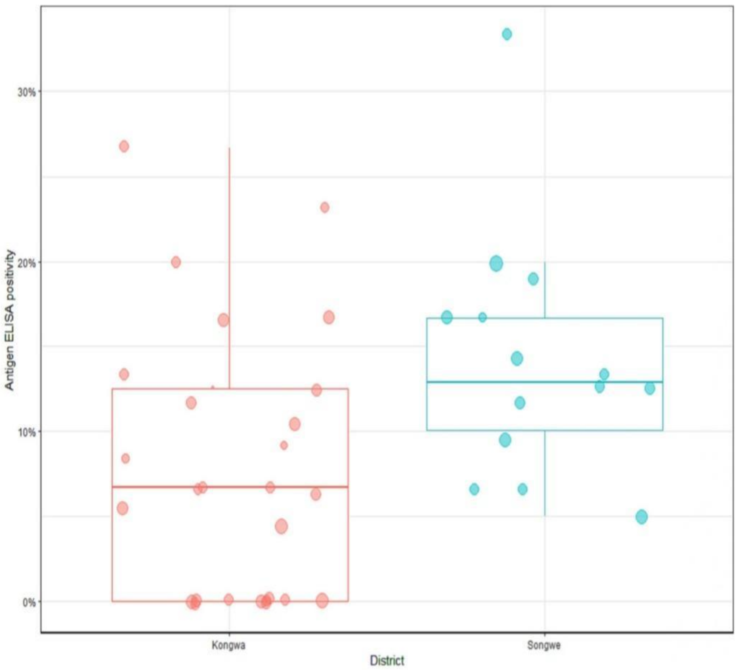

Fig. 2. Boxplots shows distribution of antigen ELISA positive pigs by village and districts: Positivity was more evenly distributed in both districts: Each bubble represents village (28 in Kongwa and 14 in Songwe), and its size is determined by the number of pigs sampled.

proportion of households deworming pigs, those with unprotected water sources, the proportion of households without latrines, and the proportion of households practising open-filed defecation (Fig. 3).

4. Discussion

In the Kongwa and Songwe districts of Tanzania, this study estimated the seroprevalence of antigen-ELISA-based cysticercosis and assessed the parameters linked to the seroprevalence of *Taenia spp* infection in pigs. The results indicate that PCC is widespread in the study areas, which is evidence that there exist *Taenia spp* carriers in the community under investigation, free-range pig management, and open defecation, all of which are conducive to PCC transmission. The presence of PCC in the investigated locations lends credence to the conclusions drawn from earlier research (Kabululu et al., 2015; Maganira et al., 2019). Pigs raised in these rural areas are also consumed in urban areas, which implies a great public health risk for human taeniasis/cysticercosis in both rural and urban areas if slaughtered pigs are not properly examined (Mkupasi et al., 2011; Schmidt et al., 2019).

Table 3
Multivariable mixed effects logistic regression model on factors associated with antigen ELISA positivity (fixed effects as presented; random effects: district and village level).

Individual level variables	Categories	Antigen ELISA Positive/n (%)	Odds ratios	p-value
Age group	Young	5/96 (5)	Reference	
	Growers	28/311 (9)	2.05 (1.07-3.92)	0.03 *
	Adults	34/285 (12)	3.13 (1.48-6.6)	0.003**
Pig sex	Male	27/278 (10)	Reference	
	Female	40/414 (10)	0.81 (0.47-1.4)	0.45
Origin of pigs:	Within household	55/507 (11)	Reference	
	Outside households	12/185 (6)	0.5 (0.25-0.99)	0.05 *
Village level variables				
Water Source:	Protected	34/356 (10)	Reference	
	Unprotected	33/336 (10)	0.94 (0.39-2.26)	0.89
Open defecation	No	54/555 (10)		
	Yes	13/137 (9)	2.76 (0.66-11.54)	0.16
Deworming of pigs	No	14/190 (7)	Reference	
	Yes	53/502 (11)	2.23 (1.08-4.61)	0.03 *
Households with latrine	Yes	54/634 (9)	Reference	
	No	13/58 (22)	5.2 (0.73-36.9)	0.10

Young: (3 - 4 months), Growers: (5 - 8 months), Adult: (≥ 9 months), protected: (Tap water, secured well), unprotected: (rivers, ponds, open wells), ELISA: Enzyme Linked-Immunosorbent Assay, * Significant ($p < 0.05$). ** Significant ($p < 0.01$).

This study found that the village-level proportion of households without latrines and open defecation was positively correlated with Ag positivity (albeit not statistically significant). Lack of and/or limited use of latrine is a noteworthy risk factor linked to the sero-prevalence of PCC. Similarly, other researchers in Tanzania (Ngowi et al., 2004a), Kenya (Eshitera et al., 2012), and South Africa (Krecek et al., 2012) have reported a lack of latrine as a significant risk factor for PCC transmission. This may be because the observed latrines in this study were not fully protected and hence facilitated easy access to human faeces found in open environments by non-confined pigs in these areas.

In contrast, different studies have reported higher PCC prevalence in households with latrines (Maganira et al., 2019; Pondja et al., 2010). This may be explained by the fact that in these studies, pigs in households with latrines had access to human faeces for one reason or another. For example, latrines were not fully protected as observed in this study. A study from Mexico, found that pigpens were positioned to trap human excreta to feed the pigs (Sarti et al., 1997). This suggests more context-specific behavioural factors associated with *T. solium* transmission should be assessed and tackled accordingly. Successful strategies to reduce the lack of (the use of) latrines, are also not yet in place and will need to be developed to decrease the burden of *T. solium*.

The current study demonstrates that the oldest animals have the highest seroprevalence, consistent with previous reports in many areas where PCC is endemic. (Komba et al., 2013; Pondja et al., 2010). The correlation between age and PCC seroprevalence may be due to older animals having been exposed to PCC for a more extended period than younger animals (Pondja et al., 2010) and infections are usually not cleared within a short time. In some instances, adult pigs escape easily from their pens because of poor pen thus increasing the risk of acquiring PCC by ingesting tapeworm eggs in human faeces found in open environments. The demonstrated lower risk of PCC in younger pigs may also be a feature of passive maternal immunity transfer (Elahi et al., 2006). In addition, maternal antibodies are known to protect against other larval cestode infections (Gemmell, 1999) and have been demonstrated to slowly decrease in piglets born to sows infected with cysticercosis (Gonzalez et al., 1999).

In addition, pigs originating from outside the household were found to be a risk factor for PCC seroprevalence. This result demonstrates clustering of infections and suggests the existence of attribute(s) outside the household that aid in the transmission of *T. solium* eggs to pigs. Factors important for this finding are the existence of human tapeworm carriers, open defaecation and free-range pig management. Furthermore, human carriers of tapeworms are responsible for contaminating the environment with *T. solium* eggs and proglottids, which can spread human and porcine cysticercosis, especially in cases where personal hygiene is compromised (Lescano et al., 2007; Cortez Alcobedes et al., 2010).

Furthermore, this study found that, the seroprevalence of PCC did not significantly differ between the sexes of pigs. Some previous studies from Peru (Jayashi et al., 2012) and Tanzania (Komba et al., 2013) did not find differences between pig sexes. The current study, on the other hand, found a strong interaction between sexes and pig age, with male pigs between the ages of 5 and 12 months having a greater risk of developing PCC than males younger than five months. Adult pigs from most households have been observed foraging for food and roaming freely, raising the danger of pork tapeworm infection from infected human excrement.

Free-range pig and semi-confinement management systems have been reported as important risk factors for PCC in Tanzania (Komba et al., 2013; Shonyela et al., 2017), Mozambique (Pondja et al., 2010), and Burkina Faso (Ganaba et al., 2011).We did not find an association between the confinement of pigs and PCC, which is likely because the confinement status reported in this study may not represent the actual management situation because seasonal pigs were confined during the cropping seasons. A study in Burkina Faso explains that pigs roaming some of the time versus penned all the time during the rainy season were 6.5 times more likely to be infected than penned pigs (Ganaba et al., 2011). In the study area pigs were normally allowed to roam during the dry season and confined during the crop production season (rainy season). Therefore, it is essential to emphasize the proper use of latrines to reduce the risk of

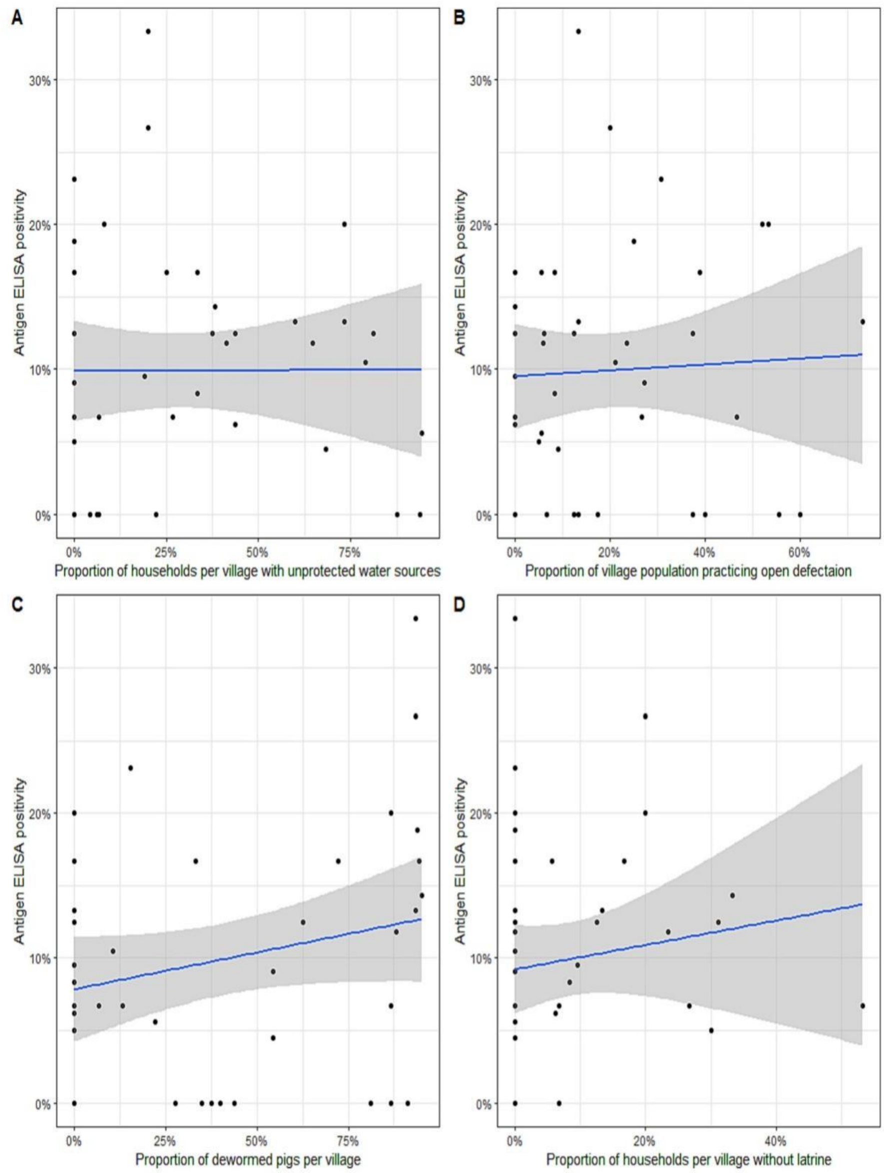

Fig. 3. Scatter plots showing correlation between village level Ag-ELISA positivity and village level proportions of household with unprotected water source (A), people who practiced open-field defecation (B), dewormed pigs (C) and households without latrine (D).

pigs ingesting *T. solium* eggs from the environment. This should be coupled with formulating and enforcing local bylaws at the village level.

The study found that deworming of pigs was positively correlated with the seroprevalence of PCC. This is not surprising because none of the anthelmintics used (Wilson et al., 2023) were efficacious against PCC (Mkupasi et al., 2013). However, this observation was in contrast to the results reported by Kungu et al. (2017), whereby a high prevalence of PCC was found in households in which pigs were not dewormed. Therefore, farmers should be encouraged to seek veterinary advice on the best ways to control PCC.

The study strength depends on the large sample size of 692 pigs, which made it possible to evaluate porcine cysticercosis in detail. One possible limitation of this study is that the *T. hydatigena* may be prevalent in our study districts, which may have caused crossreactions and increased seroprevalence estimates. However, we do not think that was particularly strong on the factors associated with sero-positivity, and we also do not think it may explain differences in sero-positivity between the two districts. Estimated seroprevalence of PCC is based on Ag-ELISA alone, which may be an underestimation or overestimation due to diagnostic inaccuracies of the test. Although the assay is highly sensitive, it does not distinguish between various species, such as *T. solium and T. hydatigena*. Recently, the test sensitivity and specificity were reported to be 82.7% and 86.3%, respectively (Kabululu et al., 2020a). In Tanzania, different studies estimated that the prevalence of *T. hydatigena* ranges between 1.4% and 10.3% in pigs (Ngowi et al., 2004b; Kabululu et al., 2020a) which highlights the impact of *T. hydatigena* on Ag ELISA positivity. It further highlights the need for validated diagnostic tests that allow differentiation of *T. species* in pigs.

5. Conclusions and recommendations

The high seroprevalence of PCC, up to 14% estimated in the present study, calls for action on this important zoonotic parasitic disease not only in the rural communities of Kongwa and Songwe districts but also in the urban areas of Tanzania, where pigs from these areas are transported for consumption and slaughter. The control measures for PCC should include vaccination and treatment of pigs and public health education emphasising hygiene practices, efficient and regular use of sanitary facilities, stringent and appropriate meat inspection, and the proper cooking of pork. Further research is required to determine the relative contributions of various *Taenia species* to the observed PCC seroprevalence among pigs in the study area. Furthermore, human surveys on taeniasis and cysticercosis are required to clarify the public health risk linked to porcine cysticercosis in the study area and determine whether and where control interventions are most necessary.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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CHAPTER FOUR

PAPER THREE

Effect of community health education intervention on prevalence and pig farmers' knowledge, attitudes and practices related to porcine cysticercosis in Tanzania

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Abstract

Porcine cysticercosis (PCC) is a food-borne zoonotic disease prevalent in resource-poor rural communities with free-range pig management systems and low sanitation practices. The current study assessed the effectiveness of community-based health education using a co-created health education package (HEP) on smallholder farmers' knowledge, attitudes, and practices (KAP) and the PCC prevalence in Kongwa and Songwe Districts, Tanzania. A cluster-randomized health education intervention was carried out between June 2019 and December 2021, with pre-and post-intervention evaluations of PCC prevalence and smallholder farmers' KAP. A baseline cross-sectional study was followed by health education training using HEP which comprised brochures, booklet and posters. The training was given to trainers who then trained the community. A commercial Ag-ELISA kit (apDia, Belgium) was used to identify circulating antigens in pig serum and establish the PCC prevalence. A total of 692 and 486 respondents were face-to-face interviewed during baseline and post-intervention, respectively, while, 692 and 317 pigs were sampled during baseline and post-intervention, respectively. The baseline seroprevalence of PCC was 10.2% and 9.1% in the intervention and control groups, respectively. Twelve months after health education, the study found that health education increased the knowledge level (β = 1.779, p = 0.004), attitudes level (β = 1.024, p =0.038) and practice level (β = 0.719, p = 0.023) overtime. Furthermore, the study found greater reduction of PCC in the experimental group (3.9%) compared to the control group (0.3%) although the reduction was not statistically significant (OR =0.70 95%CI= 0.27 - 1.83; p=0.47). The reduction of PCC is a gradual process and requires more time. The short observation period compromised the power of the study to definitively attribute the reduction of PCC seroprevalence to the interventions. Therefore, the future health education intervention should include assessment and treatment of human taeniosis, which could be an important step to immediately interrupt the lifecycle of *T.solium* which may have helped seeing larger short-term effects of health education intervention.

Keywords: Health education intervention, helminths, animal welfare, knowledge, practices, the difference-in-differences method (DID)

1.0 Introduction

Taenia solium taeniasis-cysticercosis (TSTC) infects humans and pigs with a wide distribution (WHO, 2012; Del Brutto, 2014). *T. solium* taeniasis-cysticercosis is the foodborne parasite causing the highest global disability-adjusted life years (DALYs) (Torgerson et al., 2015). As the intermediate host, pigs, acquire the larval form, porcine cysticercosis (PCC), of the parasite by ingesting human faeces containing infective eggs or proglottids of the parasite (González et al., 2000). PCC is one of the most significant zoonotic diseases worldwide, causing marked production losses to smallholder farmers. It lowers the value of pigs and pork and has emerged as the primary constraint to the trading of pigs and pork (Kayuni, 2021). Humans serve as definitive hosts, containing/harbouring the adult tapeworm that causes taeniasis (Del Brutto, 2014). Humans acquire the cystic form (human cysticercosis) when accidentally ingest *T. solium* viable eggs from contaminated food or water. The ingested eggs are activated by intestinal secretions into oncospheres in the intestine, which then travel through the intestinal walls to other organs including the muscles and brain where they develop into cysts. (Abuseir et al., 2007; Praet et al., 2010). Human cysticercosis is one of the most significant preventable parasitic zoonoses affecting the human central nervous system (CNS) and is the leading cause of 30% of epilepsy cases in endemic areas (Gripper and Welburn, 2017).

