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Landscape analysis: Prevalence and control of Porcine Cysticercosis and Human Taeniasis/ Neurocysticercosis

South Africa, Tanzania, Uganda and Zambia report

GALVmed

Protecting Livestock – Improving Human Lives

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Executive summary

Rationale and objectives

Taenia solium cysticercosis is a global parasitic zoonotic neglected tropical disease that is endemic across the developing countries of Africa, Asia and Latin America and impacts the health and livelihoods of subsistence farming communities. This Landscape Analysis Report focuses on this disease in Tanzania, Uganda and Zambia in sub-Saharan Africa, where pigs and humans are infected mainly where traditional pig production systems are maintained. Although some have deemed the parasite to be eradicable, interventions implemented thus far have not been entirely successful. This tapeworm parasite is found in pigs during the larval stage of the life cycle, and humans serve as the host for both the adult form and the larval stage that migrates to the brain. In humans, the brain form can lead to epilepsy, chronic headaches, seizures, hydrocephalus, and other neurological conditions. Several tests are available to diagnose *T. solium* in pigs and in humans, but differ in sensitivity and availability across all communities where this parasite is endemic.

T. solium infection (taeniasis or HuT) is an intestinal infection in humans of adult tapeworms that follows ingestion of larval stages in pork. Porcine cysticercosis (PC) refers to the infection of pigs with *T. solium* larvae, which develops after ingestion of ova excreted in human feces. If the human ingests the egg stage, this may develop to larvae, which invade the central nervous system, resulting in human neurocysticercosis (NC). This can cause seizures, various other neurologic signs, and epilepsy. The infection is endemic in areas where sanitation is poor, pigs scavenge for food and veterinary meat inspection is limited.

GALVmed is aware that countries in Eastern and Southern Africa may differ in their approach to PC, HuT and NC control. In preparation for introducing the PC interventions being tested, this Landscape Analysis Report has been undertaken to understand the knowledge, attitudes and practices amongst pig farmers, pig traders and policy makers in each of the four target countries. Additional purposes of this report are to assess the status of the disease and the existing framework for control. This would identify gaps and lead to recommendations on the use of the PC control tools to control *T. solium* infection.

The objectives of this report included:

1. Identifying the stakeholders and key opinion leaders with a view to maintaining regular contact and exchange of information.
2. Providing disease and control status of taeniasis/cysticercosis, current knowledge, attitudes and practices of key stakeholder communities for each country through analysis of questionnaires implemented to the public sector (government officials representing veterinary, medical, public health, environment, agriculture, education), pig farmers and pig traders.
3. Providing a landscape analysis of taeniasis/cysticercosis control in each of the target countries.
4. Identifying potential partners for Phase 2 PC control tools.
5. Identifying gaps in policy and reasons for indifference towards PC and implications for and recommendations to GALVmed.

Study area and methodology

The Landscape Analysis covered three target countries: Tanzania, Uganda, and Zambia. The study involved extensive desk studies to review and analyze key policy and scientific documents. The sample of respondents involved in the study included 87 policy maker representatives drawn from the government and public sector, academia, and industry. A total of 1,909 farmers and 55 pig traders from Tanzania, Uganda, and Zambia also formed part of the sample. The study employed both primary data and secondary data collection methods. Data from the study were analyzed using binomial and multinomial proportions expressed as percentages.

Summary of findings

South Africa (only desk review)

South Africa has undertaken and published the first community based research on the prevalence of pork tapeworm across several provinces. As a result, there is an understanding of the extent of the geographic distribution of *T. solium* in pigs and humans. National government programs for control and prevention of porcine cysticercosis/human taeniasis and human neurocysticercosis are lacking in regulations, education and prevention/control.

Main findings include:

- In terms of knowledge, all were unclear if HuT or NC were notifiable.
- 75% agreed South Africa does not engage in health education focused on PC/HuT/NC.
- 100% are aware of a *T. solium* vaccine.
- 75% agree that no improvements have been made to the meat inspection service in the last 10 years.
- 50% unaware if South Africa is engaged in control strategies, and 75% report there is no drug administration for taeniasis, porcine cysticercosis control nor active identification and treatment of taeniasis countrywide.
- Meat inspection of all anatomical sites is not consistent across the country.

Tanzania

Tanzania has published an extensive number of peer reviewed scientific papers on the prevalence of PC, HuT and human NC as well as education and interventions in high pig production areas. This results in an understanding of the extent of this parasite's distribution geographically in pigs and humans. National government programs focusing on PC, HuT and human NC regulations, education and prevention and control are continuing to advance in Tanzania.

Some findings include:

- 99% of farmers keep pigs for sale, and 98% do not slaughter their pigs at home.
- 55% of pig farmers are aware of humans with epilepsy.

- In terms of policy makers' awareness, 100% reported that HuT and 97% that NC are not notifiable, 30% are aware of a *T. solium* vaccine, and 40% state that no improvements have been made to the meat inspection service in the last 10 years.

Uganda

In the last 10 years, Uganda's pig population increased to 3 million as compared to 1.0-1.6 million for the other three countries in this report. Uganda has undertaken and published research of PC/HuT/NC statistics in peer reviewed scientific journals, which demonstrates the high prevalence levels in humans and pigs in production areas. With this impetus, national government programs for regulation, education, prevention, and control of PC, HuT and human NC are advancing.

Some findings include:

- Pig management/husbandry figures confirm that 87% keep pigs primarily for sale, 97% of meat is not inspected, and 85% of farmers and their families consume pork, with few slaughtering pigs at home.
- Regarding PC awareness, 38% of pig farmers and 59% of pig traders had heard of human tapeworm infection, 72% of pig farmers and 63% of pig traders have heard of epilepsy in their village, 81% of pig famers did not recognize measles, but 98% of pig traders with and only 35% knew what these were.
- Regarding practices, 54% of pig farmers have latrines.
- In terms of economics, pork represents 41% of pig traders' income.
- In terms of policy makers' awareness, 77% reported that taeniasis and 73% that NC are not notifiable, 53% are aware of a *T. solium* vaccine, and 57% state that no improvements have been made to the meat inspection service in the last 10 years.

Zambia

Zambia has produced leading research in the diagnostics of this parasite in humans and pigs, resulting in an understanding of distribution geographically in pigs and humans in this country. National government programs in PC, HuT and NC including regulations, education and prevention and control are developing.

Some findings include:

- Pig management/husbandry figures confirm that 66% of farmers keep pigs free-range. All surveyed pig farmers reported feeding maize and crops, with 53% feeding kitchen leftovers.
- Regarding PC awareness, 100% of pig traders had heard of tapeworm infection, 83% of pig traders have heard of epilepsy in their village.
- Regarding practices, 92% of pig farmers have latrines.
- In terms of economics, 100% pig famers recognize measles and understand the decreased loss of value to the carcass depending on the presence of measles.
- In terms of policy makers' awareness, 68% reported that taeniasis and 73% neurocysticercosis not notifiable, 38% are aware of a *T. solium* vaccine, and 38%

state no improvements have been made to the meat inspection service in the last 10 years.

Conclusions

Several objectives were outlined for this report and have been achieved:

1. Identifying the stakeholders and key opinion leaders with a view to maintaining regular contact and exchange of information. This objective was realized through questionnaires implemented to pig farmers, pig traders and policy makers across four countries.
2. Providing disease and control status of taeniasis/cysticercosis, current knowledge, attitudes and practices of key stakeholder communities for each country through analysis of questionnaires implemented to the public sector (government officials representing veterinary, medical, public health, environment, agriculture, education, etc.), pig farmers and traders, and industry, etc. This objective was achieved through questionnaires, contact and exchanges with stakeholders and an extensive review of the peer reviewed scientific literature. This resulted in identifying each country's unique achievements to prevent and control the disease.
3. Providing a landscape analysis for taeniasis/cysticercosis control in each of the target countries. This report outlines the landscape analysis for each of the four countries.
4. Identifying potential partners for Phase 2 PC control tools. Throughout this project, this goal was achieved by engaging and building trust and confidence with stakeholders ranging from on-the-ground pig farmers and pig traders to policy holders with broad experience in government, academic and industry players.
5. Identify gaps in policy and reasons for indifference towards PC and implications for and recommendations to GALVmed. Gaps in policy and reasons behind indifference towards PC and the implications have been identified in the summaries and recommendations for each country and in the final summary.