The International Task Force for Disease Eradication (ITFDE) deemed PCC eradicable, yet the disease still persists in the northern, central, and southern highlands of Tanzania (Mwang'onde et al., 2018; Kajuna et al., 2022). PCC has been associated with various factors including poor sanitation in the environment, a lack of or inadequate hygiene practices, financial constraints, poor management of pigs, and a lack of education on PCC transmission in endemic areas (WHO, 2015). The lack of education in the community is a primary factor leading to practices that aid the spread and persistence of PCC (Lescano et al., 2007; Sorvillo et al., 2011). Earlier prevention/controlling efforts of *T. solium* taeniasis and cysticercosis transmission include the treatment of taeniasis in humans (Haby et al., 2020), treatment of cysticercosis in pigs (Kabululu et al., 2020) and health education (Ngowi et al., 2008). Health education is a crucial instrument for raising awareness and inspiring long-lasting improvements in management techniques that enhance technical proficiency and reduce the prevalence of the disease. Limited studies evaluating the effectiveness of health education in the context of TSTC have been conducted in Tanzania, and the studies had reported reduction of prevalence of PCC infections (Ngowi et al., 2008) and improved knowledge (Mwidunda et al., 2015; Holst et al., 2022) and pig management (Kajuna et al., 2023). However, previous health education on TSTC, on the other hand, had been limited to minimal community engagement and lacked of long-term sustainability.

Health education has been recommended to be a priority even in areas where other control strategies are intended, but its effectiveness depends on the proper design that requires careful planning, consideration of the local context and One Health approach in collaboration with the local communities to ensure it sustainably. This study used HEP consisting of brochures, booklets and posters, which was co-created with community participation to ensure knowledge uptake and sustainability. The aims of our study were to assess the HEP's effectiveness in reducing the prevalence of PCC and in improving pig farmers' understanding of PCC and their practices in Kongwa and Songwe Districts in Tanzania.

2.0 Materials and Methods

2.1 Ethical consideration

This study has been approved by the Ministry of Health ethics review board, the Tanzania National Institute for Medical Research (NIMR), under the reference number NIMR/HQ/R.8a/Vol.IX/2802, and the Vice Chancellor of Sokoine University of Agriculture (SUA), under the reference number SUA/ADM/R.1/8/352 in the Republic of Tanzania. In addition, the Klinikum rechts der Isar Ethics Committee at the Technical University of Munich, Germany, approved the study with permission number 537/18 S-KK. All study participants and village authorities verbally consented after we described the goal of the study and the farmers' right to decline participation. All data collected from study participants were kept confidential. At the end of the trial, we provided the health-education intervention to the control group.

2.2 Study period and area

The study was conducted from June 2019 to December 2021 in the PCC endemic districts of Kongwa and Songwe located in central and Southern highland zones of Tanzania, respectively. The study involved 28 and 14 villages in Kongwa and Songwe Districts respectively. Kongwa District (5°30 6°00" S and 36° 00 36°15" E) has a total land area of 4,041 km^2 and is located at 900 to 1000 m above sea level. The district had an estimated 56,498 pig's population. Songwe District (8°25 85°65′S and 32°00 33°14′E) has a total land area of 14,965 km^2 and is located at 900 and 2750 m above sea level and an estimated 33,046 pigs population (NBS, 2012). The two districts were purposively selected based on pig population and their PCC endemicity. In addition, the pig farmers in these areas practice free-range pig management which facilitates *T. solium* cysticercosis transmission

2.3 Study design, sample size, and sampling

A cluster-randomized controlled trial was conducted, this study compared two proportions (the one receiving health education and the control group). Based on previous studies by (Komba et al., 2013; Ngowi et al., 2014) in Mbozi and Kongwa districts, respectively, we have estimated a prevalence of porcine cysticercosis (P1) to 30% in both Kongwa and Songwe districts. We assume that our educational intervention will reduce the porcine sero prevalence (P2) down to 15% and would like to have a power of 80% to detect such a 50% reduction with 95% confidence. The sample size was calculated by the formula n = [Zα√ (2pq) - Zβ√P1q1 + P2q2]2 / (p1 – p2)2 (Dohoo et al., 2003). Where n = estimated sample size, Zα =1.96 Confidence interval, Zβ = - 0.84, P1, P2 estimated prevalence in the cross sectional and post-health education survey, respectively, q1 = 1- P1, q2 = 1- P2 (unaffected proportion of the population).Consequently, a sample size of n = 672 was needed for the investigation. The villages were chosen based on probability proportion to pig population size following the inclusion criteria: the villages have 20 pig-keeping households, and the villages should be accessible (Carabin et al., 2018). About 692HH and 692 pigs were sampled at baseline, and 486HH and 317 pigs were sampled in the post-HE intervention. By dividing the needed sample size by the total number of villages used in this study (n = 42), 16 pigs and 16HH were sampled from each village. We had examined one pig randomly selected from each of the randomly selected household to avoid clustering at household level. The HHs were chosen based on the presence of at least one 3 months pig; the second criterion for a household was willingness of the pigs' owner to participate in the study.

2.4 Data Collection

2.4.1 Questionnaire and observation survey

A KOBO toolbox software questionnaire was administered in a face-to-face interview with the head/adult permanent resident of each chosen HH before and post-health education intervention. The interview was conducted by one research assistant and the principal investigator in the village office. The questionnaire included both closed-ended and open-ended questions that prompted respondents on various themes related to *T. solium* transmission and prevention, housing, feeding and general husbandry practices. In addition, a checklist for direct observation of items was used to evaluate and verify hygiene and sanitary practices, such as the presence and conditions of latrines, the availability of facilities for hand washing and open defaecation. Other pig management and welfare factors, such as the number of pigs, the type of management, quality of pens, presence of intact walls and water troughs in the pig pens were also explored.

2.4.2 Measurement of the prevalence of porcine cysticercosis

Based on the farmer's history and observation at visitation, information about each study pig including age, sex, breed, and origin was recorded before sampling. Blood samples of 5 ml were collected from the jugular vein using a sterile vacutainer needle or a sterile syringe and transferred into a plain vacutainer tube where it was centrifuged at 1500G for ten minutes to recover the serum. The sera were divided into aliquots of 1.8 ml cryogenic vials and stored at -20°C. The circulating *T. solium* antigens were analysed using a commercial cysticercosis antigen enzyme-linked immunosorbent assay (Ag-ELISA) kit (apDia, REF 650501, Belgium) (Dorny et al., 2004) at Sokoine University of Agriculture (SUA) CYSTINET-Africa Project laboratory.

2.5 Randomization of study villages to intervention and control groups

Two groups of villages, one receiving health education (the treatment group) and the other acting as a control, were compared. The intervention was not administered to pig farmers in the control group. The villages were stratified into 3 strata based on the comparability of the PCC prevalence measured at the baseline study using Ag-ELISA. There were 10 villages in the first stratum with zero prevalence, 13 villages in the second stratum with a prevalence of 4.5 to 9.5%, and 19 villages in the third stratum with a prevalence of 10.5 to 33.3%. Half of the selected villages in each stratum were randomly assigned to either the intervention or control groups.

2.6 Health education intervention

2.6.1 Health education materials

Community health education was provided using the HEP, which also contained brochures, booklets and posters. In its preparation, the relevant communities were involved and considered the level of awareness and risky behaviour against *T. solium* infection (Nyangi et al., 2022).The posters, booklets, and leaflets were made more visual than textual material to enable illiterate pig farmers better understand the messages. Churches, school classrooms, and village offices served as venues for seminars. The training themes involved the life cycle of *T. solium*, ways to prevent and control TSTC, improved hygiene practices, water, sanitation and hygiene (WASH) practices and improved pig management, which included the construction of good pig pens using locally available materials and pig feeding using locally available feeds.

2.6.2 Mode of training delivery

Health Education (HE) training was conducted from October to December 2020, in all intervention villages in Kongwa and Songwe Districts. The objective of the training was to improve smallholder's farmer's knowledge, attitudes reduce the risk behavioural associated with *T. solium* taeniasis/cysticercosis transmission and reduce the prevalence of PCC. Before the start of the HE program, a meeting was conducted with the district and village officials to clarify the goals of the training. The baseline data on knowledge of the *T. solium* lifecycle, prevention, and WASH program for training the trainers (ToT) were collected using the questionnaire. The training was given for three days, with the first two days dedicated to training the trainers (ToT) which included village and ward leaders, as well as livestock and human health specialists. The training for ToT was evaluated using the same questionnaire administered at pre-HE training. Then, three among the trained ToT with high scores was selected to participate in single-day training of the selected pig farmers. The approach was strategically designed to ensure the sustainability of health education in the study area beyond the study period. The training was administered for about five hours, and sections of the training included, lectures, discussions (participant group discussions), questions and answer sections and dissemination of brochures and

2.7 Post-Health Education Assessment of KAP

A second survey was conducted one year following the community health education intervention using the same data collection instruments utilized in the baseline survey. The number of households that continue to keep pigs, the reasons for quitting pigs keeping, various programs addressing hygiene and pig management, and whether or not village leaders had completed the training of villagers on hygiene practices and proper pig management were all determined by adding seven questions to the baseline questionnaire

2.8 Data Analysis

For cleaning and archiving, the survey data were input into a Microsoft Excel spreadsheet. The analysis was carried out using STATA (version 17; Stata Corp). Only HH with "full participants"—those who took part in the cross-sectional survey and the post-health education intervention survey—were considered in this analysis. The analysis was performed in three steps (1) Performance score of all questions in KAP was calculated, the distinctions in the proportions in the correct responses on KAP towards PCC transmission and between farmers in the control and treatment groups were described using percentages (2) Pearson Chi-Square tests were used to determine whether KAP in the villages differed significantly between the baseline and post-intervention periods for the treatment groups (intervention) and control. (3) The difference-in-differences method (DID) compares the changes in outcomes over time (Branas et al., 2011).

Linear Mixed Model (LMM) DID analysis was also used to evaluate the effect of a community-based health education intervention on KAP, other demographic characteristics of the study participants were controlled in the analysis. Additionally, mixed-effects logistic regression models were performed assessing the changes in prevalence of PCC between intervention and control villages considering the study design (clustering on village level and strata by district) by including random effects. Furthermore, included were fixed effects for pig sex and age group of the pigs.

3.0 Results

3.1 Study participants

The flow of participating villages and HH during a community-based randomized health-education intervention trial is shown in Figure 1. A total of 276 (76 %) participants together with their leaders in the treatment group received leaflets after the training session. Village members who did not partake the training, leaflets were circulated to them through their neighbours or leaders. However, the follow-up study was completed by 492 (71%) of the pig farmers who were surveyed after the intervention. The analysis only included 486 HH due to an individual identification (ID) number mismatch. At the follow-up survey, only 321 (66 %) of the 486 households surveyed continued to keep pigs. About 85 (52%) of the remaining households reported death of their pigs due to African swine fever (ASF), 74 (45%) had sold their pigs and 6 (3%) had financial constrains to sustain pig production .The post-intervention survey selected only 317 pigs that met the criteria for sampling.

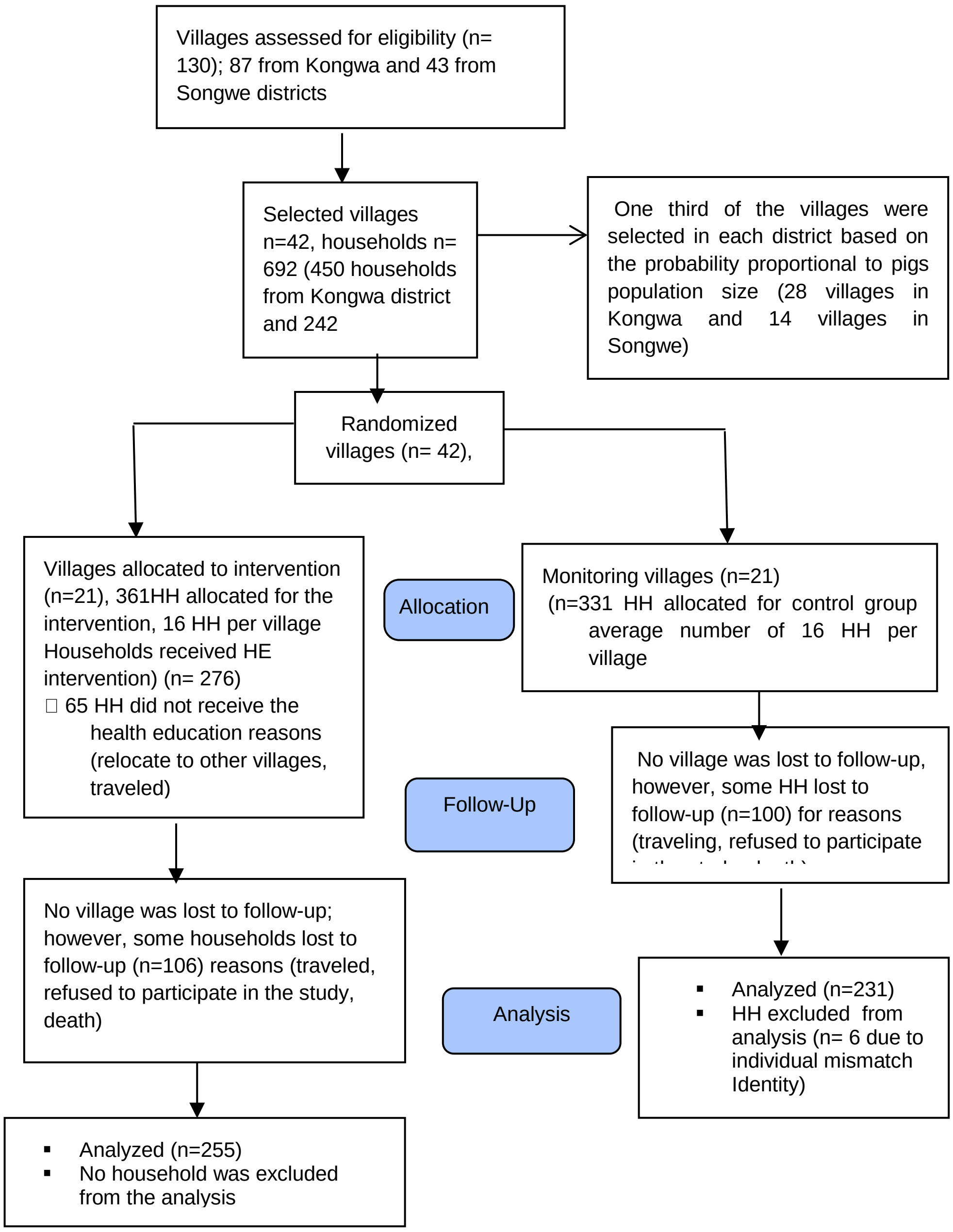

Figure 1: Flow of pig farmers during a community-based randomized health-education intervention trial in the Kongwa and Songwe districts of Tanzania, from 2019 to 2021.

3.2 Baseline KAP, and PCC prevalence

The baseline survey showed that 615 (88%) of the 692 farmers interviewed kept between one and ten pigs, and 496 (72%) had heard of PCC. Comparable knowledge, attitudes, and behaviors about PCC were present in both the intervention and control groups from the outset. Only 116 respondents (17%) had good methods for PCC prevention and control, while 502 respondents (72%) had a favorable attitude towards control of PCC. Forty-two per cent (292) of the respondents had little knowledge about PCC. The PCC seropositivity was somehow uniformly distributed between the intervention and control villages in both Kongwa and Songwe districts (Fig 2). The intervention and control villages in Songwe district had PCC prevalence of 16% (95%CI 11.8-21.8%) and 16.7% (95%CI 10.0-27.9%) during the baseline survey. While the intervention and control villages in Kongwa district, had PCC prevalence of 9.5% (95%CI 5.5-16.4%) and 6.3% (3.4-11.6%), respectively during the baseline survey

3.3 Effect of community-based health education intervention on the enhancement of Knowledge, Attitudes, and Practices

Table 1: Shows a significant change in knowledge, attitude, and practice levels from baseline to follow-up in both control and intervention groups in Kongwa and Songwe Districts. The intervention group showed a greater change in knowledge level than the control group, with a significant decrease in low knowledge level -17.3% ($p < 0.001$) and a significant increase in moderate knowledge level 17.6 ($p < 0.001$). The treatment group showed a significant increase in knowledge of transmission during the follow-up period, whereby an increase of 41.5% of pig farmers recognized that pigs acquire *T. solium* cysticercosis through ingesting human faeces with *T. solium* eggs ($p < 0.001$).

The treatment group also demonstrated a significant improvement in knowledge about preventive measures such as stopping open-field defecation ($p = 0.011$) and proper use of latrines ($p = 0.037$) (Table 2). The identification of measly pork was correctly described by 35.5% and 41.2% of untrained and trained farmers, respectively, at baseline.