Policy recommendations

1. Strengthen Education and Training: The action is to strengthen PC education and awareness and build training and capacity. Education can reach across all communities. Educators are many: in elementary schools as part of the science curriculum, health inspectors, all veterinary and medical professionals, local leaders (at the village level), and pig traders (at the community level). Consider countries, which have been successful as an endemic country model: Mexico's educational programs significantly reduced the threat of PC, improved pork production, and reduced human disease.
2. Education Tools: This is a question to address with all stakeholders. Effective educational tools are available. If one country does not have these tools, they would reach out to others who have established and implemented novel programs. Colleagues in Tanzania have implemented novel educational materials, and also in South Africa have championed PC educational tools ("Let's Break the Pork

Tapeworm Cycle" as well as "Livestock Keeper Manuals") which continue to be translated into local and global languages reaching and multiplying across endemic PC countries, improving livestock risk of PC.

3. Advance Treatment and Prevention: Controls in humans should be integrated with those in pigs (e.g. mass treatment pigs similar to what is done for trypanosomiasis along with disease identification and treatment for humans).
4. Vaccines and Anthelmintics should be made available at an affordable cost, in step with educational and promotional materials for the end user (pig farmers, pig traders, pig producers, etc.). The pork producers nationally and globally have financial incentive to produce safe pork, because pork demand and distribution markets internally and externally are increasing. Pig traders (the "businessmen on the ground") are motivated. If they had training and legislative support, they would walk away with more safe meat, impacting healthier families and wealthier countries.
5. Treatment and Prevention: Awareness of vaccine and anthelmintic amongst policy makers may reflect this because of the current ongoing trials in their countries. Approximately 30-75% of policy makers are aware of a vaccine available for PC in pigs, and 0-40% aware of anthelmintic treatment for PC in pigs. So approximately 50% are aware of these treatments. Their awareness is an advocacy tool. However, apart from that, we don't have pig level data of infected animals, how many need the drug, etc.
6. Policy Makers can further help by making the disease legally notifiable, strengthening the requirements for meat inspection and advocate allocation of funds
7. Donor Support: Due to competing needs and limited resources, donor support will be invaluable. Stakeholder dialogue to sensitize, inform at district, national and regional levels within countries and across.
8. One Health: All Ministries at national, district levels together with all stakeholders must work together and have a common understanding of methods and needs to effectively reduce this disease, and improve regulations and /or implement laws which impact this disease. Laws and policies must be consistent.

List of Acronyms

ASF: African Swine Fever
COCTU: Coordinating Office for Control of Trypanosomiasis in Uganda
CVM: College of Veterinary Medicine & Biomedical Sciences
DFID: Department for International Development
ELISA: Enzyme-linked immunosorbent assay
FAO: Food and Agriculture Organization of the United Nations
GALVmed: Global Alliance for Livestock Veterinary Medicines
GHO: Global Health Observatory
HuT: Human taeniasis

ILRI: International Livestock Research Institute
MDA: Mass drug administration
MRI: Magnetic resonance imaging
NC: Human neurocysticercosis
OIE: World Organisation for Animal Health
OFZ: Oxfendazole
PC: Porcine cysticercosis
PCR: Polymerase chain reaction
PWE: Persons with epilepsy
TAMU: Texas A&M University
WHO: World Health Organization

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Introduction

GALVmed is committed to creating solutions that address sustainable poverty alleviation by making available and accessible animal health products (vaccines, medicines and diagnostics) to livestock keepers in the developing world. As part of the program "Protecting livestock, improving human life" funded by the Bill & Melinda Gates Foundation and with UK aid from the UK Government, GALVmed is implementing activities regarding the field testing of a vaccine (TSOL18) against porcine cysticercosis (PC) co-administered with oxfendazole (OFZ) as a control strategy for *Taenia solium* (pork tapeworm). This intervention will lead to the reduction of the prevalence of PC, and ultimately decrease the prevalence of human taeniasis and neurocysticercosis.

It is necessary to evaluate the prevalence and control of PC, human taeniasis (HuT), and human neurocysticercosis (NC) and how these will integrate within the framework of each of four countries in Eastern and Southern Africa, namely the target countries of South Africa, Tanzania, Uganda, and Zambia. It is essential to understand how PC, HuT and NC impact each country's agricultural, medical, food safety and public health frameworks. There is also a need to evaluate the current One Health approach in each of the four countries and the opportunities to be implemented as part of national control programs. To gain an understanding of potential issues and concerns, a Landscape Analysis Report

was commissioned by GALVmed, to contribute to the evaluation package that will support advocacy activities and engagements with other partners and donors.

Brief introduction to disease and transmission

T. solium cysticercosis is a global parasitic zoonotic neglected tropical disease that is endemic across the developing countries of Africa, Asia and Latin America and impacts the health and livelihoods of subsistence farming communities. Four individual literature reviews focus on this disease in South Africa, Tanzania, Uganda and Zambia in sub-Saharan Africa, where pigs and humans are infected mainly where traditional pig production systems are maintained [1, 2]. Although some have deemed the parasite to be eradicable, interventions implemented thus far have not been entirely successful. This tapeworm parasite is found in pigs during the larval stage of the life cycle, and humans serve as the host for both the adult form and the larval stage that migrates to the brain. Wildlife have not been found to harbor the parasite [3]. In humans, the brain form can lead to epilepsy, chronic headaches, seizures, hydrocephalus, and other neurological conditions [4]. Several tests are available to diagnose *T. solium* in pigs and in humans, but differ in sensitivity and availability across all communities where this parasite is endemic.

Note: References in the above section can be found in the "General" section of the References.

Transmission. *T. solium* infection (taeniasis or HuT) is an intestinal infection in humans of adult tapeworms that follows ingestion of larval stages in pork. Porcine cysticercosis (PC) refers to the infection of pigs with *T. solium* larvae, which develops after ingestion of ova excreted in human feces. If the egg stage is ingested by the human, this may develop to larvae which invade the central nervous system, resulting in human neurocysticercosis (NC). This can cause seizures, various other neurologic signs, and epilepsy. The infection is endemic in areas where sanitation is poor, pigs scavenge for food and veterinary meat inspection is limited.

Purpose and objectives

GALVmed is aware that countries in Eastern and Southern Africa may differ in their approach to PC, HuT and NC control. In preparation for introducing the PC interventions being tested, this Landscape Analysis Report has been undertaken to understand the knowledge, attitudes and practices amongst pig farmers, pig traders and policy makers in each of the four target countries. Additional purposes of this report are to assess the status of the disease and the existing framework for control. This would identify gaps and lead to recommendations on the use of the PC control tools to control *T. solium* infection.

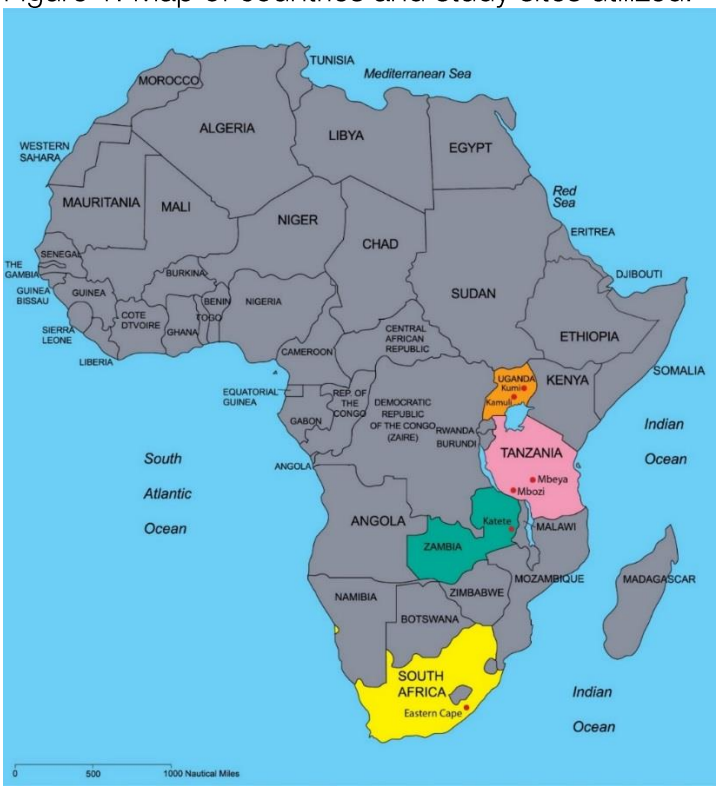
The objectives of this report included:

1. Identifying the stakeholders and key opinion leaders with a view to maintaining regular contact and exchange of information.
2. Providing disease and control status of taeniasis/cysticercosis, current knowledge, attitudes and practices of key stakeholder communities for each country through analysis of questionnaires implemented to the public sector (government officials representing veterinary, medical, public health, environment, agriculture, education), pig farmers and pig traders.
3. Providing a landscape analysis of taeniasis/cysticercosis control in each of the target countries.
4. Identifying potential partners for Phase 2 PC control tools.
5. Identifying gaps in policy and reasons for indifference towards PC and implications for and recommendations to GALVmed.

Study location rationale

Figure 1 illustrates the location of study sites in the four target countries for this report: South Africa, Tanzania, Uganda, and Zambia. These countries were selected with consideration to current active research in response to endemic PC, HuT and NC and increasing numbers of small scale pig populations.

Figure 1: Map of countries and study sites utilized.



South Africa

Methodology

Literature review

The aim of this literature review was to examine the extent of porcine cysticercosis (PC), human taeniasis (HuT) and human cysticercosis (NC) and their control in South Africa. This review includes a brief introduction to the disease; summary of the prevalence of PC, HuT, human NC and their control; and diagnostic tools. The peer-reviewed scientific journal literature as well as "grey literature" sources (e.g., reports, letters to the editor, newspaper articles, magazine articles, websites, etc.) is reviewed for South Africa from 1996 to 2017.

This literature review was created using the following steps: identification of information resources to search for appropriate literature, searching, screening results, and inclusion.

First, based on the scope of the literature review, appropriate information resources for primary and secondary peer-reviewed literature were identified as: PubMed, Embase, Web of Science, and Scopus. CAB Abstracts, AGRIS, FAOSTAT, GIDEON, Global Health, Global Health Observatory (GHO) Data, and Google Scholar were also identified as resources to search for primary and secondary, peer-reviewed and non-peer-reviewed, and grey literature.

Second, these resources were searched using the indicated interfaces. Searches were conducted and updated between September 2016 and May 2017. Searches included no restrictions for language or date. Searches were conducted in English. Sources searched included: PubMed, Embase (through the OVID interface), Web of Science (through the Thomson Reuters interface), Scopus (through the Elsevier interface), CAB Abstracts (through the OVID interface), AGRIS (through both the native FAO interface and the OVID interface), FAOSTAT (through the native interface), GIDEON (through the EBSCO interface), Global Health (through the OVID interface), Global Health Observatory (GHO) Data (through the WHO interface), and Google Scholar.

Search terms represented the primary concepts for the literature review: parasite, intervention, and location. Searches combined the concepts for the parasite and associated diseases (*Taenia solium, T. solium*, porcine cysticercosis, swine cysticercosis, taeniosis, taeniasis, cysticercosis, cardiocysticercosis, neurocysticercosis, cysticercal meningitis, cysticercosis cellulosae), interventions (control, control*, vaccine, vaccines, vaccination, vaccin*, diagnosis, diagnostic, diagnos*, therapy, therapies, therapeutic, therap*, anthelmintic, anthelmintic*, educate, educate*, education, education*, sanitary, sanitation, sanita*), and country. Resources were searched both using terms from all three concepts and only parasite name and country. Results were exported to and managed in a group library in Zotero.

During screening, titles and, if available, abstracts from the results were evaluated according to the following criteria: date (1996-2017 inclusive), country, and parasite. Items were not excluded due to publication type or language. Results for additional parasites,

e.g., *Taenia saginata* were excluded unless they also included relevant information about *T. solium*. Additionally, key publications were used to identify additional references through both backward and forward citation searching (identifying works cited in the key publication); these were screened using the criteria above. Remaining items were reviewed for relevance.

Finally, in the inclusion phase, the authors extracted data on porcine cysticercosis, human cysticercosis, taeniasis, neurocysticercosis, control methods for *Taenia solium*, and diagnostic tools for *T. solium* from identified publications to include in this literature review.

Questionnaires

Pig farmer and pig trader questionnaires were not implemented in South Africa. Only policy maker questionnaires were implemented in this country.

Policy Makers: A standard policy maker questionnaire was prepared to interview experts across One Health disciplines to understand and collect their views/suggestions towards designing a vision for control of taeniasis/cysticercosis in humans and pigs in South Africa. Sections of the policy maker questionnaire include: demographics and current *T. solium* strategies. The questionnaire is included in this report as Appendix 3. The experts interviewed represented two from the animal health/veterinary/agriculture/livestock sector and two from the human health/medical/public health arena.

Each policy maker was invited by email to participate via completion of a survey specific to their country; policy makers were contacted no more than four times and could opt-out of the survey if desired at any time. The surveys were provided in a fillable PDF form and in a Word document format, and participants returned completed questionnaires via email. Participants were also provided with the option to complete the survey by phone if desired. Data from the surveys was compiled into a spreadsheet for analysis. A list of respondents with contact details is available in Appendix 4.

Data analysis methodology

For questions with categorical responses, binomial and multinomial proportions (expressed as percentages) were generated and presented as simple contingency tables. The simple contingency table is available in Appendix 8 and is comprised of three columns: one for the question asked, followed by a second column for the possible set of responses (answers), and the third column for the percentages of respondents who selected a particular response. All analyses were performed using SAS version 9.4 (Cary, NC, USA).

Results and discussion

Disease and control status in scientific iterature

The aim of this section is to examine the extent of porcine cysticercosis (PC), human taeniasis (HuT), and human neurocysticercosis (NC) and its control in South Africa. This section includes demographic data, a summary of the prevalence of PC, HuT, NC; control; diagnostic tools; and a bibliography. The peer-reviewed scientific journal literature as well as “grey literature” sources (e.g.,

reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for South Africa from 1996 to 2017. The bibliography for South Africa is on pages 46-49.

a. Demographic Data

As of 2015, the human population of South Africa was over 54 million [33]. The commercial population of pigs was 1.6 million as of 2011/2012, and the communal pig population was 230,000 in the Eastern Cape [4]. Eastern Cape has 69.4% of country's total, with the largest percentage of agricultural households that farm 1 to 10 pigs. The province also has the largest percentage of agricultural households that farmed 11 to 100 pigs in the country [24].

b. Prevalence and Control (vaccine, therapeutic, education/sanitation) of PC, HuT, and Human NC

1. *PC Prevalence:* Prevalence studies on *T. solium* in South Africa are lacking in the literature [15]. In two comprehensive reviews of the literature in Eastern and Southern Africa, Phiri et al. [20] summarized prevalence in pigs in sub-Saharan countries, including South Africa (see Table 1 below). Additional prevalence rates found in the literature are indicated in Table 2.

Table 1. South African prevalence rates and surveys, from "Results of prevalence studies on porcine cysticercosis conducted in Eastern and Southern Africa countries" [9]

PC prevalence (%)	Number of pigs surveyed	Type of survey	Area surveyed	Reference
	> 100,000	Post-mortem	National	[31]
0.5 – 25.1				
0 – 9.1	28,242	Post-mortem	National	[9]

In the Eastern Cape Province, risk factors for cysticercosis included district (Qumbu and Tsolo districts were greatest), breed (not crossbred), and most importantly the absence of a latrine (89% increase in possibility of porcine infection) [14]. In a smaller study of 35 pig farmers in North West Province, 49% "said that their pigs had access to human fecal material, substantiating a poor infrastructure and standard of living" [30]. The authors of that study also noted "there is a strong evidence of a tendency towards an association between epilepsy, [pork] consumption habits and some identified epidemiological risk factors", such as lack of meat inspection and slaughter facilities [30].

Table 2. Results of prevalence studies on porcine cysticercosis conducted in South Africa

PC prevalence (%)	Area surveyed	Number of pigs surveyed	Type of survey	Reference
56.7	Alfred Nzo, Oliver R. Tambo Districts, Eastern Cape Province	261	Lingual/Serological	[12, 13]
0-54.55	Alfred Nzo District, Eastern Cape Province	191	Lingual	[11]
3.6 6.3 5.9 16.6 4.6 0 0 0 5.2	Gauteng Limpopo North West Western Cape Eastern Cape Free State Kwa-Zulu Natal Northern Cape Overall	824	Serological	[25]
34 14	Free State Gauteng	436 240	Serological	[29]

2. *HuT Prevalence:* Humans serve as the host for the adult form of *T. solium.* A non-prevalence study identified *Taenia* spp. segments in stool samples of 1,924 persons from Gauteng, North West, and Mpumalanga provinces [21]. Additional prevalence studies are summarized in Table 3 below.