The study found significant improvement in knowledge for farmers in both the trained (63.9%) and untrained groups (45.5%) at follow-up (Table 2)

The attitudes in the intervention villages improved significantly, with 88% agreeing that pigs left free are at high risk of acquiring *T. solium* cysticercosis (p <0.001). The intervention villages exhibited a stronger agreement that pork should be inspected by veterinary officials (P = 0.023) and showed a higher level of willingness to condemn the infected pigs (p <0.001) (Table 2). The intervention villages showed a significant increase in the ability to identify measly pork (p <0.001) and consultation with veterinary officials (p = 0.002).

Table 1: Change in knowledge, attitudes, and practice levels from baseline to follow-up in Kongwa and Songwe districts 2019 - 2022, (n=486)

			Control group					**Intervention**
	Baseline	follow-up	Changes in control group (%)	p-value	Baseline	follow-up	Change in intervention group (%)	**p-value**
	N=231	N=255			N=231	N=255		
	n, %	n, %			n, %	n, %		
				Change in Knowledge level from baseline to follow-up				
Low	102 (44.2)	101 (43.7)	-0.5	0.930	94 (36.9)	50 (19.6)	-17.3	**<0.001****
Moderate	105 (45.5)	115 (49.8)	4.3	0.350	128 (50.2)	173 (67.8)	17.6	**<0.001****
High	24 (10.4)	15 (6.5)	-3.9	0.130	33 (12.9)	32 (12.5)	-0.4	**0.89**
				Change in Attitude level from baseline to follow-up				
Negative	45 (19.5)	32 (13.9)	-5.6	0.100	24 (9.4)	19 (7.5)	-1.9	**0.430**
Neutral	20 (8.7)	30 (13.0)	4.3	0.130	32 (12.5)	8 (3.1)	-9.4	**<0.001****
Positive	166 (71.9)	169 (73.2)	1.3	0.750	199 (78.0)	228 (89.4)	11.4	**<0.001****
				Change in Practice level from baseline to follow-up				
Control	N=231	N=231						
Poor	90 (39.0)	128 (55.4)	16	<0.001**	98 (38.4)	108 (42.4)	4	**0.370**
Moderate	88 (38.1)	84 (36.4)	-1.7	0.70	92 (36.1)	106 (41.6)	5.5	**0.200**
Good	**53 (22.9)**	**19 (8.2)**	**-14.7**	**<0.001****	**65 (25.5)**	**41 (16.1)**	**-9.4**	**<0.001****

N, number of pig farmers

***Significant (p < 0.05). **Significant (p <0.001)**

Table 2: **Change in pig farmer's knowledge attitudes and practices between intervention and control villages from baseline to follow-up post-health education in Kongwa and Songwe districts, Tanzania 2019 – 2022 (n = 486)**

Variables			Control villages				Intervention villages	
Questions related to knowledge	Baseline N=231	Follow-up N=231	Change in control group	p-value	Baseline N=231	Follow-up N=231	Change in intervention group	P -value
How does *T. solium* cysticercoids spread among pigs??	n, %	n, %	(%)		n, %	n, %	(%)	
Consuming *T. solium* eggs through human faeces	67 (29.0)	93 (40.3)	11.3	0.011*	93 (36.5)	199 (78.0)	41.5	<0.001**
Is it possible to stop pigs from developing *T. solium* cysticercosis? (Yes)	98 (42.4)	104(45.0)	2.6	0.570	116 (45.5)	202 (79.2)	34.0	<0.001**
If so, describe the precautions.								
Pigs being housed indoors all the time	92 (93.9)	104(100.0)	6.1	0.010*	114 (98.3)	202 (100.0)	1.7	0.061
Proper use of toilets	2 (2.0)	7 (6.7)	4.7	0.790	3 (2.6)	35 (17.3)	14.7	0.011*
People should quit defecating in open spaces	11 (11.2)	3 (2.9)	-8.3	0.011*	3 (2.6)	19 (9.4)	6.8	0.037*
Questions related to attitudes								
Free-range pigs are at high risk of acquiring *T. solium* cysticercosis (Agree)	133 (57.8	160 (69.3)	11.5	0.400	157 (61.6)	225 (88.2)	26.6	<0.001**
I must only purchase or sell pork that has undergone inspection by veterinary officials. (Agree)	175 (75.8)	204 (88.3)	12.5	0.220	205 (80.4)	240 (94.1)	13.7	0.023*
I would abhor pork infected with *T. solium* cysts.	143 (61.9)	151 (65.4)	3.5	0.034*	181 (71.0)	218 (85.5)	14.5	<0.001**
Reported practices								
Can you identify measly pork? (Yes)	82 (35.5)	105(45.5)	10	0.029*	105 (41.2)	163 (63.9)	22.7	<0.001**
Which actions would you take if you found your pigs are infected with *T. solium* cysts?								
Consult veterinary doctor	128 (55.4)	139 (60.2)	4.8	0.300	163 (63.9)	195 (76.5)	12.6	0.002*
Wash your hands before preparing pig feed (Yes)	58 (25.1)	36 (24.3)	-0.8	0.480	57 (22.4)	55 (32.4)	10	0.110
Treatment of water before drinking								
Boil	4 (1.7)	30 (13.0)	11.3	0.140	1 (0.4)	40 (15.7)	15.3	0.400

N, number of pig farmers; *Significant ($p < 0.05$). **Significant ($p < 0.001$)

3.4 Community-based health education intervention effect on improving pig management and hygiene

Both intervention and control villages demonstrated a significant improvement in the overall latrines and pig pens' qualities with a higher percentage of good quality pens and latrines in the follow-up period compared to the baseline ($p < 0.001$). Also, both intervention and control villages showed a significant reduction in open defecation during the follow-up period ($p < 0.001$). However, the intervention villages had slightly higher percentages of no open defecation compared to the control villages. The control villages showed a significant increase in indoor pig management ($p = 0.004$) with higher percentages of farmers keeping pigs indoors during the follow-up period. The distribution of pigs in semi-intensive and free-range management didn’t show a significant change between the intervention and control villages (Table 3).

Table 4 shows the difference in difference analysis for the effect of a community-based health education intervention on knowledge, attitude, and practices. The intervention was more successful in increasing knowledge (β =1.779, p=0.0037) and attitude over time (β =1.024, p=0.038). The analysis found that sex and district had statistically significant effects on the outcome. Being male was associated with higher knowledge scores (β =1.958, $p < 0.0001$) and higher attitude scores (β =0.643 p 0.009). The district of Kongwa was also associated with higher knowledge (β =1.947, $p < 0.0001$ and attitude (β = 3.183, p =<0.0001)

Table 3: **Change in pig management and the hygienic situation between intervention and control villages from baseline to follow-up post-health education in Kongwa and Songwe districts, Tanzania 2019 – 2022**

Variables	Control villages			Intervention villages		
	Baseline N, %	Follow-up N, %	P-value	Baseline N, %	Follow-up N, %	p-value
Pig management						
Indoor	171 (76.7)	136 (85.5)	0.041*	197 (81.4)	135 (83.3)	0.650
Semi-intensive	34 (15.2)	11 (6.9)		26 (10.7)	13 (8.0)	
Free-range	18 (8.1)	12 (7.5)		19 (7.8)	14 (8.6)	
Overall latrine impression						
Good	16 (7.5)	51 (22.7)	<0.001**	12 (5.3)	55 (24.2)	<0.001**
Moderate	162 (76.1)	125 (55.6.)		189 (83.3)	126 (55.5)	
Poor	35 (16.4)	49 (21.8)		26 (11.5)	46 (20.3)	
Overall pig pen impression						
Good	17(8.9)	24 (17.0)	0.001**	12 (5.8)	37 (25.9)	<0.001**
Moderate	145(75.5)	78 (55.3)		173 (83.2)	85 (59.4)	
Poor	30(15.6)	39 (27.7)		23 (11.1)	21 (14.7)	
Presence of drinkers in the pig pen?						
No	67 (30.3)	53 (37.6)	0.152	114 (47.3)	68 (47.6)	0.962
Yes	154 (69.7)	88 (62.4)		127 (52.7)	75 (52.4)	
Presence of feeders in the pig pen?						
No	30 (15.5)	17 (12.1)	<0.001**	43 (20.7)	4 (2.8)	<0.001**
Yes	163 (84.5)	124 (87.9)		165 (79.3)	139 (97.2)	
Open defecation by children?						
No	158 (72.1)	236 (99.2%)	<0.001**	162 (69.5)	243 (100.0)	<0.001**
Yes	61 (27.9)	2 (0.8)		71 (30.5)	0 (0.0)	

N, number of pig farmers; *Significant ($p < 0.05$). **Significant ($p < 0.01$)

Table 4: **Community health education effect on knowledge, attitudes, and practices towards *Taenia solium* porcine cysticercosis in Kongwa and Songwe districts, Tanzania 2019 – 2022 (n = 486): difference in difference (DID) estimation**

	Knowledge			Attitude			Practices		
Effect	**Estimate (β)**	**Standard Error**	**P-Value**	**Estimate (β)**	**Standard Error**	**P-Value**	**Estimate (β)**	**Standard Error**	**P-Value**
Intervention	1.508	0.451	<0.001 **	1.229	0.283	<0.001 **	0.457	0.224	0.042*
Control	Reference			Reference					
Time*Treatment	1.779	0.609	0.004**	1.0244	0.492	0.038	0.719	0.317	0.023*
Sex									
Male	1.958	0.344	<0.001 **	0.643	0.247	0.001**	-0.067	0.179	0.709
Female	Reference			Reference					
District									
Kongwa	1.947	0.366	<0.001 **	3.183	0.253	<0.001 **	2.501	0.193	<0.001 **
Songwe	Reference			Reference					
Age									
15-25	Reference			Reference					
26-35	1.245	0.624	0.047*	0.922	0.439	0.036	0.798	0.323	0.014*
36-45	1.787	0.622	0.004**	1.477	0.441	<0.001 **	1.442	0.323	<0.001 **
46-55	2.066	0.656	0.002**	1.758	0.465	<0.001 **	1.242	0.341	<0.001 **
56+	2.245	0.713	0.002**	1.896	0.508	<0.001 **	1.071	0.371	0.004**
Educational attainment									
Without a formal education	Reference			Reference					
Primary Education	2.333	0.407	<0.001 **	1.736	0.288	<0.001 **	1.267	0.211	<0.001 **
Secondary and above	4.428	0.646	<0.001 **	2.989	0.458	<0.001 **	3.113	0.337	<0.001 **

N, number of pig farmers; *Significant (p < 0.05). **Significant (p < 0.01)

3.5 Seroprevalence of PCC following community health education trial

The seroprevalence of PCC decreased from 11.7% to 7.8% (-3.9 percentage points) in the villages that received the health education intervention, compared to 9.1% to 8.6% (-0.5 percentage points) in the control villages. Disaggregated by district, seroprevalence in Kongwa decreased from 9.5% to 8.7% (-1.2 percentage points) in intervention villages and increased from 6.3% to 7.2% (+0.9 percentage points) in control villages. For Songwe, PCC seroprevalence decreased from 16.0% to 6.0% (-10 percentage points) in intervention villages and from 16.7% to 15.2% (-1.5%) in control villages (Figure 2 and Table 5). The odds ratio for the total intervention impact on PCC prevalence taking into consideration strata (i.e. districts) and village level clustering was 0.70 (95% CI 0.27 to 1.83).The odds ratio for the overall intervention effect on PCC prevalence taking into account strata (i.e. districts) and village level clustering was 0.70 (95%CI 0.27 to 1.83, p=0.47).

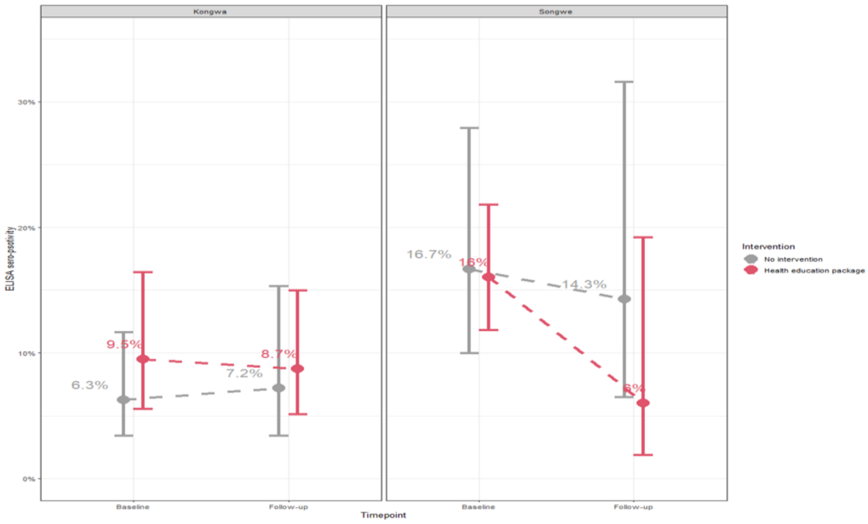

Figure 2: Ag-ELISA positivity between intervention and control villages during Baseline and follow up in Kongwa and Songwe Districts. Note that One year after health education PCC seropositivity reduced by 10% in the intervention villages in Songwe district, while PCC seropositivity reduced by 0.8% in the intervention villages in Kongwa district

Table 5: Prevalence of Porcine cysticercosis following *Taenia solium* Taeniasis cysticercosis community-based health education trial in Kongwa and Songwe districts in Tanzania

Variables	Baseline		Follow-up		Change	ds Ratio [95%CI]£
	n/N	ce (%) [95%CI]*	n/N	ce (%) [95%CI]*	revalence (%)	
th education intervention	37/353	11.7 (8.3-16.5)	12/165	7.8 (4.7-13.1)	-3.9	0.70 [0.27-1.83]
Kongwa	20/250	9.5 (5.5-16.4)	9/121	8.7 (5.1-14.9)	-0.8	
Songwe	17/136	16.0 (11.8-21.8)	6/54	6.0 (1.9-19.2)	-10.0	
No intervention	30/339	9.7 (6.4-14.8)	13/152	9.4 (5.3-16.5)	-0.3	
Kongwa	13/233	6.3 (3.4-11.6)	7/111	7.2 (3.4-15.3)	+0.9	
Songwe	17/140	16.7 (10-27.9)	3/56	15.2 (6.5-31.6)	-1.5%	

4.0 Discussion

This study assessed the effect of community-based health education intervention using an HEP on knowledge, attitudes, and practices (KAP) among smallholder pig farmers and the seroprevalence of PCC in disease-endemic settings in Tanzania. Comparing pre- and post-randomization changes in knowledge, attitudes, practice, and PCC prevalence between control and intervention groups allowed us to study the effect of the intervention. The community-based health education intervention was effective in enhancing knowledge, attitudes, and practices regarding the transmission and prevention of PCC. The findings also suggest that the intervention was more effective over time, which could be due to increasing exposures to HEP messages through the given leaflets or a greater understanding of the concepts being taught. This suggests that after the intervention the community could take the right options on disease control measures leading to the prevention/ control of the parasite. However, the change in practices was significant in both treatment and control group and probably required a longer observation period to observe the effect of health education in the treatment group. Research by Kajuna et al. (2023) discovered a noticeable improvement in the condition of the pig pens and houses confined pigs about 25 months after the digital health education intervention. This study's findings agree with previous studies, which found health education to improve the knowledge of smallholder pig farmers in various pig diseases (Ngowi et al., 2011; Chilundo et al., 2020).

In addition, the study found that health education improved farmers' desire to condemn cysticerci-infected pork and to buy/sell pigs or pork that has undergone a veterinary inspection. The findings of this study were comparable to the findings in a study by (Mwidunda et al., 2015) where the education intervention improved school children's attitudes toward condemnation of cysticerci-infected pigs. The unavailability of effective drugs to treat cysticerci-infected pigs in Tanzania makes the confiscation of infected pork the available option to safeguard public health. The United Republic of Tanzania Animal Disease Act No. 17 of 2003 and animal disease regulation of 2007 mandate total condemnation of cysticerci-infected pork, and disposal of heavilyinfected pig carcasses were recommended measures mandated by World Organization for Animal Health (WOAH) for Terrestrial Animal Health Code (WHO, 2015). Despite an increase in positive attitudes toward buying/selling pigs or pork that has undergone veterinary inspection, its implementation is not realistic in many rural areas of low-middle income countries including Tanzania due to the practice of home slaughtering of pigs where meat inspection is limited/non-existent (Wilson &Swai, 2014). It is therefore suggested that the government should construct slaughter facilities at the village level to facilitate the meat inspection and deploy meat inspectors to the community level.