Table 3. Results of prevalence studies on human taeniasis conducted in South Africa

HuT prevalence (%)	Area surveyed	Number of persons surveyed	Type of survey	Reference
18[a]	Thekwini municipality	120 (households)	Coprology	[28]
0[a]	Ugu district	1057	Coprology	[34]

[a] This study included results from all *Taenia* spp.

3. *NC Prevalence:* In a review of existing literature, researchers noted that the "literature in…South Africa (92%) tended to be heavily biased towards human neurocysticercosis" [23]. The following studies contained information pertaining to this report's topic but were not prevalence studies. First, six of over 250 epilepsy surgery patients were found to have *T. solium* infections in their nervous system over a 5-year period but reported improvement after the surgery [2]. In 2006, scientists estimated that there were 34,662 NC-associated epilepsy cases in the Eastern Cape Province alone in 2004 [3]. Although these studies provide some idea of NC burden in South Africa, the remainder of the literature generally consisted of individual case descriptions. One instance of NC reported in 1999 described symptoms that included seizures, multiple subcutaneous nodules, and presence of cysticerci in the brain and muscles determined via MRI [1]. A second case reported headaches, hydrocephalus, and a lack of focal neurological signs in the patient [10]. Both these cases were treated with albendazole. A third case involved a woman in the Free State province who had vertebral collapse due to *T. solium* cysts [16]. In addition to neurological signs, there was one report of cysticercosis infection in pharyngeal (behind the nose and mouth, connecting to the esophagus) tissue that was treated with surgery and albendazole [22], and another where infection was also found around heart tissues [27]. With all studies, it is important to keep in mind the effect that negative South African cultural attitudes toward epilepsy have on those who need to seek treatment and the lack of effective treatment options available [5].

Table 4. Results of prevalence studies on neurocysticercosis conducted in South Africa

NCC prevalence (%)	Area surveyed	Number of persons surveyed	Type of survey	Reference
37	Eastern Cape Province	92 PWE[a]	CT scan	[6]
0	Agincourt, Mpumalanga	82,818	Serological	[19]

[a] Only those seeking care were represented in the population of this study.

c. Control*:* For a general (non-specific to South Africa) landscape analysis of *T. solium* control, see Thomas's report [26]. A GALVmed report recommended that PC control in South Africa would be best accomplished through a "private good" approach via vaccination and/or oral oxfendazole [8].
    - Education/Sanitation: There is a need for education on *T. solium* transmission. Of 122 emerging pig producers in the Eastern Cape Province, 80% did not know how HuT was acquired, but 75% knew someone in their village complaining of a tapeworm infection [11]. This was supported by a later study in which 90% of pig owners surveyed had no knowledge of human tapeworm infections and 46% of those who had observed cysts in pork did not know what they were [25].
    - Policy: No information found.
    - Vaccination: No information found.
    - Therapeutic/Anthelmintic: Treatment of neurocysticercosis in humans has been accomplished by using either albendazole [1, 10, 16, 22] or praziquantel [16].

d. Diagnostic Tools*:* For neurocysticercosis, researchers identified CT scanning as the most reliable diagnostic tool, while a commercially-available antigen-based ELISA test showed "very poor" performance [6].

This literature review section reflects a significant body of published data related to *T. solium* porcine cysticercosis, human taeniasis, human neurocysticercosis and control in South Africa.

Questionnaire analysis

As previously mentioned, pig farmer and pig trader questionnaires were not implemented in South Africa. The analysis below is for only policy maker questionnaires. The full contingency table is available separately from this report, and the simple contingency table of responses is available as Appendix 8.

Policy maker analysis

A summary of the results of the questionnaire conducted with South African policy makers (n=4) is below:

Demographics
• Respondents were 50% male and 50% female and aged from 41-60 years. • Median number of years in role was 10.5 (range from 3 to 36). • Half of respondents worked with the Department of Agriculture, Forestry and Fisheries.
Knowledge
• *T. solium* taeniasis is not a notifiable disease in South Africa, but whether neurocysticercosis was notifiable was unclear to respondents. • 75% of respondents agreed that South Africa does not engage in any health education specifically focused on *T. solium* control. Any education is done through extension. • All respondents agreed that no improvements have been made to the meat inspection service in the last 10 years in regards to *T. solium* control. • 75% of respondents are aware that a vaccine for control of *T. solium* is available.
Practice
• Respondents were divided (50/50) on whether South Africa engaged in any *T. solium* control strategies. • 75% reported that South Africa does not currently undertake mass drug administration for taeniasis, and all respondents agreed that South Africa does not engage in any active identification and treatment of taeniasis cases. • Half of respondents agreed that the heart, masseter muscles, and tongue muscle were examined by eye for cysts. 100% agreed that the diaphragm (by eye), heart (incised), and masseter muscle (incised) were examined for cysts. • No anthelmintic treatment is used for cysticercosis control in South Africa. • Participants were unclear on if there was a program in place to improve *T. solium*-based sanitation.

Summary of findings

South Africa has undertaken and published the first community based research on the prevalence of pork tapeworm across several provinces. As a result there is an understanding of the extent of the geographic distribution of *T. solium* in pigs and humans. National government programs for control and prevention of porcine cysticercosis/human taeniasis and human neurocysticercosis are lacking in regulations, education and prevention/control.

Some findings include:

- 73% of pig farmers are female.
- Demographic data confirm that 50% policy makers are male.
- 50% work for the Department of Agriculture, Forestry and Fisheries.
- In terms of knowledge, all were unclear if HuT or NC were notifiable.
- 75% agreed South Africa does not engage in health education focused on PC/HuT/NC.
- 100% are aware of a *T. solium* vaccine.

- 75% agree that no improvements have been made to the meat inspection service in the last 10 years.
- 50% unaware if South Africa is engaged in control strategies, and 75% report there is no drug administration for taeniasis, porcine cysticercosis control nor active identification and treatment of taeniasis countrywide.
- Meat inspection of all anatomical sites are not consistent across the country.

Recommendations

This report has reviewed the current status of porcine cysticercosis/human taeniasis and human neurocysticercosis across South Africa and the following strategies are recommended to control and prevent this disease:

- Education: Implement additional innovative and successful educational programs (i.e., illustrating the pork tapeworm life cycle and how to break the life cycle), which were developed in the Eastern Cape Province in collaboration with resource-poor communities who are pig producers. These efforts are a model that can be multiplied and implemented across all educational levels from school to post-matriculation across all communities and provinces in South Africa.
- Pig Management and Husbandry: Change management of pigs, which will produce safer pork and reduce transmission of this disease to the environment and to humans. This includes increased awareness of transmission, improvement of human public health, and an understanding of how this intervention will lead to safer pork and thereby increase wealth for small scale pig farmers with greater demand and higher value in the marketplace.
- Interventions to Impact Disease: Improve interventions through steps such as regular diagnostics, prevention of infection, vaccine and anthelmintic treatments.
- One Health Approach: This is continued to effectively prevent and control PC, HuT and NC in South Africa. This interdisciplinary effort that includes animal, human and environmental specialists will prevent and control this disease. PC is listed as a priority zoonotic disease that is “an endemic and cross-boundary disease that has a significant potential to affect human health locally and the potential to spread globally and not addressed in other programs that are present and of concern in South Africa in 2015” [35]. In 2017 this status continues. The One Health interdisciplinary approach is sustained in this country [36].

Tanzania

Methodology

Literature review

The aim of this literature review was to examine the extent of porcine cysticercosis (PC), human taeniasis (HuT), human neurocysticercosis (NC) and their control in Tanzania. This review includes a brief introduction to the disease; summary of the prevalence of PC, HuT, NC and their control; and diagnostic tools. The peer-reviewed scientific journal literature as

well as “grey literature” sources (e.g., reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for Tanzania from 1996 to 2017.

This literature review was created using the following steps: identification of information resources to search for appropriate literature, searching, screening results, and inclusion.

First, based on the scope of the literature review, appropriate information resources were identified. PubMed, Embase, Web of Science, and Scopus were identified as resources to search for primary and secondary peer-reviewed literature. CAB Abstracts, AGRIS, FAOSTAT, GIDEON, Global Health, Global Health Observatory (GHO) Data, and Google Scholar were identified as resources to search for primary and secondary, peer-reviewed and non-peer-reviewed, and grey literature.

Second, these resources were searched using the indicated interfaces. Searches were conducted and updated between September 2016 and May 2017. Searches included no restrictions for language or date. Searches were conducted in English. Sources searched included: PubMed, Embase (through the OVID interface), Web of Science (through the Thomson Reuters interface), Scopus (through the Elsevier interface), CAB Abstracts (through the OVID interface), AGRIS (through both the native FAO interface and the OVID interface), FAOSTAT (through the native interface), GIDEON (through the EBSCO interface), Global Health (through the OVID interface), Global Health Observatory (GHO) Data (through the WHO interface), and Google Scholar.

Search terms represented the primary concepts for the literature review: parasite, intervention, and location. Searches combined the concepts for the parasite and associated diseases (*Taenia solium, T. solium*, porcine cysticercosis, swine cysticercosis, taeniosis, taeniasis, cysticercosis, cardiocysticercosis, neurocysticercosis, cysticercal meningitis, cysticercosis cellulosae), interventions (control, control*, vaccine, vaccines, vaccination, vaccin*, diagnosis, diagnostic, diagnos*, therapy, therapies, therapeutic, therap*, anthelmintic, anthelmintic*, educate, educate*, education, education*, sanitary, sanitation, sanita*), and country. Resources were searched both using terms from all three concepts and, also only parasite name and country. Results were exported to and managed in a group library in Zotero.

During screening, titles and, if available, abstracts from the results were evaluated according to the following criteria: date (1996-2017 inclusive), country, and parasite. Items were not excluded due to publication type or language. Results for additional parasites, e.g., *Taenia saginata* were excluded unless they also included relevant information about *T. solium*. Additionally, key publications were used to identify additional references through both backward and forward citation searching (identifying works cited in the key publication); these were screened using the criteria above. Remaining items were reviewed for relevance.

Finally, in the inclusion phase, the authors extracted data on porcine cysticercosis, human cysticercosis, taeniasis, neurocysticercosis, control methods for *T. solium*, and diagnostic tools for *T. solium* from identified publications to include in this literature review.

Questionnaires

Pig farmers: Sections of this questionnaire include: demographics, pig management, and human health. A standard questionnaire was prepared to interview 554 pig farmers to explore and analyze the current situations of pig production and husbandry, and understand knowledge, attitudes and practices regarding porcine cysticercosis/neurocysticercosis among the respondents.

Policy makers: A standard policy maker questionnaire was prepared to interview experts across One Health disciplines to understand and collect their views/suggestions towards designing a vision for control of taeniasis/cysticercosis in humans and pigs in Tanzania. Sections of the policy maker questionnaire include: demographics and current *T. solium* strategies. The questionnaire is included in this report as Appendix 10. The experts interviewed included 12 from the animal health/veterinary/agriculture/livestock sector and 15 from the human health/medical/public health arena.

Policy makers were contacted in one of two ways. Some were contacted by email to invite their participation via completion of a survey specific to their country; policy makers were contacted no more than four times and could opt-out of the survey if desired at any time. The surveys were provided in a fillable PDF form and in a Word document format, and participants returned completed questionnaires via email. Participants were also provided with the option to complete the survey by phone or in person with an interviewer if desired. Data from the surveys was compiled into a spreadsheet for analysis. A list of respondents with contact details is available in Appendix 5.

Data analysis methodology

For questions with categorical responses, binomial and multinomial proportions (expressed as percentages) were generated and presented as simple contingency tables. The simple contingency tables are available in Appendices 10-12 and are comprised of three columns: one for the question asked, followed by a second column for the possible set of responses (answers), and the third column for the percentages of respondents who selected a particular response. All analyses were performed using SAS version 9.4 (Cary, NC, USA).

Results and discussion

Disease and control status in scientific literature

The aim of this section is to examine the extent of porcine cysticercosis (PC) and human taeniasis/human cysticercosis (HuT/NC) and its control in Tanzania. This section includes demographic data, a summary of the prevalence of PC, HuT, NC, control; diagnostic tools, and a bibliography. The peer-reviewed scientific journal literature as well as “grey

literature" sources (e.g., reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for Tanzania from 1996 to 2017. The bibliography for Tanzania is on pages 49-55.

a. Demographic Data

As of 2015, the human population of Tanzania was over 53 million [85], upward from almost 45 million in 2012 [54]. The pig population of Tanzania in 2008 was estimated at 1.6 million [81], an increase of 300% since 1995 when the estimates were 434,638 [80].

b. Prevalence and Control (vaccine, therapeutic, education/sanitation) of PC, HuT, and Human NC

1. *PC Prevalence*: PC "was first reported in pigs in Tanzania in the Mbulu district in 1985" with five positives out of 13,514 pigs, and the numbers showed steady increases over the next four years [70]. Table 5 (below) includes a summary of early prevalence surveys from a review [72].

Table 5. Tanzanian prevalence rates and surveys, from "Results of prevalence studies on porcine cysticercosis conducted in Eastern and Southern Africa countries" [72]

PC prevalence (%)	Number of pigs surveyed	Type of survey[a]	Area surveyed	Reference
0.04 – 4.9	45,794	P	Mbulu District	[71][b]
4.5 – 37.7	83	P	Northern highlands	[3]
3.2 – 46.7	770	L	Mbulu District	[56]
0 – 26.9	1789	L	Southern highlands	[4]

[a] P=post-mortem, L = lingual examination, S = serological.

[b] Survey conducted from 1985-1989.

Table 6 summarizes prevalence studies in Tanzania; additional summaries are available in the literature [81, 34]. The absence of latrines, free-range animal husbandry/lack of confinement, increased age of pigs, using rivers and ponds as water sources, and lack of official or even adequate slaughter facilities without regulation or pig inspection before and during slaughter are risk factors associated with corresponding high prevalences of PC [7, 33, 35, 50, 58]. Conditions of slaughter facilities in Dar es Salaam were assessed as not well developed which contributed to high condemnation numbers [42, 43]. The Arusha abattoir's records indicated that from 2005-2007, *T. solium* infections were the leading cause of condemnation (1.397%) for pig carcasses [41].

In addition to these common risk factors, type of feed provided for pigs and feeding method may provide opportunity for parasites to move from humans to pigs [7]. Prevalence levels measured by lingual examination are generally lower than those

measured via Ag-ELISA; a comparison study of multiple African countries including Tanzania suggested that "if more than 10% of pigs are tongue cyst-positive in an area, then these areas will be at high risk of cysticercosis with more than 30% of pigs being infected", showing a consistent relationship between results of the two tests [23]. One study identified the hind and forelimbs of pigs as having the highest proportions of cysts, with the "tongue, heart, triceps brachii, and diaphragm" showing lower proportions, and "estimated that 10.6% of the cysts would be located at inspected sites if regulations were followed carefully" [3]. Another study showed minimal evidence of *T. solium* in 70 pig carcasses at slaughter labs, indicating that pre-slaughter lingual examinations are a useful way to reduce infected pork in the food supply [60]. A recent study focuses on the intervention of vaccination, which has given much promise in recent years [1].

Table 6. Results of prevalence studies on porcine cysticercosis conducted in Tanzania

PC prevalence (%)	Area surveyed	Number of pigs surveyed	Type of survey	Reference
7.3	Mbulu District	784	Lingual exam Ag ELISA	[63]
7.5	Iringa	308	Lingual exam	[87]
26.7	Mbulu Mbozi Kongwa	86	Lingual exam	[75]
17.4	Mbulu District	770	Lingual exam	[57, 58]
14.9	Kongwa District	314	Lingual exam	[66]
5.9	Dar es Salaam (highest from Manyara and Dodoma regions)	731	Post-mortem dissection	[42]
11.7 and 32	Mbozi District	300	Lingual exam Ag ELISA	[32, 33]
6 and 30.7	Mbeya District	300	Lingual exam Ag ELISA	[32, 33]
26	Mbeya and Mbozi Districts	180	Serum test	[35]
13, 25, and 8.2	Babati District	1481	Lingual exam, Ag ELISA, dissection	[31]
11.5	Mbozi and Mbeya (higher) Districts	482	Ag-ELISA	[30]
1.54	Morogoro	260	Ag ELISA	[27]
14.9	Kongwa District	309	Lingual exam	[64]
15 – 31	Mbeya Region	2234	Ag ELISA	[5]
15 – 24	Mbeya Region	2632	Ag ELISA	[6]

7.6 8.4 16.9	Chunya District Iringa District Ruvuma Region	722 808 302	Lingual exam	[4]
1.2	Mbeya District	243	Dissection	[8]

2. *HuT Prevalence:* Humans serve as the host for the adult form of *T. solium.* Risk factors for HuT in rural areas of Tanzania are present and include no access to tap water, lack of boiling drinking water, no or poorly maintained toilets, not raising pigs in contained management systems, being female, and increasing age [50, 52, 87]. *T. solium* sero-epidemiological data from global endemic areas has been reviewed [15].