Furthermore, the study found that health education intervention did not affect disease dynamics during the observation period. Poor latrine quality, the continued management of semi-intensive and free-ranging pigs, and poor pig pens are risk factors that contribute to the transmission of PCC (Komba et al., 2013), which could partially account for the lack of positive effects of health education intervention. Despite the observed increase in pig confinement during follow-up, some pigs could still access human faeces in the contaminated environment due to partial pig confinement and open-field defecation behaviour. In both the intervention and control villages the study observed a general reduction in the seroprevalence of PCC after the intervention; indicating that the reduction cannot be due to the intervention alone but rather may be the consequence of other reasons that took place in the study areas such as sanitation initiatives with a slogan (The house is toilet) that was launched in 2018 and focused on encouraging households to build and utilize latrines hygienically. The campaign might be the reason for PCC reduction due to a decrease in reported open field defecation behaviour as resulted in a decrease in the environmental contamination with human faeces, hence reducing the environmental contamination with the parasite eggs. Another reason could be the COVID-19 pandemic, which was first reported in Tanzania in February 2020. As a means of protection from the pandemic, frequent hand washing was emphasized. Hand washing is one of the ways to prevent/control *T. solium* infections (Aiello and Larson, 2002). The results of this study are comparable to those by Kajuna et al., (2023), in which a digital health literacy intervention had no appreciable effect on PCC prevalence.

This study found that there was a significant improvement in the observed practices such as indoor pig management, good pig pens, and quality latrines in both intervention and control villages. Since the changes observed in both the control and intervention villages suggest that the improvement was not due to the health education alone, but rather to other factors such as information contamination (from the intervention villages or other sources or like the COVID-19 pandemic, enforcement of by-laws governing indoor pig rearing, sanitation initiatives, or the Hawthorne effect. The Hawthorne effect is a type of human behaviour reactivity that occurs when people alter one aspect of their behaviour when they become aware that they are being observed (McCarney et al., 2007).The change in practices may be influenced by poverty and cultural norms and therefore difficult to change in a short time. Therefore, to observe positive behavioural changes, more time is needed this study's findings are comparable to those of earlier ones that were carried out in Tanzania (Ngowi et al., 2008), and Mozambique (Chilundo et al., 2020).

The study's benefits and shortcomings

The study's strength is in the cluster design it takes into account, which is important for assessing the intervention's effect on the follow-up response based on the baseline response. Also, the study used the developed HEP from community participation. The mode of delivery of health education was designed to ensure the sustainability of health education in the study area beyond the study period. The current research has some limitations. Health education has some drawbacks as a stand-alone strategy, primarily because learning does not always result in behavioral and practical changes needed to reduce disease incidence. As a result, cross-disciplinary approaches are anticipated in the mediation. In addition, unlike other intervention tools, we have not included a practical section on pig feeding and housing structure. Furthermore, this study did not include an assessment and treatment of human tapeworm carriers which would be an important step to immediately interrupt the life cycle of *T.*

solium which may have helped seeing larger short-term effects of our health education intervention.

5.0 Conclusions

This study revealed that community-based health education intervention using the HEP has significantly improved the knowledge and attitudes of smallholder pig farmers toward PCC transmission and control. The fact that additional time is required to witness changes as a consequence of an education intervention may help to explain why the intervention did not lower PCC prevalence and enhance the observed behaviours. To effectively and sustainably disseminate educational messages for the long-term control of *T. solium* infection in endemic locations, we advise community health education interventions utilizing the HEP.

Author's contributions

Christina Wilson: conception, study design, data curation, writing original draft, investigation, Hezron Emmanuel Nonga, and Robinson Hammerrthon Mdegela: supervision, reviewing the manuscript. Geoge Makingi: investigation and data curation, Helena Aminiel Ngowi: funding acquisition, study design, supervision, reviewing, editing the manuscript, and project administration, Ernatus Martin Mkupasi: project management, supervision, manuscript revision, Andrea Sylvia Winkler: funding acquisition, evaluation, and editing of the study design; and manuscript editing. The final paper draft was approved by all authors before submission.

Informed consent statement

After being given information about the goal and scope of the study, participants verbally agreed to participate. Instead of names, an identification number was given to each home for confidentiality and data security.

The availability of data

On request, the corresponding author can provide the data used to support the findings of this study.

Conflicts of interest
No conflicts of interest were disclosed by the authors.

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CHAPTER FIVE

5.0 GENERAL DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 General discussion

The baseline survey revealed PCC seroprevalence in both the intervention and control groups. Twelve months after the HE intervention, the study found there were no appreciable differences in terms of PCC between intervention and control villages due to the fact that farmers were not fully adopt the recommended practices. The study observed prevalent of poor latrine quality, the continued management of semi-intensive and free-ranging pigs, and poor pig pens which might be the risk factors that contribute to the perpetuation transmission of PCC (Kajuna *et al.,* 2022; Komba *et al.,* 2013; Shonyela *et al.,* 2017) and hence could partially account for the lack of positive effects of health education intervention.

The study observed a general reduction in the prevalence of PCC after the intervention in both the intervention and control villages, indicating that the reduction cannot be attributed solely to the intervention but may be the result of other factors that occurred in the study areas, such as sanitation initiatives with a slogan (The house is toilets), which were launched in 2018 and focused on encouraging households to build and use latrines hygienically. The campaign may be the explanation for PCC reduction owing to a drop in reported open field defecation behaviour, which resulted in a decrease in the environmental contamination with human faeces, hence decreasing environmental contamination with parasite eggs. Another explanation might be the COVID-19 pandemic, which was first detected in Tanzania in February 2020. Hand washing was promoted as a way to guard against the pandemic. Hand washing is one strategy to prevent and control *T. solium* infections (Aiello & Larson 2002; Marther, 2011). This study's findings are consistent with those of Kajuna et al. (2023) who found that a digital health literacy intervention had no significant influence on PCC prevalence.

This study revealed that PCC is still prevalent in pigs kept by smallholder farmers in Kongwa and Songwe districts in the central part and southern highlands of Tanzania, respectively. The PCC seroprevalence in the study areas is an indication of the existence of *T. solium* carriers in the study communities. Transmission may be enhanced by free-range pig management, and open defecation. In addition, the existence of PCC in the pig production area implies high economic impacts (Kayuni, 2021) and a great public health risk for human infections in both rural and urban areas if slaughtered pigs are not properly inspected (Mkupasi *et al.,* 2011; Schmidt *et al.,* 2019). Ag-ELISA alone, was used as a diagnostic method in this study, and therefore the reported seroprevalence estimates can be assumed underestimation or overestimation due to diagnostic inaccuracies of the test.

Risk factors for PCC transmission in the study areas included increased age of the pig, pigs originating within the household, and pigs kept in a household that practised deworming. The study found that older pigs have the highest seroprevalence, which is consistent with prior observations in areas where PCC is prevalent. (Dermauw *et al.,* 2016; Gulelat *et al.,* 2022; Mkonda and Xinhua, 2017).The relationship between age and PCC seroprevalence might be explained by the fact that older pigs have been exposed to PCC for a more extended period than younger ones (Pondja *et al.,* 2010), and infections are usually not cleared within a short time. Adult pigs can easily flee from their pen due to poor pen condition, and hence increasing the chances of contracting PCC by consuming tapeworm eggs in human faeces prevalent in open environment, (Maganira *et al.,* 2018).In addition younger pigs are protected through the initial exposure period, perhaps via maternal transfer of antibodies, but become susceptible later. Maternal antibodies are protective for other larval cestode infections (Pondja *et al.,* 2010) and have been shown to slowly decrease in piglets born to cysticercosis infected sows. In addition, pigs within the household posed a risk factor for PCC seroprevalence. This result demonstrates clustering of infections and suggests the existence of attribute(s) inside the household that aid in the transmission of *T. solium* eggs to pigs. Pigs may be infected by either ingestion of faeces and/or feed-stuff and water contaminated with *T. solium* eggs (Braae *et al.,* 2015c; Mwang'onde *et al.,* 2018). In addition, other studies had reported inadequate hygiene, poor husbandry practices and existence of human tapeworm carriers are among important attributes that might have contributed to this observation. (Cortez Alcobedes *et al.,* 2010; Lescano *et al.,* 2007).

The study found that deworming of pigs was positively correlated with the seroprevalence of PCC. This is not surprising because farmers admitted to routinely deworming their pigs using ivermectin and albendazole (Wilson *et al.,* 2023): none of the anthelmintic used were efficacious against PCC (Mkupasi *et al.,* 2013a, 2013b). However, this observation was in contrast to the results reported by Kungu et al. (2017), whereby a high prevalence of PCC was found in households in which pigs were not dewormed. 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 (Kabululu *et al.,* 2020b; Mkupasi *et al.,* 2013). For proper treatment and control of PCC in Tanzania, relevant bodies should strive to make sure oxfendazole, are made available for use, at affordable prices, and pig farmers should be advised accordingly.

This study found a positive correlation—though not a single one that was statistically significant—between Ag positivity and the households in the village that do not have latrines and that practice open defecation. Infrequent latrine usage is a significant risk factor for PCC seroprevalence. In addition, this study found that there was a good coverage of latrines in the study areas; however, the majority of them were inappropriate because they lacked water and soap for hand washing, had insecure walls, no doors, and were roofless. There is still a chance that PCC might spread via inappropriate latrines, non-confined pigs in these areas had easy access to human faeces found in open environments or directly to latrines with no doors. Previous research (Ngowi *et al.,* 2004; Krecek *et al.,* 2012) indicated that limited latrine usage, was a significant contributing factor to the transmission of *T. solium*. Thus, the results of the present study confirm the importance of having and using latrines with functional doors.

In addition, the baseline survey reported poor knowledge among farmers regarding PCC transmission and prevention could be associated with the observed attitudes and risk practices among farmers, hence disease perpetuation. This is probably due to the fact that no specific health education intervention had been provided for the control of *T. solium* infections in the area. 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 (Jayashi *et al.,* 2012; Lescano *et al.,* 2007; Sorvillo *et al.,* 2011). The findings are similar to the findings from earlier studies in Tanzania (Chacha *et al.,* 2014; Maridadi *et al.,* 2011) 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.

This study found that the primary variables that strongly correlated with KAP scores were respondents' levels of education and the geographical locations (districts). The age of the respondents had an important effect only on the knowledge and attitudes score. In addition, this study showed that male respondents knew more about PCC than did their female counterparts. The results of this study were similar to those of a study conducted by Kungu et al. (2017), which found that Ugandan men farmers understood PCC more than their female counterparts. Furthermore, the study showed that there were no statistically significant variations in the attitudes and practices of the two genders. Therefore, it is essential to understand how sociodemographic characteristics affect the efforts to reduce and eventually eradicate *T. solium* infections. To raise awareness and change practices and attitudes regarding the control of TSTC, greater thought should be given to health education. The findings of this study have shown promising results for community health education provided using the adopted HEP developed from community participation in the studied areas. Community health education significantly improved knowledge, attitudes, and practices toward the prevention of PCC among smallholder pig farmers.

The study found that in both the intervention and control villages, there was a notable improvement in the practices that were observed, such as good pig pens, indoor management, and quality latrines. Because of the changes seen in both the control and intervention villages, it appears that other factors, such as the Hawthorne effect, the enforcement of by-laws governing indoor pig rearing, information contamination from the intervention villages or the COVID-19 pandemic, were more likely to have contributed to the improvement than health education alone. Thus, a longer time is required to observe positive improvements in behaviour. Research by Kajuna et al. (2023) discovered a noticeable improvement in the condition of the pig pens and household confined pigs about 25 months after the digital health education intervention. These study findings agree with those of previous studies, which found health education to improve the knowledge of smallholder pig farmers (Ngowi *et al.,* 2011; Chilundo *et al.,* 2020).

5.2 General Conclusions

- This study showed that the majority of pig farmers in Kongwa and Songwe Districts were aware of PCC and had positive attitudes toward PCC prevention measures. 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.

- This study showed that PCC is still prevalent in Kongwa and Songwe districts, PCC seroprevalence increasing with pig age, pigs originating from outside the household, and pigs kept in a household that practised deworming.

- The study also showed that community- based health education intervention increases the knowledge, attitudes, and practices of smallholder pig farmers regarding PCC transmission and control. However, health education intervention did not significantly reduce the seroprevalence of PCC during the observation period.

5.3 Recommendations

- This study recommends treating cysticerci-infected pigs to protect smallholder pig farmers' health and livelihoods in the studied areas and other endemic areas across the country
- This study recommends that the village government/authorities should create by-laws that prohibit semi-extensive/free-range pig husbandry
- The study recommends conducting human surveys on taeniasis and cysticercosis to identify public health risks associated with porcine cysticercosis in the study region
- The study recommends future research to integrate community health education with the treatment of taeniasis and PCC for a minimum of three years, which is believed to be the parasite’s life span
- Future health education intervention should include assessment of the time length to which the acquired knowledge translated to behavioural change
- This study recommends that the government should develop risk communication and community engagement (RCCE) strategy for control of TSTC in human and pigs
- The study recommends future research to advocate social behaviour change (SBC) among pig farmers
- The study recommends future research CHE studies should access the association of the socio-economic conditions of the pig farmers and changes in practices

5.4 Study contribution

- The study contributes to the body of knowledge in evaluating community-based health education package (HEP), which was co-created with community participation to ensure knowledge uptake and sustainability in reducing seroprevalence of porcine cysticercosis and improving smallholder pig farmer's knowledge, attitudes and practices in Kongwa and Songwe Districts in the central and southern highland regions of Tanzania, respectively

- The study contributes to the body of knowledge in accessing the current status of the seroprevalence of porcine cysticercosis and its associated risk factors in Kongwa and Songwe Districts in the central and southern highland regions of Tanzania, respectively

- The study contributes to the body of knowledge in accessing the status of knowledge, attitude and practices regarding *T.solium* porcine cysticercosis prevention and control among smallholders pig farmers in Kongwa and Songwe Districts in the central and southern highland regions of Tanzania, respectively

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APPENDICES

Appendix 1: Questionnaire to explore pig Knowledge, Attitude and Practices (KAP) related to *T. solium* cysticercosis transmission and control farmers'

To be filled in by research team:

Date__________________________ name of interviewer________________________

District _______________Ward _______________Village_______________ Sub village ______________

GPS co-ordinates: longitude N ______latitude E ________altitude-

Date__________________________ name of interviewee _________________

District _______________Ward _______________Village_______ Sub village

Please fill in this questionnaire truthfully. All responses will be kept confidential and will not be used against you in any way. The information will be used for research purposes only.

Personal Information
Identity number……………………
Sex: (1) Male
(2) Female
Age (years) ________________

Demographic Characteristics

1. For how long did you and your family live in this village…………
2. Level of Education
   (1) No formal education
   (2) Primary school education
   (3) Secondary school education (Form 1 – 4)

(4) Secondary school education (Form 5 – 6)
(5) College education

3. Position of the respondent in the household
(1) Father
(2) Mother
(3) Daughter/son
(4) Others (Mention)…………………………………

4. Your job is?
(1) Farmer
(2) Fisherman
(3) Pastoralist
(4) Private sector employee
(5) Government employee
(6) Businessman
(7) Others

5. How many people (including yourself) are there in your household? ....

6. Do people in your family including yourself own any animal?
(1) Yes
(2) No

7. If the answer for question 6 is yes, which animal (s) (More than one answer is possible)
(1) Chicken
(2) Cows
(3) Ducks
(4) Goats
(5) Pigs
(6) Other

8. Is the household still keeping pigs a) Yes b) No

9. How many pigs do you have in this household?...........................

9b. If the answer for question 8 is no, mention the reasons for not keeping pigs…… (Additional questions for post Health education intervention)

KNOWLEDGE

10. Which health problems you usually face in pig husbandry? (More than one answer is possible)

(1) *T. solium* cysticercosis
(2) Other worms
(3) African swine fever
(4) Mange
(5) None
(6) Others ………….

11. Have you heard about *T. solium* cysticercosis in pigs?
(1) Yes
(2) No

12. If you have heard about *T. solium* porcine cysticercosis, where have you heard of it?
(1) Friend
(2) Leaflets
(3) Mass media
(4) Book/articles
(5) School
(6) Parents/family
(7) Veterinary officers
(8) Others …………

13. How do you call *T. solium* porcine cysticercosis in your local language?

14. How do pigs acquire *T. solium* cysticercosis? (More than one answer is possible)
(1) Eating human faeces with *T. solium* eggs
(2) Eating food contaminated with *T. solium* eggs
(3) Eating grasses and vegetables contaminated with human faeces
(4) Drinking water contaminated with *T. solium* eggs
(5) Don't know
(6) Others……………………………………….

15. How would you know the *T. solium* cysts infected pigs
(1) I don't know
(2) Through tongue examination
(3) Through faeces examination
(4) Though skin examination

15. B Mention other methods to identify *T. solium* infected pigs………

16. Can you identify 'measly' pork?
   (1) Yes
   (2) No

17. Where will you find cyst in pig's body?
   (1) Skeletal muscle
   (2) Tongue
   (3) Brain
   (4) Heart
   (5) Intestine
   (6) Others

18. Which actions would you take if you found your pigs are infected with *T. solium* cysts?
   (1) I will consult veterinary doctor
   (2) I will use traditional medicine
   (3) No actions will be taken
   (4) I will sell the pigs
   (5) I will slaughter and consume the pork
   (6) Others…………………………

19. Is it safe for humans to consume 'measly' pork?
   (1) Yes
   (2) No
   (3) Don't know

20. If the answer for question 19 is no, why??
   (1) Might get infected with *T. solium* cysticercosis
   (2) Might get tapeworm (Taeniosis)
   (3) Infected pork is not delicious
   (4) Infected pork is strictly prohibited
   (5) Don't know
   (6) Others (mention) ....