Table 7. Results of prevalence studies on human taeniasis conducted in Tanzania

HuT prevalence (%)	Area surveyed	Number of persons surveyed	Type of survey	Reference
1.1 – 4.1	Mbeya Region	830	Ag-ELISA, Ab-ELISA, CT scan, copro-Ag-ELISA	[51, 52]
16.3	Mbulu District	544	Cysticercus IgG Western Blot Assay	[47, 48, 49]
0.4 (noted as endemic)	Kongwa District	1057	Coprology	[17]
1.5 3.0	Mbeya Region Mbozi Region	3000	Copro-Ag-ELISA	[11]

3. *NC Prevalence: T. solium* infections can cause NC in both pigs and humans, and is considered "the most common parasitic infection of the central nervous system in humans" [24]. In pigs, NC can cause behavioral changes in pigs, and reducing overall movement [80] in addition to neurological signs recently found in research such as seizures, loss of muscle control, salivating, walking in circles, etc. [78]. Additionally, a study of six pigs infected with *T. solium* NC showed larger amounts of collagen in brain tissue in pigs presenting seizures [14]. Since "clinical signs in pigs were [not]…consistent", researchers caution against only using these signs to diagnose porcine NC [45].

   In humans, epilepsy is highly correlated with NC caused by *T. solium*, although there are examples of NC without epilepsy in humans [24]. One study of 212 persons with epilepsy (PWE) showed that PWE with NC were "more likely to be

older at first seizure…consumed more pork, and were more often a member of the Iraqw tribe" [2]. The prevalence of active convulsive epilepsy in Ifakara, Tanzania was 14.8% in 2013 [68]. A study of 212 people with epilepsy found via cerebral CT scanning higher incidences of epilepsy in those with lesions "definite…highly suggestive…or compatible" with NC at 2.4%, 11.3%, and 4.2%, respectively, when compared to non-epileptic persons [83]. Another study of epilepsy prevalence found the highest numbers in Ifakara, Tanzania compared to other sub-Saharan African countries and noted that adult-onset epilepsy had a strong association with *T. solium* infections [37, 68]. See Table 8 and Majofane et al. [36] for a summary of human NC prevalence studies in Eastern and Southern Africa.

Table 8. Results of prevalence studies on neurocysticercosis conducted in Tanzania

NCC prevalence (%)	Area surveyed	Number of persons surveyed	Type of survey	Reference
14 – 56	Tanzania	(multiple studies)	CT scanning Serology Cerebral spinal fluid screening	[69]
1.7	Manyara and Singida regions	340		[76]
76	Mbulu District	25 (positive for cysticercosis)	CT scanning	[48, 49]
2.8	Hai District	218 (positive for epilepsy)	CT scanning, western blot assay	[26]
2.7	Northern highlands	291 (positive for epilepsy)	CT scanning and serology	[25]

4. *Control*: Scientists encourage a multi-faceted approach to controlling *T. solium* in Tanzania to involve multiple stakeholders, including medical, veterinary, environmental, and social representatives [19, 51, 79]. A global review of control and elimination focused on community based interventions [12].
    - Education/Sanitation: Methods to educate communities in Tanzania have employed educational videos [73], mass media such as radio programs [60], and in-person training and handouts [65]. Knowledge related to *T. solium* transmission was rated very important, significantly lacking among pig farmers, and high in changeability, highlighting knowledge and education to fill gaps as desirable targets for intervention [60]. Superstitions and habits of pig farmers must also be addressed [40], as one study found that people in Iringa district believe that epilepsy is caused by "spirits, witchcraft and/or inheritance", which may impact availability of medical attention for epileptic

persons [13]. One of the more unique solutions to the lack of education for *T. solium* is an educational computer game/program named "The Vicious Worm" released in 2014, which significantly increased the knowledge level of learners in only two weeks after experiencing this health education tool [18, 28, 77];. Education has been shown to reduce prevalence of *T. solium* in Tanzanian communities, but some respondents reported that they would continue some high risk-practices even after learning [65]. Another study involved primary and secondary school children, found that PC education improved scores by about 10% in primary schools six months after education, but scores were lower for secondary students [53]. On a positive note, a 2008 study of villager porcine cysticercosis education found a 42% improvement in knowledge at 10-12 months' post-education, although actual practices did not improve [62]. Also, one study noted that "health and pig management education intervention would have a significant financial benefit to the smallholder pig farmers in Mbulu District" [61]. A study of 80 households in the Southern highlands found a "substantial portion of respondents" who were aware of *T. solium* infections in the area, though the percentage of households with correct information on the *T. solium* life cycle was lower [39]. Recommendations for community education topics include: house pigs in pens exclusively, build and use latrines with closing doors (including for children's feces), wash hands after using latrines and before eating, boil all drinking water, do not eat or sell infected pork, seek medical attention if showing symptoms of worm infection or epilepsy, and see livestock extension assistance if cysticercosis is discovered in any pigs [65].

- Policy*:* In addition to education on multiple *T. solium*-related topics, a working group suggested the establishment of a regional reference center with accompanying medications and equipment to create "infrastructure for research, training, surveillance and control activities" [16].
- Vaccination: No information available.
- Therapeutic/Anthelmintic: For human *T. solium* infections, praziquantel and niclosamide are the two currently available treatments [29]. One study noted significant reductions of taeniasis cases when school-aged children were treated with praziquantel and the "track and treat" method [10, 11].

Several treatments for pigs with varying efficacy are available and include oxfendazole, which seems to be the most effective against muscular cysts but has limited availability in "most endemic settings" in addition to little effectiveness against brain cysts [29]. Ivermectin (not effective against *T. solium*) and oxfendazole (effective against muscular cysts) have been tested in naturally-infected pigs and have not been effective against brain cysts [44]. In addition to this treatment, two vaccines for porcine cysticercosis are being developed [29]; another study suggested using TSOL18 antigen as a cysticercosis control vaccine [20]. The treatment of pigs via vaccination and oxfendazole was recommended to be accomplished through both public and private good

efforts; pig farming is generally condensed into small areas, and the Tanzanian government is supportive of control/prevention efforts [22].

One study [64] suggests a combined treatment approach to target human and pig populations or combine cysticercosis treatments with treatment for other gastrointestinal helminths. The "CystiSim" model is a possible tool to evaluate the effect interventions for both pigs and humans [9].

5. *Diagnostic Tools:* For PC these include (1) lingual palpation, which is less sensitive and not effective in pigs with light infections [87]; (2) postmortem dissection, a detailed and generally comprehensive measure; (3) serum testing via ELISA and immunoblot assays, which can identify infections in pigs who passed lingual inspections [74]; and (4) possible serum genetic testing [38]. Lingual palpation or examination is much more useful for identifying infected pigs than cysticercosis-free pigs, is "not suitable for monitoring the incidence of [PC] seroconversion", and cannot "enable approval of pig meat for human consumption" [67].

   For NC, diagnostics in persons with epilepsy include "cerebral computed tomography (CT)" [83] or testing levels of "anticysticercal antibodies" in serum and cerebrospinal fluid samples [82].

This literature review section reflects a significant body of published data related to *T. solium* porcine cysticercosis, human taeniasis, human neurocysticercosis and control in Tanzania.

Questionnaire analysis

Pig farmer analysis

The pig farmer questionnaire was designed to quantify the demographics of each target country's pig farmers, their pig husbandry practices, the environmental factors which impact the prevalence of cysticercosis in their pigs (i.e., presence and use of latrines, etc.), and knowledge about tapeworm infection (taeniasis) and neurocysticercosis in humans in these communities (n=559). Simple contingency table results are in Appendix 9.

A summary of the results of the questionnaire conducted with Tanzanian pig farmers (n=559) is below:

Demographics
• Respondents were 66% male and 34% female. • Respondents were from a wide range of villages around Tanzania, with 14% from Msanyila.
Pig management/husbandry awareness
• 57% practiced a confined husbandry system, with 19% allowing their pigs to free range completely. • 59% fed a commercial feed, 31% feed a mixture of commercial feed and household scraps, and 9% reported feeding only household scraps. • 99% reported that they kept pigs for sale, and only 1% of respondents kept pigs for home consumption. • Worms was the highest reported pig health issue encountered (94%), followed by other (11%), anorexia (7%), and cysticercosis (3%). • 98% do not slaughter their pigs at home, but only 38% had the meat inspected.
Knowledge about tapeworm infection
• Only 19% have heard of human tapeworm infections. • When asked how people acquire tapeworm infections, 46% said “infected meat”, 40% didn’t know, and 14% said other. • 55% of respondents had heard of humans with epilepsy. • 42% had observed “measles” in pig meat.
Environmental factors
• 93% of pig farmers reported that a latrine was both present and used, and 6% reported that a latrine was not present or used. • Water was sourced from a borehole for 41%, 39% from natural sources, and 14% from taps. 55% of these sources were closed, and 39% were natural.

Policy maker analysis

The policy maker analysis is presented below with results from 30 Tanzanian policy makers.

The simple contingency table with details of these results is available in Appendix 10.

Demographics
• Respondents were 73% male and 27% female and aged from 20-60 years. • Median number of years in role was 5.5 (range from 0.3 to 18). • Respondents were involved in academia, veterinary services, health services, and other areas.
Knowledge
• *T. solium* taeniasis is not reported to be a notifiable disease, and 97% reported that neurocysticercosis is also not a notifiable disease in Tanzania. • 67% agreed that Tanzania does engage in health education for *T. solium* control.

- 40% of respondents agreed that no improvements pertaining to *T. solium* control were made to the meat inspection service in the last 10 years, but 40% did not know if improvements were made. 20% agreed that improvements had been made.
- Only 30% of respondents are aware that a vaccine for *T. solium* is available.

Practice
• Only 53% reported that Tanzania currently is undertaking mass drug administration for taeniasis. • Respondents agreed (90%) that Tanzania does not engage in active identification and treatment of taeniasis cases. • Respondents agreed that the heart (95%) and tongue muscle (80%) is examined visually for cysts but were divided on which other parts were examined for cysts. • Only 53% agreed that Tanzania currently treats pigs with anthelmintics and engages in programs to improve sanitation to treat taeniasis infections. • Respondents tended to agree (67%) that Tanzania currently engages in *T. solium* control strategies.

Summary of findings

Tanzania has published an extensive number of peer reviewed scientific papers on the prevalence of PC, HuT and human NC as well as education and interventions in high pig production areas. This results in an understanding of the extent of this parasite's distribution geographically in pigs and humans. National government programs focusing on PC, HuT and human NC regulations, education and prevention and control are continuing to advance in Tanzania.

Some findings include:

- Pig farmers and policy makers were 66-80% male.
- 99% of farmers keep pigs for sale, and 98% do not slaughter their pigs at home.
- 55% of pig farmers are aware of humans with epilepsy.
- In terms of policy makers' awareness, 100% reported that HuT and 97% that NC are not notifiable, 30% are aware of a *T. solium* vaccine, and 40% state that no improvements have been made to the meat inspection service in the last 10 years.

Recommendations

This report has reviewed the status of porcine cysticercosis/human taeniasis and human neurocysticercosis across Tanzania and the following strategies are recommended to control and prevent this disease:

- Education: Efforts to create awareness through education at primary, secondary and tertiary levels and across all communities of all provinces across Tanzania. Educational programs in localized areas such as the Mbeya and Mbozi districts continue to be successful. In Tanzanian communities has been innovative for many years, and significantly increased awareness in communities and lowered prevalence of PC. Some examples cited are: 1. In primary and secondary school children, scores improved by about 10% in primary schools six months after

education; 2. In 2008, villager porcine cysticercosis education improved 42% in knowledge at 10-12 months' post-education; and 3. and "health and pig management education intervention would have a significant financial benefit to the smallholder pig farmers in Mbulu District". Methods to educate communities in Tanzania have employed educational videos, mass media such as radio programs, and in-person training and handouts.

- Pig management and husbandry: Improved pig management will produce more safe pork and reduce transmission to the environment and humans. This will increase awareness of transmission, and an understanding of how interventions will lead to safer pork adding value in this market sector, and improve public health.
- Interventions to impact disease: Improve interventions through regular diagnostics, prevention of infection, vaccine and anthelmintic treatments.
- One Health approach: Tanzania is the first country in the WHO African region and globally to develop a costed National Action Plan for Health Security (NAPHS) which include programs that support the One Health approach. This includes the March 2017 Prioritization of Zoonotic Diseases workshop and the June 2017 Planning for Performance (P4P) Workshop for One Health Platform (hosted by CDC and USAID) [86].

Uganda

Methodology

Literature review

The aim of this literature review was to examine the extent of porcine cysticercosis (PC) and human taeniasis/human cysticercosis (HuT/NC) and its control in Uganda. This review includes a brief introduction to the disease; summary of the prevalence of PC, HuT, human NC and their control; and diagnostic tools. The peer-reviewed scientific journal literature as well as "grey literature" sources (e.g., reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for Uganda from 1996 to 2017.

This literature review was created using the following steps: identification of information resources to search for appropriate literature, searching, screening results, and inclusion.

First, based on the scope of the literature review, appropriate information resources were identified. PubMed, Embase, Web of Science, and Scopus were identified as resources to search for primary and secondary peer-reviewed literature. CAB Abstracts, AGRIS, FAOSTAT, GIDEON, Global Health, Global Health Observatory (GHO) Data, and Google Scholar were identified as resources to search for primary and secondary, peer-reviewed and non-peer-reviewed, and grey literature.

Second, these resources were searched using the indicated interfaces. Searches were conducted and updated between September 2016 and May 2017. Searches included no restrictions for language or date. Searches were conducted in English. Sources searched included: PubMed, Embase (through the OVID interface), Web of Science (through the

Thomson Reuters interface), Scopus (through the Elsevier interface), CAB Abstracts (through the OVID interface), AGRIS (through both the native FAO interface and the OVID interface), FAOSTAT (through the native interface), GIDEON (through the EBSCO interface), Global Health (through the OVID interface), Global Health Observatory (GHO) Data (through the WHO interface), and Google Scholar.

Search terms represented the primary concepts for the literature review: parasite, intervention, and location. Searches combined the concepts for the parasite and associated diseases (*Taenia solium, T. solium*, porcine cysticercosis, swine cysticercosis, taeniosis, taeniasis, cysticercosis, cardiocysticercosis, neurocysticercosis, cysticercal meningitis, cysticercosis cellulosae), interventions (control, control*, vaccine, vaccines, vaccination, vaccin*, diagnosis, diagnostic, diagnos*, therapy, therapies, therapeutic, therap*, anthelmintic, anthelmintic*, educate, educate*, education, education*, sanitary, sanitation, sanita*), and country. Resources were searched both using terms from all three concepts and, also only parasite name and country. Results were exported to, and managed in a group library in Zotero.

During screening, titles and, if available, abstracts from the results were evaluated according to the following criteria: date (1996-2017 inclusive), country, and parasite. Items were not excluded due to publication type or language. Results for additional parasites, e.g., *Taenia saginata* were excluded unless they also included relevant information about *T. solium*. Additionally, key publications were used to identify additional references through both backward and forward citation searching (identifying works cited in the key publication); these were screened using the criteria above. Remaining items were reviewed for relevance.

Finally, in the inclusion phase, the authors extracted data on porcine cysticercosis, human cysticercosis, taeniasis, neurocysticercosis, control methods for *T. solium*, and diagnostic tools for *T. solium* from identified publications to include in this literature review.

Questionnaires

Pig Farmers: A standard questionnaire was prepared to interview 862 Ugandan pig farmers to explore and analyze the current situations of pig production and husbandry, and understand knowledge, attitudes and practices regarding PC/HuT/NC among the respondents. Sections of this questionnaire include: demographics, pig management, and human health. The questionnaire is included in this report as Appendix 1.

Pig Traders: A standard questionnaire was prepared to interview 10 pig traders to explore and analyze the current situations of pig production and husbandry, and understand knowledge, attitudes and practices regarding PC/HuT/NC among the respondents. Sections of this questionnaire include: demographics, human health, awareness of cysticercosis in pigs, and pig trade related items. The questionnaire is included in this report as Appendix 2.

Policy Makers: A standard policy maker questionnaire was prepared to interview experts across One Health disciplines to understand and collect their views/suggestions towards designing a vision for control of taeniasis/cysticercosis in humans and pigs in Uganda. Sections of the policy maker questionnaire include: demographics and current *T. solium* strategies. The questionnaire is included in this report as Appendix 3. The experts interviewed represented 14 from the animal health/veterinary/agriculture/livestock section and 16 from the human health/medical/public health arena.