21. Is there any means of preventing pigs from acquiring *T. solium* cysticercosis?
   (1) Yes
   (2) No
   (3) Don't know

22. If the answer to question 21 is yes mention the preventive measures (More than one answer is possible)

(1) Keeping pigs indoor all the time
(2) To have toilets/latrines with closing doors
(3) Proper use of toilets
(4) People should stop open field defecation
(5) Others ………………………………

23. Do you think *T. solium* porcine cysticercosis can cause economic losses?

(1) Yes
(2) No
(3) Don't know

24. If the answer to question 23 is yes, mention the effects (More than one answer is possible)

(1) Lack of market for infected pig/pork
(2) Condemnation of infected pork
(3) Low price for infected pig/pork

25. Can *T. solium* cysticercosis in pigs be treated?

(1) Yes
(2) No
(3) Don't know

26. If the answer to question 25 is yes mention the drugs which can be used (More than one answer is possible)

(1) Mebendazole
(2) Oxfendazole
(3) Don't know
(4) Others………………………

27. Human can also get *T. solium* cysticercosis?

(1) Yes
(2) No
(3) Don't know

28. If the answer for question 27 is yes how (Explain)....................

Attitudes

In the next few questions please tell us about the attitudes of pig farmers towards knowledge, practices and prevention/control of *T. solium* cysticercosis in pigs and human.

29. I am aware that *T. solium* cysticercosis is a zoonotic disease

(1) Agree
(2) Disagree
(3) Not sure

30. *Taenia solium* causes great losses to pig farmers
(1) Agree
(2) Disagree
(3) Not sure

31. I know that pork infected with *T. solium* should be rejected
(1) Agree
(2) Disagree
(3) Not sure

32. I must buy/sell pork which has been slaughtered and inspected by the Veterinary officials
(1) Agree
(2) Disagree
(3) Not sure

33. Poor hygiene resulting in the contamination of the environment with human faeces put pigs and human at risks of acquiring *T. solium* cysticercosis
(1) Agree
(2) Disagree
(3) Not sure

34. I would report to a veterinarian/livestock extension officer if *T. solium* cysticercosis was found in your pig.
(1) Agree
(2) Disagree
(3) Not sure

35. I would condemn pork infected with *T. solium* cysts.
(1) Agree
(2) Disagree
(3) Not sure

36. Using toilets/latrines and closing the toilet/latrine's door prevents pigs from accessing human faeces
(1) Agree
(2) Disagree
(3) Not sure

PRACTICES

37. How do you normally rear pigs during daytime?
    (1) Keep in pig pen (indoor) all the time
    (2) Keep in pig pen (indoor) sometimes
    (3) Free roaming all the time
    (4) Tethering
    (5) Others, list………………………
38. If you do not keep indoors all the time, explain why? …………
39. Which feed type did you feed your pigs (more than one answer is possible)
    (1) Grasses and vegetables
    (2) Food leftover
    (3) Maize corn
    (4) Rice puddles
    (5) Others ……
40. Do you wash your hands before preparing pigs feed?
    (1) Yes
    (2) Sometimes
    (3) Never
41. If the answer for question 40 above is yes, do you use soap?
    (1) Yes
    (2) Sometimes
    (3) Never
42. Are there any disadvantages of free-range pig management?
    (1) Yes
    (2) No
    (3) Don't know
43. If the answer to question 42 is yes, mention them (More than one answer is possible)
    (1) Pigs may contract African swine fever
    (2) Pigs may acquire *T. solium* cysticercosis
    (3) Pigs may acquire Mange
    (4) May lead to quarrels with neighbours
    (5) Others ....
44. How frequently you deworm your pigs?
    A. Once after every three months
    B. Every six months
    C. Once per year

D. (4) others
E. Not deworming

45. Which drug is commonly used to deworm your pigs?
a. Albendazole
b. Oxfendazole
c. Praziquantel
d. Ivermectin
e. Don’t know

46. Have you ever slaughtered a pig at home?
(1) Yes
(2) No

47. If yes, the pig was inspected before selling the pork?
(1) Yes
(2) No

48. If yes who inspected the meat?
(1) Village/ward livestock extension officer
(2) Veterinarian officer
(3) Village/ward health extension officer
(4) Village/ward agriculture extension officer

49. If the meat was not inspected what were the reasons? (More than one answer is possible)
(1) Lack of transport for the inspector
(2) High inspection cost
(3) Limited number of meat inspectors
(4) Poor infrastructure
(5) No need to inspect meat
(6) Others

50. Have you ever sent your pigs to a slaughter slab?
(1) Yes
(2) No

51. If yes, was meat inspected after slaughter?
(1) Yes
(2) No

52. If the answer to question 51 is yes, who inspected the meat?
(1) Veterinarian officer
(2) Village/ward livestock extension officer
(3) Village heath extension officer

(4) Village/ward agriculture extension officer
(5) Others (Mention) ……….

53. If the answer of question 51 is yes, is water available at the slaughter slab?
(1) Yes
(2) No

54. If the answer for question 51 is yes, are there toilet services?
(1) Yes
(2) No

55. Where do you obtain water for family and livestock consumption?
(1) River
(2) Well (bore hole)
(3) Tap
(4) Others

56. How do you treat water before drinking?
1) Boil
2) Filter
3) No treatment
4) Others (mention)…………………………………………

57. Where does your family usually defecate? (Choose one answer)
(1) Home latrine
(2) Public latrine
(3) Field
(4) River
(5) Another place: ………

58. Where do your friends/neighbours/visitors usually defecate? (Choose one answer)
(1) Home latrine
(2) Public latrine
(3) Field
(4) River
(5) Another place: ………………………………………………

59. Where did you keep children's faeces?
(1) Home toilet
(2) Field
(3) In the soil

(4) In the river
(5) Other mention

60. Is there any member of your family who does not use the toilet?
(1) Yes
(2) No

61. If the answer to question 65 is yes, explain why ....

62. Do yourself and family members get dewormed?
(1) Yes
(2) No

63. How frequently your family get dewormed?
(1) At three months interval
(2) At six months interval
(3) Once per year
(4) Others

64. Which drug is commonly used for deworming yourself and family members?
(1) Albendazole
(2) Praziquantel
(3) Ivermectin
(4) Don't know

65. Do you have a vegetable garden at your home land?
(1) Yes
(2) No

66. If yes, which manure, do you use?
(1) Inorganic fertilizers
(2) Animal manure
(3) Human faeces
(4) Composite manure
(5) Others

67. Do you receive any education on control of *T. solium* cysticercosis transmission?
I. Yes
II. No

68. If question 67 is yes, mention the title of the training…………

69. Do you think *T. solium* cysticercosis transmission in pigs/human can be prevented in your community?
    (1) Yes
    (2) No
    (3) Don't know
70. If the answer for question 69 is yes, explain how……………
71. Would you prefer to get health education on the control of *T. solium* porcine cysticercosis?
    (1) Yes
    (2) No
72. How would you like (prefer) to learn about *T. solium*/cysticercosis? (Choose one answer)
    (1) By reading a book
    (2) Through education session
    (3) By watching TV
    (4) through village meeting
    (5) Other (specify): ……………………………………

Do you have any comment about *T. solium* cysticercosis? ....

THANK YOU FOR COMPLETING THE QUESTIONNAIRE!

Appendix 2: Household's observation form

To be filled in by research team:

Date ____________________Interviewer

____

District _____________ Ward………………. Village

____________ sub village…………………….

Household Identification number………

Household latrine Infrastructure

1. Is the household own family latrine?
   A) Yes
   B) No
2. What is the latrine floor made of?
   a. Dirt floor/mud
   b. Cement
   c. Other: …………………………………………….
3. Is the latrine wall complete?
   i. Yes
   ii. No
4. Is the latrine had roof?
   i. Yes
   ii. No
5. Is the latrine roof complete?
   i. Yes
   ii. No

6. Human faeces found in floor and around the latrine?
   (1) Yes
   (2) No
7. Children practiced open defecation
   i. Seen
   ii. Not seen

7. B If seen where do family members deposit the faeces?

a) In the latrine
b) Outside latrine

8. Hand washing facilities:
(a) Observed less than 5m from latrine
(b) Observed above 5m from latrine c) not present

9. Soap and water for washing hands are available?
   a. Yes
   b. 2) No

10. Type of latrine:
1) Flush latrine
(2) Pit latrine

11. How many latrines are there?
   a. One
   b. two
   c. More than two

12. Overall impression of latrine:
   1. Good
   2. Average
   3. Poor

Pig management

13. How do you normally rear pigs during daytime?
   (1) Keep in pigpen (indoor)
   (2) Free roaming
   (3) Tethering
   (4) Others, list………………

14. What is the pigpen floor made of?
   (1) Dirt floor/mud
   (2) Wood
   (3) Cement
   (4) Tiles
   (5) Other (specify)…………………………………………

15. Is the pig pen wall complete?
   (1) Yes
   (2) No

15. B What material are the pigpen walls made of?

(1) Clay bricks
(2) Block

16. Is the pig pen had roof?
(1) Yes
(2) No

16. B What material is the pigpen roof made of?
(1) Clay bricks
(2) Block
(3) Wood
(4) Thatched reeds
(5) Other: ……………………………………….

17. Is the pig pen having feeders?
i. Yes
ii. No

18. Is the pig pen having drinkers?
1) Yes
2) No

19. Overall impression of pigpen
I. Good
II. Average
III. Poor

20. Is the family having vegetable garden?
i. Yes
ii. No

21. If yes which vegetable do the family planted?

Pigs' details

22. No of pigs in a herd
23. The sex of the sampled pigs
24. Age of the sampled pigs

……………………………………

Thank you for your observations!

Appendix 3: Booklet (practical guide) with illustrations

1.0 INTRODUCTION

Pigs play a significant role, especially in small-scale enterprises where they contribute to securing the livelihoods of rural and urban communities. The pork tapeworm, *Taenia solium* has been an obstacle in pig production in many developing countries for many years, resulting in considerable economic and health burdens. This parasite is transmitted from a pig to a human through the consumption of infected pork, leading to an intestinal worm infection (taeniasis). *Taenia solium* can also be transmitted from a human to a pig or accidentally to a human through ingestion of feed or water contaminated with human faeces that may contain the microscopic *Taenia solium* eggs. Infection in this way is known as cysticercosis and occurs in tissues and the brain. Neurocysticercosis (NCC) manifested by epileptic seizures is the most dangerous form of *Taenia solium* infection in humans while cysticercosis in pigs results in considerable economic losses due to pork condemnation. Based on previous studies conducted in Tanzania, it is estimated that in 2012 Tanzania spent around 5 million USD to manage human epilepsy caused by *Taenia solium* and lost nearly 3 million USD due to condemnation of pork infected with *Taenia solium* (Trevisan *et al*., 2017).

Prevalence and transmission of *Taenia solium* cysticercosis and taeniasis can largely be reduced and ultimately eliminated when local communities are equipped with the necessary knowledge and tools to enable them to implement control measures. Most of these measures are basic but have a greater impact on the control of the diseases.

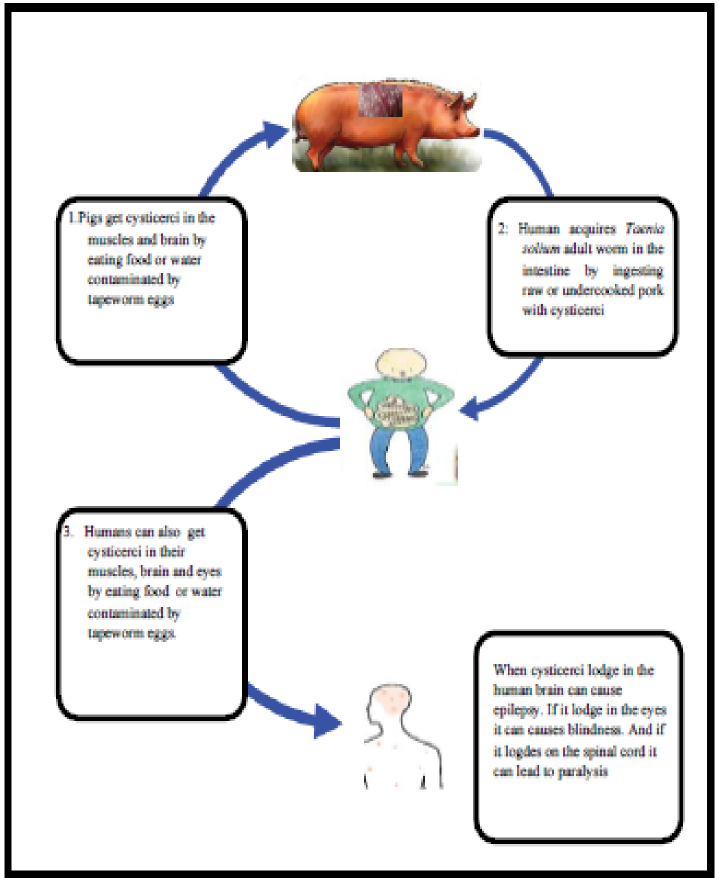
A comprehensive sociological study conducted in Tanzania in 2018 identified the following risk factors for TSCT: (i) Drinking unsafe water and poor personal hygiene, (ii) Absence or poor conditions of latrine/toilets, (iii) Limited use of latrine/toilets, (iv) Not washing hands with water and soap after visiting latrine and before eating, (v) Not washing fruit and vegetables before eating, (vi) Insufficient cooking of pork, (vii) Allowing pigs to roam, (viii) Home slaughter of pigs without professional meat inspection, (ix) Selling or consumption of infected pork/pigs, and (x) Not attending hospitals when sick.

The obtained risk factors led to the development of several toolkits to guide local communities and households to implement Water, Sanitation, and Hygiene (WASH) as well as pig management measures for prevention and control of TSCT in their areas. This TSCT community implementation toolbox is targeted at local community trainers and households.

GUIDE 1

Understand the life cycle of tape worm (*Taenia solium)*

Taenia solium life cycle involves both humans and pigs. Read the following diagram from the first to the last step for more details.



GUIDE 2

Different types of toilets and importance of using and maintenance

There are three main types of latrines; (1) pit latrines, (2) ventilated improved pit latrines (VIPs) and (3) pour-flush latrines (URT, 2016). For schools and households in areas where no or insufficient water for flushing is available close to the latrine or where poor facilities are used for cleaning, the VIP latrine is the most suitable. If sufficient amount of water is available close to the latrine and the facilities are expected to be well maintained, a pour-flush latrine may be considered. Although these three latrine types are recommended, there is a range of options available for schools and households, and any latrine is better than no latrine.

a) Pit latrines

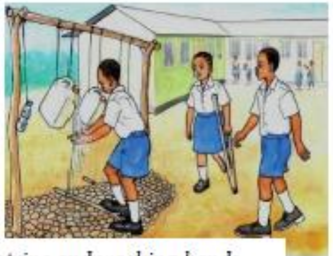
(b). Pour latrines

(c) Improved Pit Latrine for schools (no vent pipe)

(d) VIP latrines

The most important things to consider in any type of toilet are the following:

- The toilet should have solid walls, a roof and a door that should be closed
- The toilet should be cleaned regularly to keep it safe for the user
- The toilet should be used by everyone who needs the service. Avoid helping yourself in the field or in the bush
- It is important to wash your hands with clean running water and soap immediately after leaving the toilet



People should always use sanitary latrine and washing hands with soap after visiting latrines.

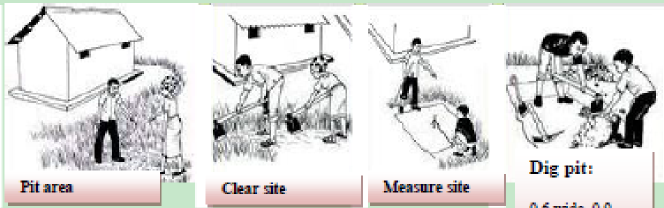
Source: URT (2016).

GUIDE 3

How to build a traditional toilet in a stable soil

Read the following diagram from the first to the last steps to learn how to build a traditional toilet in a stable soil

1. Dig pit



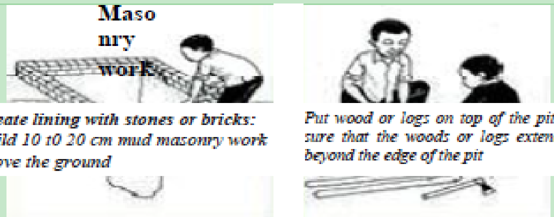
Dig pit:

0.6 wide, 0.9 long and 5m deep

The pit should be dug:

- At least 10 metres away from kitchen or homestead
- 30 metres from water sources
- In the back of the dwelling house for privacy purposes

2 Sitting the latrine



Maso nry work

Create lining with stones or bricks: Build 10 to 20 cm mud masonry work above the ground

Put wood or logs on top of the pit an make sure that the woods or logs extends 50 cm beyond the edge of the pit

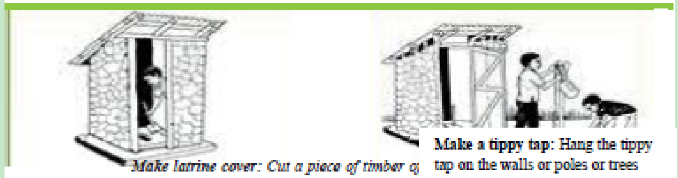
3. Make a pit cover, a squatting hole and

Put mud on the pit: *Cover the woods or log with mud, leaving squatt hole of about 12.5 cm wide and to 25 cm long.*

If possible install a Sanplat toile to make it easy to clean and look modern.

Superstructure: *Then construct a superstructure with a roof using locally available materials and plaster the wall with mud or cowdung*

4. Make a latrine cover and hand washing station



Make latrine cover: *Cut a piece of timber of of 17 cm wide and 30 cm long and in it is centre fix a stick of about 30 cm long with a nail*

Make a tippy tap: Hang the tippy tap on the walls or poles or trees

Source: (USAID/WASHplus Project 2014)

4

GUIDE

How to build a shallow but hygienic latrine in rocky and sandy soils

Read the following diagram from the first to the last steps to learn how to build a shallow toilet that is hygienic on rocky and sandy soils

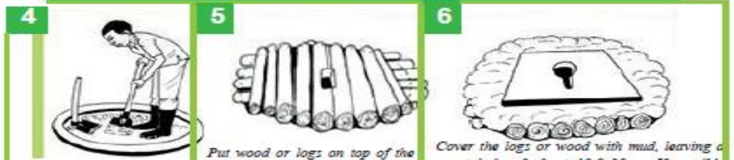
1 Identify site for the toilet

2 Clear the site

3 Demarcate the area for the pit

The pit should be dug:

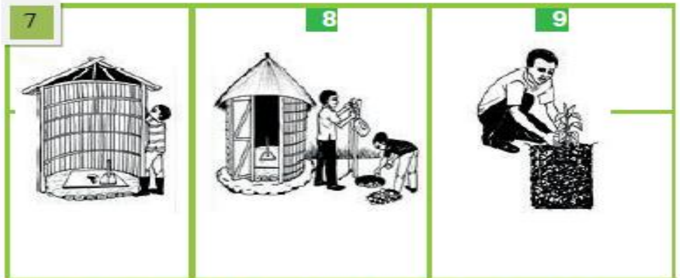
- At least 10 metres away from kitchen or homestead
- 30 metres from water sources
- In the back of the dwelling house for privacy purposes



4 *Dig pit of about 1 metre or less deep*

5 *Put wood or logs on top of the pit and make sure that the woods or logs extends 50 cm beyond the edge of the pit*

6 *Cover the logs or wood with mud, leaving a squat hole of about 12.5x25cm. If possible install a SanPlat to make the toilet easy to clean*



7 *Construct temporary superstructure using bamboo*

8 *Fix a hand washing facility (tippy tap) with soap or ash. Pour ash in latrine weekly to reduce bad smell*

9 *When the latrine is full, dig another pit nearby and transfer the superstructure and slab to the new pit. Cover the old pit with soil plant*

Benefit of composted pit waste

After one year (no less), the content may be removed and the composted manure applied to a garden

Source: (USAID/WASH plus, 2014)

GUIDE 5

Procedure for washing hands

1 Wet your hands with free flowing water and lather them with soap (or ash)

Rub your hands together and clean under your nails

2

Rinse your hands with a free flowing water

3

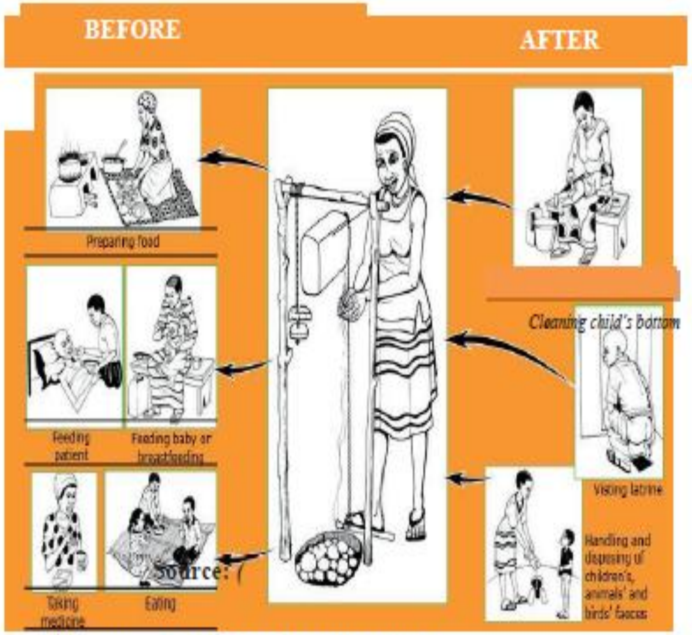
4

Shake excess water off your hands and air dry

GUIDE 6

Critical times to wash hands

Read the following diagram to find out the most important times you should wash your hands



Source: (USAID/WASHplus Project 2014)

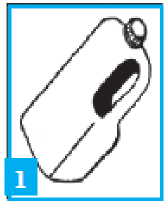
Guide 7

How to make a tilting jerry can tippy tap

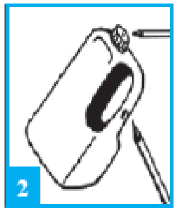
Tippy tap is an important tool for accessing running water in an environment without piped water. There are several types of tippy taps, depending on the type of container. The tool can be made using a different tippy taps are plastic containers, plastic water bottles, plastic buckets and so on. Here we will see how to make a tippy tap with a plastic jar.

Materials needed:

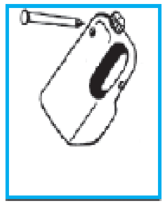
- A small jerry can with a lid (3-5 litres)
- 2 pieces of heavy string (60 cm) for hanging jerry can and (100cm) for the pedestal.
  - A thin string (60 cm) for hanging soap.
  - Three poles, 1 suspension pole (80 cm), two standing poles preferably "Y" (150 cm).
    - A mineral water bottle for keeping soap.



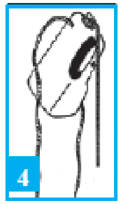
Get a clean jerry can



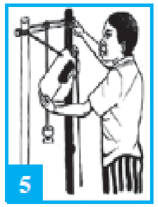
Using a nail punch a hole on the lid For the pedestal string and at the jerry can handle for the dripping water



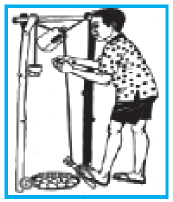
Puch a hole for hanging a string through the other side of a jerry can



Place the handing string through the nails nose and another string around the lid to attach the pedestal



Hang the jerry on two fixed poles cut the bottom off a mineral water bottle to use as a soap protector. Fix a string on them and hang on pole



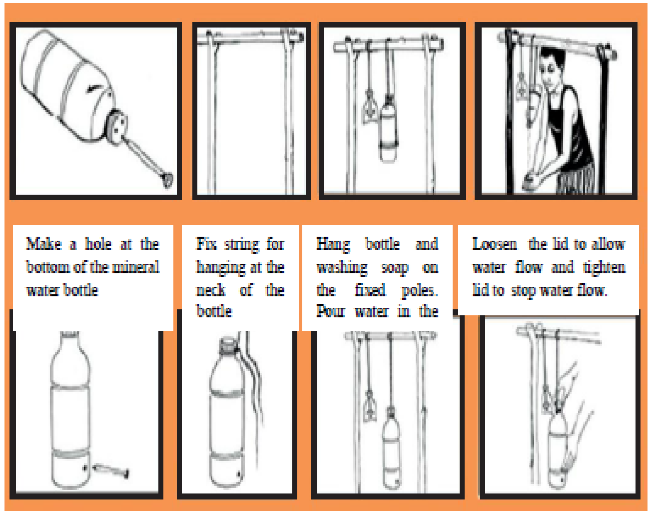
Tie solid stick to string attached to lid, long enough to reach about 10-13 cm from the ground. Step on the pedestal to tip water. Put in place a soak pit by digging a shallow hole (60 cm wide and 30 cm deep)

Source: (USAID/WASH plus, 2014)

GUIDE 8

How to make other types of tippy taps

Follow the following example to understand how to make a bottle tippy tap



Punch a few holes on the mineral water bottle lid and one on the bottle to allow in air

Fix poles.

Hang bottle and washing soap on the fixed poles. Pour water in the bottle

Use your elbow to tip the bottle facing down to allow water to flow

Source: (USAID/WASHplus Project 2014)

GUIDE 9

Water safety chain

The clean water system should be maintained based on the following factors;

- Water sources should be elevated to reduce the risk of contamination
- Water source should be fenced off to prevent humans and animals from contaminating water
- Other areas in the entire water system should be fully maintained
- Wash hands with clean water before fetching water anywhere in the water system
- Make sure the water pump is clean and safe

GUIDE 10

Small doable actions (SDA) for WASH

PROBLEM	SMALL DOABLE ACTIONS
Latrines and Faeces Disposal	
• No resources to build a latrine	• Dig a shallow pit latrine with help of community led total sanitation Committee (CLTS)
Latrine privacy • Has no door • Straw wall has gaps • Latrine doors are hanging/ broken hinges	• Hang a cloth as curtain • Patch the door so it's solid • Fix it! Often it will just take a few nails, screws, etc. for simple fixes
• Latrine smells • Flies in latrine	• Look for options to increase ventilation without losing privacy • Cover pit with "home fashioned" lid • Put bucket of ash in latrine and have users throw a handful in after every use (ash on hands is a good hand washing agent for after defecation)
• No separate latrines for girls and boys • No girl-friendly latrines	• Clearly dedicate at least half of latrines for girls •Make signs "Girls Only" and "Boys Only" to mark •Separate hand washing facilities based on gender and if possible add a mirror In a girls latrine.
• **Hand Washing**	
• No fixed hand washing facility	•Make and hang tippy tap outside of latrine
•No soap	•Buy soap and place at a handwashing facility •Make liquid soap •Use ash if soap is not accessible
•No easy access to water	•Make a tippy tap to minimize amount of water used in hand washing

Water Safety and Storage	
•Water stored in open container without lid	• Close container with cap • Devise a convenient cover for bucket
•Dirty cups used to get water out of storage container	•Make a dipper from a calabash or tin can and stick for extracting water from bucket or other receptacle •Hang dipper off ground
•Water from unprotected spring, shallow well, or other unsafe source	• Filter water to remove dirt and then treat water by boiling, solar disinfecting or chlorinating
Food Safety & Storage	
• No handwashing facility near cooking/eating area	• Hang tippy tap by cooking/eating area
• Food stored in open containers • Flies near stored food	• Devise simple covers for food storage
• No dedicated food preparation area • Food preparation area on the ground • Food preparation area not washed daily	• Create small, raised separate space for food preparation • Keep soap and water nearby to wash food preparation area daily
• Raw foods not cleaned before consumption	• Ensure easy access to clean water to rinse fruits and vegetables eaten raw

GUIDE 11

Taking care of drinking and cooking water

1. TRANSPORT

Carry your water home in a container with a lid

2. SERVING

Serve the water without letting anything dirty (such as your hands or a cup) touch it

3. STORAGE

Store water in a container with tight-fighting lid

Source: (USAID/WASH plus, 2014)

GUIDE 12

Cleaning water storage containers

Wash the containers using water, soap or ash.Small stones, sands or steel wire must not be used because they scratch the container leaving the breeding places for germs. Rugs, glass or any other material should not be used to clean drinking water containers, they can add germs that lead to contamination.

Washing water containers

Put small amount of soapy water or ash in the container, shake the container and pour out the water. Small stones, sands or steel wire must not be used because they scratch the container leaving the breeding places for germs.

2. Rinse the containers with clean water until there is no dirt, soapy water or ash

3. Use a rug to scrub the outside of the container with soap and water. Thereafter rinse them again with clean water

4. Finally, hang the containers, preferably on a rack to allow them to dry

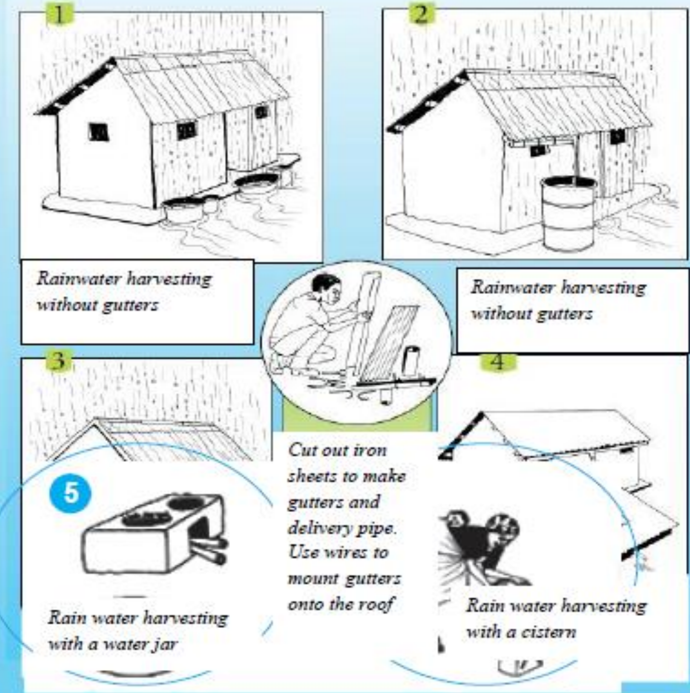
5. Cover the containers tightly and keep them away from dirty

GUIDE 14

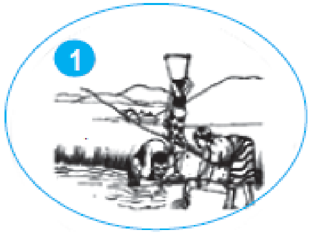
How to boil and store water for drinking

GUIDE 13

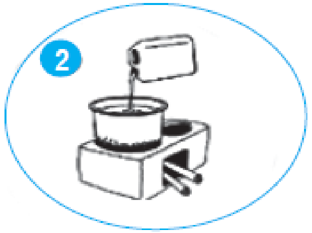
Alternative water sources



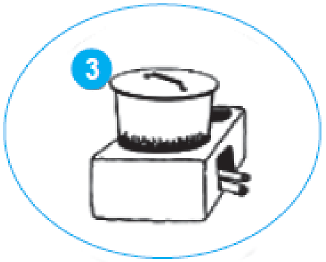
Follow the following step-by-step guide. If the water contains visible dirty or dust, first filter the water with a clean white cloth before proceeding with water treatment.



Collect water from water source



Pour water into boiling container.



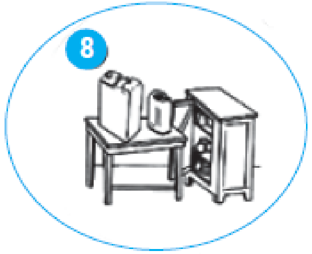
Cover the water boiling container

Boil the water until large bubbles appear.

Remove from fire and allow to cool. Do not remove lid to avoid contamination

Do not use the serving cup for drinking

Store boiled drinking water in containers



Store drinking water in tightly covered containers, in a clean environment on a stool or table and away from children and animals

Source: (USAID/WASH plus , 2014)

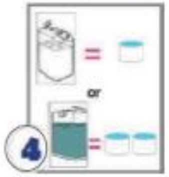
GUIDE 15

How to sanitize water for drinking using liquid chlorine (WaterGuard)

Filter a clean 20 litre jerry can with water filtered through a clean

Fill the bottle cap with WaterGuard.

Pour the capful into the 20 litres of water.



For clear water use 1 capful. For dirty water use 2 capfuls

Close the jerry can and shake

Wait 30 minutes before using.

The water is now ready to drink

GUIDE 16

How to sanitize water for drinking using chlorine (WaterGuard) in tablet form

For clean water add 1 tablet in a 20 litre jerry can (filter the water through a clean cotton cloth if dirty). Wait 30 minutes before using.

If the water looks dirty, filter through a clean cotton cloth and add 2 tablet to 20 litres of filtered water. Wait 30 minutes before using.

Remember: *Do not swallow tablets and store them away from children and sunlight. Water treated with WaterGuard that is stored in a narrow neck container with a tight fitting lid can be drunk for up to seven days. Treated water stored in a wide mouth container or without a tight fitting lid can be drunk for only 24 hours.*

Source: (USAID/WASHplus Project 2014)

GUIDE 17

How to sanitize water for drinking using solar

1. Use clean, transparent plastic bottles that hold no more than 2.5 litres

2. Fill the bottles with clear water and screw the lid on tightly

3. Lay the bottles out in the sunlight. If it is sunny, leave the bottles for 6 hours

4. If it is cloudy, leave the bottles for 2 days

5. Before drinking the water, let it cool in the same bottle

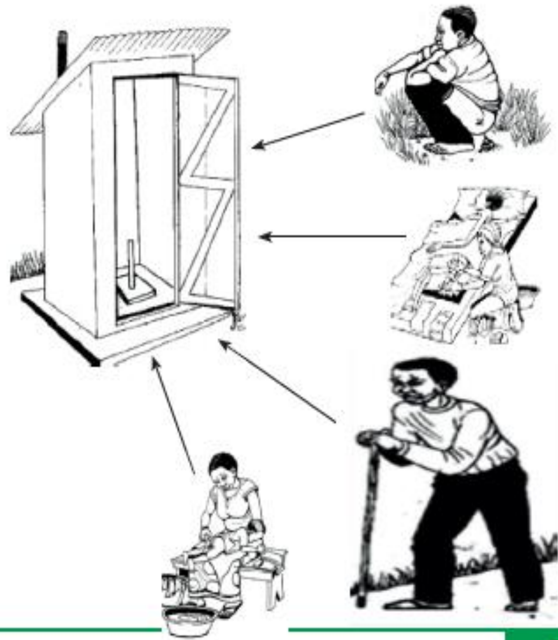
6. Store the water in the same bottle. Do not change containers

7. DO NOT use SODIS when there is a continuous rain. Use another methods such as boiling or chlorination (WaterGuard)

GUIDE 18

The correct way to dispose of human beings

Put faeces of sick people, adult, children, babies and other disabled people in a latrine.



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GUIDE

Different models of pig pen

Source: *FAO, 2009*

26

20

GUIDE

Elements of a good pig housing

Source: FAO, 2009

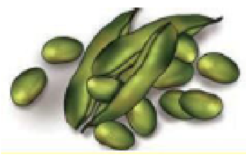
27

21

GUIDE

Locally available pig feeds

	**Rice Bran:** is very suitable for pig feeding. It contains 11% protein and can be used as the main ingredient. Rice bran can be mixed with other feeds to 30 - 45%. Rice bran can be kept no longer than 1 month because it can become mouldy.
	**Broken Rice:** is very suitable for pig feeding. It can be mixed with other feeds up to 15 - 20%. Broken rice contains about 8% protein.

	**Maize:** is a very good animal feed. It contains up to 65% carbohydrates and 9% protein. It can be mixed and cooked with other feeds, but not more than 40% in the mix ration. Wheat, millet, and other cereals locally available can as well be used
	**Soybeans and Green Soya bean plant:** is a crop that has a high nutritional value and is very good for pig feeding. It contains 38% protein (=very high). It should be dried, milled, or well-cooked in combination with other feedstuff like rice bran, broken rice, and maize.
	**Leucaena and Acacia:** are traditional, locally available tree crops. The leaves are rich in protein. After drying, they can be mixed and fed to pigs with other feeds.

	**Root Crops:** are being used for pig feeding, they can be mixed with other feeds up to around 10 - 20% (never more than 30%). First, it should be peeled and washed and then sliced, dried, and ground before use. It should not be fed to pigs as raw cassava with the skin, because of toxic substances. The sliced and dried cassava can be kept longer.

 	**Fruits and vegetables:** Fruits and vegetables damaged during transportation, storage, and handling or from food waste are used as supplementary feeds for pigs by boiling and mixing with other feeds such as rice bran, broken rice, and maize. They can also be given fresh. Suitable fruits are: Bananas, papaya, apple, watermelons, etc. While suitable vegetables are; cabbage, lettuce, spinach, morning glory, sweet potato vine, cola-cassia (needs boiling), pumpkin, guards, water hyacinth etc
	**Restaurant/Kitchen waste:** needs to be properly screened and cooking
	**Slaughter house offal;** needs to be properly screen and cooking

	**Sweet potato/yam vine and tubers** such as potato, yam, sweet potato, etc can be used as pig feed
	**Banana Stem:** The best way of feeding fresh green banana or plantain fruits is to chop them and sprinkle some salt on the slices since the fruits are very low in in-organic nutrients. Cattle and pigs relish this material. For ensiling purposes, chopped green bananas or plantains are preferred to ripe fruits which lose some of their dry matter and, in particular sugars during ensiling. Similarly, green fruits are more easily dried than ripe fruits which are very difficult to completely dehydrate.

	**Pumpkin:** Pumpkin is a good source of the vitamin B group, while a large proportion of these vitamins is lost during the preparation of the protein concentrate and isolates.
	**Alfalfa:** Low in fiber, palatable to consume for the animal, and easily digestible, it is the best nutritional package you can put into the rations feeding your livestock, dairy cattle, poultry, or pig. Contains a blend of 47 nutritional elements one of nature's most liberal balances of vitamins, minerals, and amino acids.

Source: (FAO, 2009)

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GUIDE 22

PIG SLAUGHTER HOUSE

This is a simple example of a pig slaughterhouse that can be used in villages. However, pig abattoirs should have basic requirements including:

- A strong fence to prevent uninvolved humans or animals from entering the abattoir and causing damage or spreading disease
- Clean water and sewage system to enable sanitation to be done smoothly and easily
- Waste disposal pit to destroy (burn) all wastes and condemned pork not suitable for human consumption
- Toilet for human use
- Clean and running water
- Adequate light because most slaughter takes place at night. So adequate light is especially important in meat inspections.

Picture 1: Pig slaughter house at Mkumbi village, Mbinga district (Photo: C. Mkono, 2019)

GUIDE 23

THE BEST PIG FARMING PRACTICES

1. INTRODUCTION

Pig husbandry is one of the fastest-growing activities in East and Southern Africa. Urban growth and population growth have been accompanied by a sharp increase in demand for animal protein. The ability to grow fast, healthy meat quality, and good taste provides a great opportunity for the development of pig farming as a source of income for the breeder. This document provides guides on important pig farming needs, techniques to improve productivity, and disease control as well as guidance on caring for pig rights as a living organism that can suffer pain if not treated properly. Pigs have low maintenance costs, provide fat/oil, generate income, and provide manure. The benefits of raising pigs depend more on the quality of care. Also, remember to use affordable food sources and build infrastructure. The reader is advised to consult a specialist for further advice and also to read reference books on pig farming.

2. THE TRUTH ABOUT PIG

Pigs are very clean and intelligent animals. Given a pig pen with enough space, she can choose a place to sleep, help herself, and keep her body in a very clean condition. Sanitation and environment will ensure that pigs are clean and clean surroundings as we see for many urban and rural pig keepers. Set aside special clothing and footwear for pig work and always take a good shower after working in the pigpen for a long time.

1. PIG HOUSE

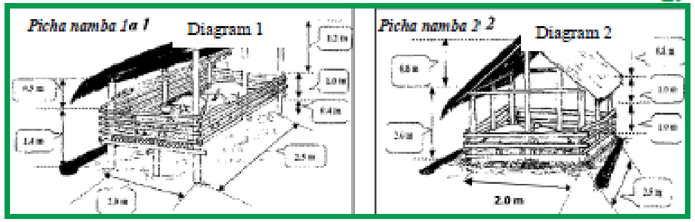
There are generally two types of houses needed in pig farming

- Pig fattening houses for slaughter
- Pig parents' houses

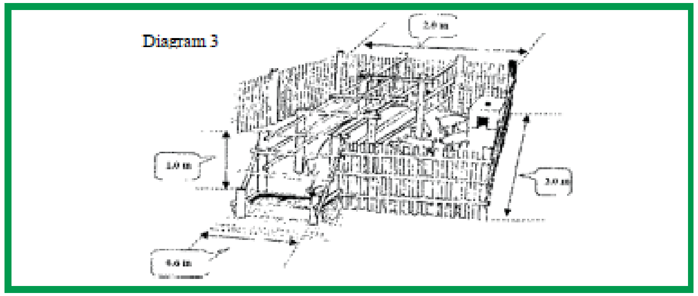
Basic features of a good pig house: -

- The house should be built in an area with adequate shade
- The house should have enough space
- Build a steep slope to allow water to drain easily
- Have feeders and drinkers
- Have a solid floor made of concrete, and wood that is moisture-resistant. The concrete floor should have a slope that can easily remove dirt inside the pavilion.
- A wooden or timber off-cut floor should provide an opportunity to remove dirt such as faeces from the pigpen.
- Have a drainage ditch, to remove water, urine, and faeces up to the storage pit
- The walls of the pig pens should be strong, able to keep pigs from getting out.
- It needs to be well ventilated inside the pigpen especially if the walls are closed (solid walls)
- The roof can be made from grass, palm fronds, or corrugated iron as shown below

1.



Pens for four pigs aged four to five months. Dimensions of the pigpen: 2 x 2.5m Observe the dimensions shown to allow air to pass through and give the pigs enough space.



2. WHERE TO FIND PIGS FOR REARING

Buy pigs from farms or trusted breeders based on the following.

- Do not breed pigs from the same family, ie brothers and sisters.
- Buy male and female from different places.
- Use expert advice to choose the best pig

Features to look for the best breeding boars:

- Breeding boars should be characterized by rapid growth and should not have any defects of any kind, especially in the legs.
- The sow should have a history of giving birth to 10 to 12 piglets per offspring.
- The sow should have more than 12 nipples.
- The breeding boar should have male genitals i.e. testicles and penis that look straight. He should also be interested in mating.

2. PRODUCTION TECHNIQUES

Taking care of a breeding boar

- Choose a breeding boar that is good, and free from any defect or disease. Separate the males and females to avoid unplanned mating. The pig should not be fat, so do not feed him too much and give him enough exercise so that he does not become lazy.
- Boars start mating sows at the age of 4 months to 9 months. Breeding boars should be allowed to mate only once a week. By the time he is 10 months old, he can mate two to three times a week. At one year of age and older he can mate every day for two to three weeks, then the rest for two weeks. One breeding boar should mate 15 to 20 sows per year.

The small size boar should mate with a small

size sow.

If a large boar mate with a small sow, he may cause her back injury.

The boar need to mate before eating, and not to use it immediately after a meal so that he does not become lazy.

Caring for a pregnant pig

- Pig pregnancy lasts three (3) months three (3) weeks and three (3) days i.e. 114 days
- Pregnant pigs should be given enough food to be added slowly from the normal allowance to 3 - 3.5 kg per day.

Pre-delivery home preparation

- Clean the breeding pigpen with water and let it dry
- Apply dry grass immediately after the house has dried
- Use a lantern lamp or electric lights if you are in cold regions in the piglets section.
- Make a breeding ground using wood or pipes (See picture number 3)

Preparing the sow before giving birth

- Give deworming 10 days before delivery
- Wash them with hand soap and brush
- Keep her in the delivery pen 7 days before giving birth
- Limit nutrition 2 days before delivery
- Only on the day of birth gives the pig drinking water

Pig care

Piglets suck the mother's milk regularly until they are 56 days old. The key things for piglets are listed in Table 1 below:

Table 1: Important things to do for piglets

DAY	SOMETHING TO DO
1	Cut a long umbilical cord with a new razor or boiled scissors and spray Iodine. Cut the sharp upper and bottom teeth. Give the mother pig a little food like half a kilogram
3	Piglets should be given an iron injection. Give them clean drinking water
5	Add the sow's food up to two and a half kilograms
10	Mark the piglets, make sure the pigpen is clean, and give the sow six (6) kilograms of food

Sow mating

- Between four and seven days after weaning, sows enters heat period. The sow that is on heat should be taken to the breeding boar and not vice versa. Repeat mating 12 hours after the first mating; then repeat mating 2 to 4 times. If the sow does not enter a heat period after 3 weeks she will be pregnant.

Signs of heat

- The genital area will change to red
- Pigs do not rest and urinate frequently
- Mucus comes out of the genitals
- A sow on heat tries to mate her mates and when a boar tries to mate she usually calms down

2. CARE OF A NEWBORN PIGLETS.

Feeding the first milk

After birth and being cleaned, make sure piglets are breastfed, the umbilical cord should be treated with (Iodine 5%) to prevent infections. If the mother dies immediately after giving birth and no other pig can have breastfed the piglets; use cow's milk, add sugar and raw egg stir, and breastfeed using a bottle baby milk.

Heat

Piglets are not born with feathers and do not have enough fat to keep them warm; so it is easy to die of cold. Use a steam or lantern lamp to increase the temperature.

Prevent anemia

Pig milk has a deficiency of iron-rich supplements. So after two or three weeks, the babies begin to weaken due to the lack of these nutrients in the body. To eliminate this problem babies need to be injected with a mineral solution into the muscles two or three days after birth. If the injection is not available, other ways to give the baby these nutrients are by giving them iron tablets, or by giving them the minerals in their tongues or their mother's nipples two to three days after birth.

Cutting teeth

A few days before birth, sharp teeth like needles protrude into two jaws. These teeth hurt the sow when the piglets are suckling; as a result, the sow kicks the piglets. This leads to infant mortality from being kicked and lack of early milk. So the sharp teeth need to be removed with a pair of scissors (See Picture 4), to reduce the effects. Consult a veterinarian for more information.

Picture 4: Pork Producers Association of Kenya

Feeding extra food

The supplementary food should be fed slowly from the tenth day after birth, as at this time breast milk is not enough. Keep giving them this food until they get used to not drinking their mother's milk again. These foods contain nutrients to build the body, strengthen and prevent disease. Pigs should be given this food in large quantities and enough water.

Castration

Piglets that are not needed for breeding purposes should be castrated during the third to fourth week. Castrated Pigs are gentle, strong, heavy, and have no male odor. The veterinarian will give you more information on how to do it.

Stopping breastfeeding

- Stop breastfeeding the piglets when they are two months old and when they weigh 10 kg.
- Give the sow enough food

2. FOOD AND FEEDING

Good nutrition for pigs is one of the most important requirements in the whole concept of productive and profitable pig farming. Pig feed costs about fifty to seventy per cent of the total cost of raising pigs. Among the many problems that lead to the poor productivity of pigs is poor nutrition. Pigs provided with good nutrition will have high productivity, and thus increasing the profitability of the pig farmers.

B. Some of the benefits of good nutrition for pigs are:

1. Good nutrition accelerates the rapid growth of pigs and thus gaining the required weight in a short period.
2. Good nutrition reduces pig rearing cost and thus increases the profitability of the pig farmers because pigs will need only a small amount of feed and will take less time to gain weight.
3. Proper nutrition will reduce the risk of infection.
4. Good nutrition increases the number of eggs produced by female pigs and that will increase the number of piglets that will be born
5. Good nutrition increases the levels of milk that will be produced by sows for piglets thus making them healthier which will enable them to grow faster and reduce the number of deaths in piglets.
6. Good nutrition increases the efficiency of breeding boar and thus increases breeding capacity

C. Nutrients important in pig nutrition

Pigs can eat a wide variety of foods that are easily digested. The balanced pig diet needs to be a mixture of five nutrients, which are:

1. Source of energy foods (such as maize, wheat, rice)
2. Body-building foods/protein (such as sunflower seeds, cotton, and seafood)
3. Mineral foods (such as salt, lime, and crushed bones)
4. Natural vitamin foods (like green leafy vegetables, vegetables, and fruits)
5. Water

D. How to make pig feed

When making pig feed you have to consider the following:

- Its mixture should contain the four nutrients mentioned above
- Choose the type of nutrients that are easily available and

affordable in your area

- The type of feed mix is important to take into accounts body

Needs as age (eg suckling, weaned, and growing pigs)

Example; table No. 2 Shows different combinations of pig feeds.

1. *Combination number 1:* recommended for pig farmers in areas where maize and sunflower cakes are readily available
2. *Combination number 2:* for those where maize, rice husks, alcoholic distilling residues and sunflower cake are readily available.
3. *Combination number 3:* for those where rice and maize bran is readily available.

Table 2: Different combinations of pig feeds

No	Type	Combination (per cent)		
		No. 1	No. 2	No. 3
1	**Carbohydrate source**			
	1.Maize bran	70.25	32.00	30.00
	2. Rice bran	-	25.00	33.00
	3. Alcohol distilling residues	-	21.00	-
	4. Sliced maize	-	-	10.00
2	**Protein source**			
	A. Plant protein			
	1.Sunflower seed cake	22.00	14.00	22.00
	2.Palm seed cake	-	-	-
	3.Boiled and sliced soya beans	-	-	-
	B. Animals protein			
	1.Milled sardines/fish	4.00	2.00	3.25
	2. Dried animal blood	0.00	2.25	-
3	**Mineral source**			
	1. Table salt	0.50	0.50	0.50
	2. lime	2.00	2.00	2.00
	3. Minerals and vitamins mix	1.00	1.00	1.00
	4. Milled bones	0.25	0.25	0.25
	TOTAL	**100**	**100**	**100**

E. Amount and how to feed the pig

- Pigs need to be fed this type of feed twice (morning and afternoon) or more per day
- The amount to feed the pigs of different breeds and age a group is shown in Table 3.
- In addition to the mentioned foods, pig farmers are advised to provide pigs with their traditional foods such as extra foods
  like, soft green leaves, pumpkin leaves, vegetables, fruits such as avocados, potato leaves, etc.

Table 3: **Amount to feed pigs of different weight**

No	Time	Pig weight (Kg)	Amount (Kg per day)
1	After weaning up to a moderate weight	10-17	0.75 kg
2	Weight above moderate	18-29	1 kg
3	Normal weight	30-40	1.5 kg
4	Moderate Heavyweight	41-60	2 kg
5	Heavyweight	61-80	2.5 kg
6	Very heavyweight	81-100	3 kg
7	Pig that is breastfeeding her piglets	120-150	6 kg

HOW TO FEED A SOW BEFORE AND AFTER GIVING BIRTH

1. Pregnancy, childbirth, and weaning

1.1 Three months after mating

- She should be given about 2 kg of feed a day
- This amount should continue until 3 weeks before giving birth

1.2 Three weeks before delivery

- Add food up to two and a half kilograms.

1.3 One week before delivery

- Start reducing feed ration, especially cereal foods (Concentrate rations).
- Add vegetables, soft vegetables, and fruits (laxative meals).

1.4 A day of giving birth

- Do not give any cereal food.
- Give vegetables and soft foods only in small amounts
- Give her enough water.

1.5 1 - 2 days after delivery

- Give her half a kilogram of a balanced diet.

1.6 Day 3 onwards

- Add whole grains in the amount of 1 kg per day.
- Increase to the required level depending on the number of piglets the sow has.

Note:

- The sow needs 3 kg of feed for its normal consumption.
- The sow will need an extra one-third (1/3) of a kilogram of feed for each of the piglets she has.

Example: If a sow has 9 piglets, how much food will she need?

Needs for sow only	Needs from the number of piglets	Amount of food per day
3 kg	One third x 9: (1/3 x 9 = 3 kg)	3 kg + 3 kg = 6 kg per day

- Continue to give the same amount of food until one week before weaning.
- One week before weaning, gradually reduce the amount to 3 kg per day.

After weaning

- Sow should be given a good feed with high levels of minerals and vitamins at a rate of 2 - 3 kg per day.
- This will help her to be on heat soon

8. DISEASES AND HEALTH

The following pig diseases are briefly described to give the pig farmers the knowledge to identify, treat/control them. Consult a veterinarian doctor once you notice these symptoms

Symptoms	Disease	Prevention and treatment
High fever, lack of comfortability, and being aggressive to piglets.	Lack of milk	The sow should be treated with antibiotics if developed fever. Professionals should check the nipples to see if they have problems since birth. Check the sharp teeth of piglet to confirm that they were not removed and removed.
Yellow diarrhea to piglets of 3 weeks old	Diarrhea for piglets	Treatment with antibiotics. Clean the pigpen, drinkers/feeders, and the surroundings often to kill germs.
Flu blisters in the nose, mouth, teats, and hoofs.	Foot and mouth disease	The disease has no proper treatment. Clean the wounds to kill virus/germs, vaccination, quarantine, proper cooking of swill, slaughter, and burial.
Sudden death, nasal bleeding, and bleeding from the anus	Anthrax	Consult veterinary officer/livestock extension officer. The meat is not good and should not be consumed.
The pig becomes itchy, and scratches and rubs against the walls of the pigpen and other objects with the skin between the legs, around the eyes, ears and neck being principally affected.	Mange	Ivermectin (1% injectable) to all pigs. Repeat after 2 weeks. also malathion (1% spray) can be used
Lesions on the body, high fever, incoordination of hind limbs, the animal die the next day after the attack. 95 - 100% mortality.	Swine fever	Quarantine, boiling of swill, restriction of movement of meat from infected areas, vaccination Disinfection, no therapy (treatment)

9. CARE, CONTROL, AND BASIC RIGHTS TO HOLD AND LEAD PIGS

Pigs should be held from an early age to help them *get along* well with humans. The pig farmers must learn how to hold, guide, and knock down the pig without causing pain or stress to the animal.

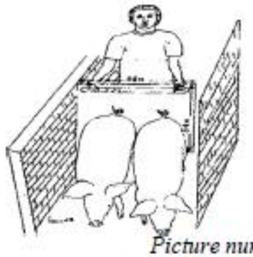
1. Carrying a piglet

Carry the piglets by grabbing the hind legs, lifting them, and placing the other hand under its belly as shown in picture number 5. There you will be able to treat, relocate or even diagnose her if she has a problem.

Picture number 5

2. Leading an adult pig

Getting the pig to go where you want is possible if you provide a pig guide board. The 80-centimeter-wide board and 80-centimeter-long board can be made using an old door or inexpensive wood. Protect the pig with one board on each side on the right and left while leaving a small space to allow him to see the side of the head, do so while pointing him in the direction you want him to go. You can guide the pig to one board (picture number 6) if there is room to protect the pig right and left as shown.



Picture number 6

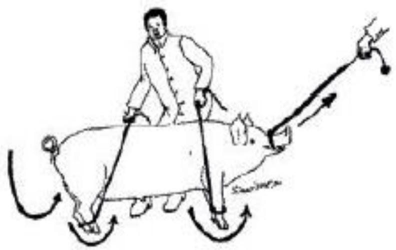
3. Control older pigs

Use a woven hemp rope or pig snare. If a pig is tied with a noose around the upper jaw and pulled forward, he will pull backward as shown in Picture 7. This technique allows you to inspect a pig, inject him, bathe him or even allow you to tie a rope around his legs to knock him down.

Picture number *7*

4. To knock down a pig

To knock down a pig, tie a rope around its mouth as shown above (Figure 8). Then tie the front legs together with one rope, and the back legs tied with another rope. Let one person control the mouth rope iii the pig should not walk, the second person should pull the straps one by one while standing (see picture number 8) on the other side as the rope under the pig's stomach pulls, the pig will fall to the ground. Tie the legs tightly to keep the pig from getting up.



Picture number 8

10. PROTECTING THE RIGHTS OF PIGS

a. Do not beat the pig for any reason
b. Do not put too many pigs in a small pigpen that does not have enough space. They will fight, get upset, and hurt each other.
c. Do not leave the pig in the sun; the pig does not have sweat glands the heat will torment him and even kill him
d. Do not put two boars in the same pigpen especially if they do not know each other; they will fight a lot.
e. Do not transport pigs to a car that does not have enough space and should be transported in the evening and the morning when there is no heat

Do this

a. Give the pigs enough space as recommended in this newsletter.
b. Give them enough food and drinking water
c. If a pig is sick, it should be treated immediately to avoid unnecessary pain
d. Slaughter the pigs according to the procedures prescribed to prevent them from dying a suffering death

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2.2 Brochure

5. Always keep your latrine clean and safe.

6. Always wash your hands with soap and water after visiting latrine and before eating.

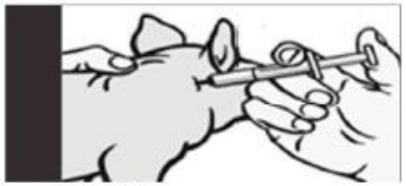
7. Always use treated or boiled drinking water.

4. Pork should always be cooked thoroughly.

4. Fruits and vegetables should be well washed before they are eaten.

9. If you feel sick visit a health facility early.

10. Always seek veterinarian's advice when your pig gets sick.



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PREVENT TAPE WORM (*TAENIA SOLIUM*)

TO IMPROVE YOUR HEALTH AND WELL BEING

cystinet africa — Cysticercosis and Taeniosis Network of Sub-Saharan Africa

Federal Ministry of Education and Research

What is tapeworm (*Taenia solium*)?

•*Taenia solium* is a tapeworm transmitted between humans and pigs
•Humans can be infected by an adult worm in the intestine, a condition named "taeniasis"
•Humans can also be infected by *Taenia solium* larvae in muscles, brain, and some other tissues, a condition named "cysticercosis"
•Pigs can only be infected by cysticercosis

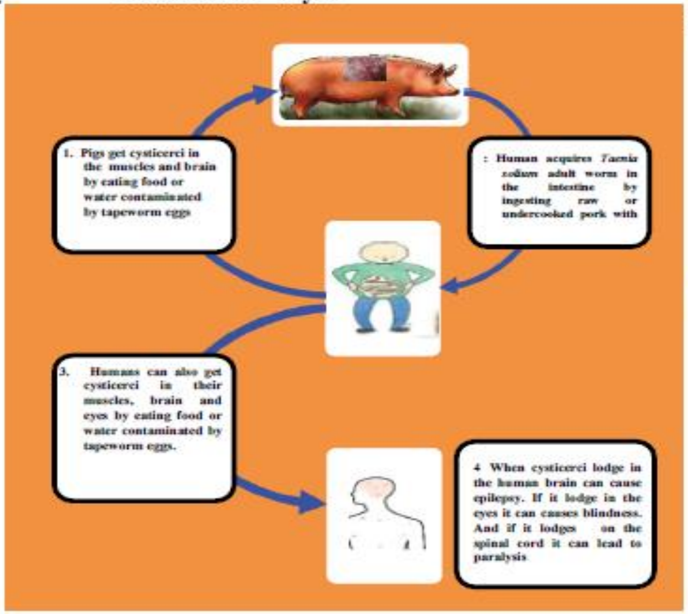
Why is it important to prevent *Taenia solium*?

•Cysticercosis in humans can lead to epilepsy, blindness or other neurological conditions
•Pork infested with *Taenia solium* cysts is unsafe to eat. Thus economic loss

Why is it important to take care of pigs?

•Roaming pigs can eat human faeces and acquire cysticercosis
•If a person eats pork infested with *Taenia solium*, he/she will acquire taeniasis

Taenia solium Lifecycle



Why is it important to maintain good hygiene?

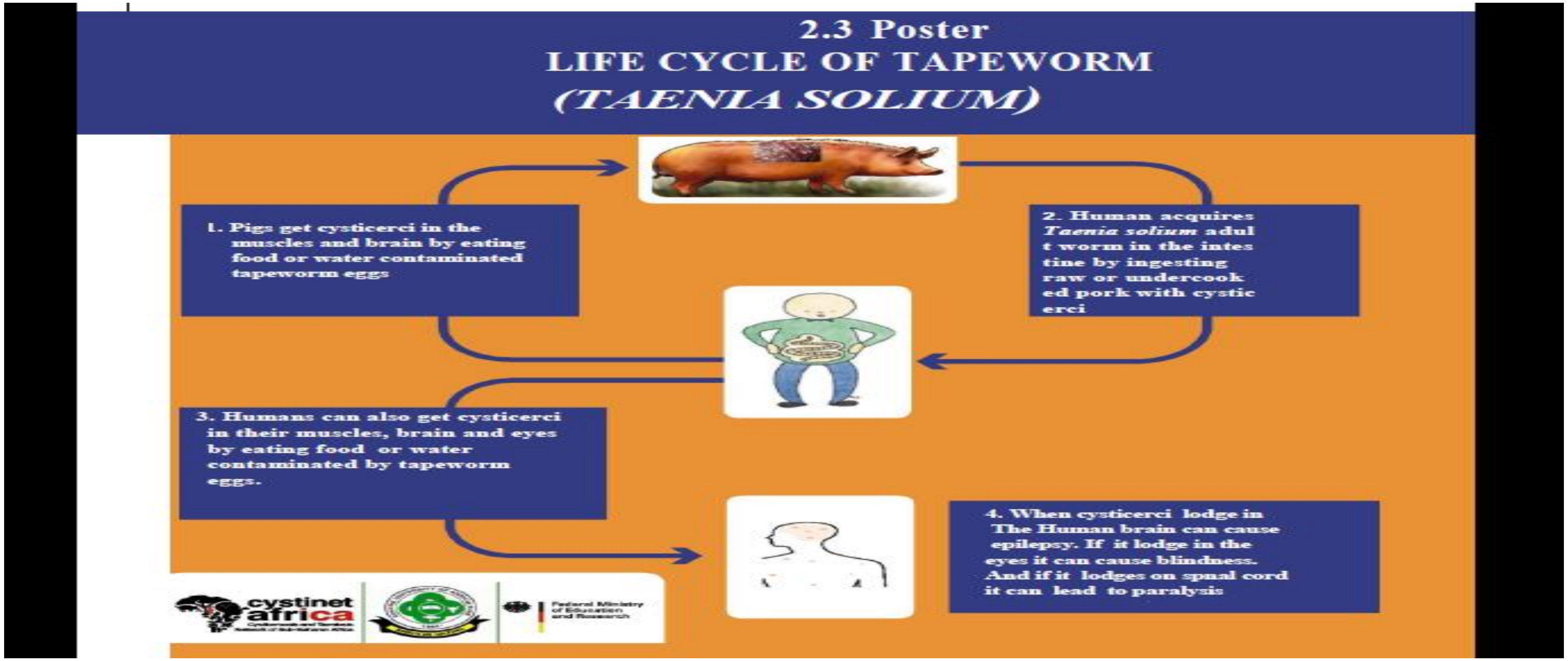
•Consumption of food or water contaminated human faeces may lead to cysticercosis in humans and pigs.
•Lack of latrines in the household encourages open defaecation, hence possible environmental contamination with *Taenia solium* eggs.
•Inadequate washing of hands in critical times makes human ands a potential source of *Taenia solium* egg transmission.

What are the important control measures for Taenia *solium?*

1. Always confine pigs

2. Pigs should always be slaughtered in a slaughter facility and meat inspection performed

3. Always use latrine/toilet


2.3 Poster
LIFE CYCLE OF TAPEWORM
(TAENIA SOLIUM)
1. Pigs get cysticerci in the muscles and brain by eating food or water contaminated tapeworm eggs
2. Human acquires Taenia solium adul t worm in the intes tine by ingesting raw or undercook ed pork with cystic erci
3. Humans can also get cysticerci in their muscles, brain and eyes by eating food or water contaminated by tapeworm eggs.
4. When cysticerci lodge in The Human brain can cause epilepsy. If it lodge in the eyes it can cause blindness. And if it lodges on spnal cord it can lead to paralysis
cystinet africa
Federal Ministry of Education and Research

Appendix 4: Study Ethical Clearance

THE UNITED REPUBLIC OF TANZANIA

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NIMR/HQ/R.8a/Vol. IX/2802

22nd June 2018

Helena Aminiel Ngowi
Sokoine University of Agriculture
College of Veterinary Medicine and Biomedical Sciences
P.O. Box 3021
Morogoro

RE: ETHICAL CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled: Development, evaluation and implementation of a practical health education intervention package for prevention and control of *Taenia solium* cysticercosis and taeniosis in Tanzania (Ngowi HA *et al.*) has been granted ethical clearance to be conducted in Tanzania.

The Principal Investigator of the study must ensure that the following conditions are fulfilled:

1. Progress report is submitted to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research, Regional and District Medical Officers after every six months.
2. Permission to publish the results is obtained from National Institute for Medical Research.
3. Copies of final publications are made available to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research.
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine as per NIMR Act No. 23 of 1979, PART III Section 10(2).
5. Site: Mbulu, Babati, Mpwapwa, Kilolo, Rungwe, Mbinga, Nyasa, Kongwe and Songwe districts in Tanzania.

Approval is valid for one year: 22nd June 2018 to 21st June 2019.

Name: Prof. Yunus Daud Mgaya

Signature
CHAIRPERSON
MEDICAL RESEARCH COORDINATING COMMITTEE

Name: Prof. Muhammad Bakari Kambi

Signature
CHIEF MEDICAL OFFICER
MINISTRY OF HEALTH, COMMUNITY DEVELOPMENT, GENDER, ELDERLY & CHILDREN

CC: RMO of Manyara, Dodoma, Iringa, Mbeya and Ruvuma regions
DMOs/DEDs of Mbulu, Babati, Mpwapwa, Kilolo, Rungwe, Mbinga, Nyasa, Kongwe and Songwe districts

Kuhusu Tasnifu hii

Tafiti hii imetathimini ufanisi wa elimu ya afya shirikishi kwa wafugaji wadogo wa nguruwe katika kudhibiti na kuzuia mnyoo tegu kwa nguruwe katika Wilaya za Kongwa na Songwe katka mikoa ya kati na nyanda za juu kusini mwa Tanzania. Ukusanyaji taarifa za utafiti ulifanyika kabla na baada ya mafunzo ya elimu ya afya shirikishi kutolewa. Taarifa hizo zilihusisha kupima uelewa, fikra na mienendo ya wafugaji wadogo wa nguruwe, pia uchunguzi wa viashiria vya mnyoo tegu kwa nguruwe.

Utafiti ulibaini kuwa kabla ya mafunzo ya elimu ya afya shirikishi kutolewa, maambukizi ya mnyoo tegu yalikuwapo kwa nguruwe wilayani Kongwa na Songwe na pia uelewa wa wafugaji wa nguruwe wadogo kuhusu maambukizi ya mnyoo tegu wa nguruwe ulikuwa mdogo. Mwaka mmoja baada ya mafunzo ya elimu ya afya shirikishi kutolewa, utafiti iligundua kuwa elimu ya afya shirikishi iliongeza kiwango cha uelewa, kiwango cha fikra, na kiwango cha mbadiliko ya mienendo wa wafugaji wadogo wa nguruwe, hata hivyo elimu ya afya haikuwa na mchango mkubwa katika kupunguza maambukizi ya mnyoo tegu kwa nguruwe. Kwa hiyo,mafunzo ya elimu ya afya shirikishi ya siku zijazo inabidi yahusishe tathmini na tiba ya mnyoo tegu kwa binadamu ambayo inaweza kuwa ni hatua muhimu ya kuzuia haraka mzunguko wa maisha wa mnyoo tegu ambayo inaweza kusaidia matokeo kwa mapana zaidi kwa muda mfupi wa mafunzo ya elimu ya afya shrikishi.