Each policy maker was contacted by email to invite their participation via completion of a survey specific to their country; policy makers were contacted no more than four times and could opt-out of the survey if desired at any time. The surveys were provided in a fillable PDF form and in a Word document format, and participants returned completed questionnaires via email. Participants were also provided with the option to complete the survey by phone or in person with an interviewer if desired. Data from the surveys was compiled into a spreadsheet for analysis. A list of respondents with contact details is available in Appendix 6.

Data analysis methodology

For questions with categorical responses, binomial and multinomial proportions (expressed as percentages) were generated and presented as simple contingency tables. The simple contingency tables are available in Appendices 13-15 and are comprised of three columns: one for the question asked, followed by a second column for the possible set of responses (answers), and the third column for the percentages of respondents who selected a particular response. All analyses were performed using SAS version 9.4 (Cary, NC, USA).

Results and discussion

Disease and control status in scientific literature

The aim of this section is to examine the extent of porcine cysticercosis (PC) and human taeniasis/human cysticercosis (HuT/NC) and its control in Uganda. This section includes demographic data, a summary of the prevalence of PC, HuT, human NC, control and diagnostic tools; and a bibliography. The peer-reviewed scientific journal literature as well as "grey literature" sources (e.g., reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for Uganda from 1996 to 2017. The bibliography for Uganda is on pages 55-58.

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a. Demographic Data

In the last 10 years, Ugandan pig populations have doubled, while the human population has increased by almost 50% [3, 32]. As of 2015, the human population of Uganda was 39 million [36], steadily climbing from 10 million in 1970 and 23.7 million in 2000 [32]. The National Livestock Census estimated pigs to number over 3 million as of 2008, with more pigs in the Central (41.1%) and Western (24.4%) regions than in the Northern region (10.7%) [16].

b. Prevalence and control (vaccine, therapeutic, education/sanitation) of PC, HuT, and Human NC

1. *PC Prevalence:* Studies on PC prevalence in Uganda are generally based on post-mortem dissection at slaughter facilities or serological tests and/or lingual examinations in the field, with prevalence ranging from 9.4-44.9% and 0-27%, respectively [22]. Some studies have found much higher prevalence rates in the field than at slaughter facilities due to lingual inspections identifying heavily-infected pigs before slaughter; unfortunately, these pigs with heavy infections are often brought back to villages and eaten by unsuspecting humans [27]. Table 9 below summarizes prevalence reported by Phiri et al. [27], and Table 10 includes more recent prevalence studies found in the literature.

Table 9. Ugandan prevalence rates and surveys, from "Results of prevalence studies on porcine cysticercosis conducted in Eastern and Southern Africa countries" [27]

PC prevalence (%)	*Number of pigs surveyed*	*Type of survey*[a]	*Area surveyed*	*Reference*
33.7 – 44.5	600	P	Moyo District	[1]
0 – 33.7[b]	249	P	Central and Northern Districts	[6]

[a] P=post-mortem.

[b] Eight fetuses from a positive slaughtered pregnant sow were all found to be infected with cysticercosis.

Risk factors for PC and HuT in Uganda include the type of pig management (free range or tethering increase risk), lack of or poor pork inspection before slaughter leading to human consumption of infected pork, lack of knowledge in communities, improper human feces disposal, limited access to safe drinking water for both humans and pigs, improper pork preparation causing contamination [22]; pig breed type, lack of latrines [13]; and the manner in which pork is cooked or preserved [28]. Interestingly, higher prevalence rates in urban areas have been observed as compared with rural settings, possibly due to pigs being fed on or accessing infected food or water even with intensive management methods being practiced [12]. Although lingual examination can identify heavily infected pigs, pigs with light infections can still enter the food supply if serological tests are not done [23].

Table 10. Results of prevalence studies on porcine cysticercosis conducted in Uganda

PC prevalence (%)	Area surveyed	Number of pigs surveyed	Type of survey	Reference
12.2	Maska, Kamuli, Mukono Districts	1185	Serological	[13]
18.0	Soroti District	178	Lingual and necropsy	[38]
8.5	Kamuli, Kaliro Districts	513	Serological	[34]
5.1	Moyo, Adjumani, Kitgum, Gulu Districts	217	Lingual	[31]
42	Wabizi abbatoir, Kampulu	136	Serological	[23]
21.5 28.1 23.2 20.3 28.1 33.9 25.7	Kayunga Kamuli Kaliro Kiberamaido Apac Amolator Total	378	Serological	[24]
12 8.3 6.2 7.4 19 19	Buyende Kayunga Kaliro Apac Oyam Kabermaido		Lingual	[21]
8.2 6.9 12.9 4.1 0 7.7 9.4	Amolator Kaberamaido Kamuli Kaliro Kayunga Apac Oyam	500	Lingual	[20]

2. *HuT Prevalence:* Humans serve as the host for the adult form of *T. solium.* Participants in one study reported that they had identified taeniasis in the home in 6.9-36% of households in six districts bordering Lake Kyoga where pork tapeworm is prevalent, meaning that tapeworm segments were seen in

stools [21]. These results should be confirmed via serological or coprological testing.

Table 11. Results of prevalence studies on human taeniasis conducted in Uganda

HuT prevalence (%)	Area surveyed	Number of persons surveyed	Type of survey	Reference
0.7[a]	Kampala	5313	Coprology	[8]
0.5[a]	Kampala	201	Coprology	[2]

[a] Included all *Taenia* spp.

3. *NC Prevalence:* Prevalence studies for NC in Uganda are limited. One study reported cases of epilepsy within the last five years in districts known to be infected with *T. solium*, with 11-35% of study participants sharing that epileptic persons were present in their home in districts bordering Lake Kyoga [21]. Incorrect diagnoses may also prevent NC from being diagnosed: *T. solium* cysts were also found in supposed onchocercomas during a prevalence survey of nodules [11]. Neurocysticercosis could be an unexpected secondary explanation for neurological symptoms associated with onchocerciasis [10]. An earlier study "demonstrated a geographical association between high prevalences of epilepsy and onchocerciases", but did not show that NC was important in the study area [9]. These results should be confirmed via serum sampling, CT scanning, or other methods. Additionally, NC is more frequently associated with adult-onset epilepsy than child-onset [19]. Notes of a workshop on cysticercosis and epilepsy noted the presence of epilepsy probably related to neurocysticercosis in Uganda, based on a "meta-analysis of epilepsy attributable to neurocysticercosis" [37].

   A study of urban, peri-urban, and rural households in Kampala, Uganda identified *T. solium* NC as one of four most important zoonotic diseases in the Kampala economic zone [14, 15].

Table 12. Results of prevalence studies on neurocysticercosis conducted in Uganda

NC prevalence (%)	Area surveyed	Number of persons surveyed	Type of survey	Reference
9.1	Iganga-Mayuge	152 PWE	Serological	[19]
33.3	Moyo District	21 onchocercomas	Excise onchocercoma and stain	[11]

4. *Control:* Challenges exist for programs attempting to control *T. solium* infections across sub-Saharan Africa, even with multiple interventions [7]. One report summarized two control measures that have been used in Uganda with limited success: ante-mortem lingual inspections of pigs and often irregular post-mortem pork inspection [22]. An effective control program should be "multidisciplinary and multilevel" and "demand full cooperation of medical, public health workers, veterinarians and the communities working in synergistic approach", as cysticercosis has vital implications for animal and human health [22]. For a general (non-specific to Uganda) landscape analysis of *T. solium* control, see Thomas's report [33].
    - Education/Sanitation: Of households surveyed in the Lake Kyoga region, 84% did not know the mode of taeniasis transmission to people [20]. Only 0.3% of 1096 farmers reported knowledge of PC, HuT, and human cysticercosis [13]. This same study also found that female farmers had less knowledge than male farmers, and highlighted the opportunity for targeted education. Although disease burden of *T. solium* and other parasites is high for Ugandan farmers, one study showed that the risk to consumers is low if pork is fried or roasted (thoroughly cooked), so training meat inspectors, butchers, and restaurant owners is an opportunity to improve public health [30]. The "Safe Food, Fair Food" project supported by the International Livestock Research Institute (ILRI) holds trainings for pig farmers to educate this population on parasites and their control/prevention [28]. As part of this project, Ouma et al. [26] identified challenges and opportunities in the smallholder pig value chain in Uganda and noted interventions that could be inserted at each stage, including: development of a biosecurity protocol for extension agents, training meat inspectors and butchers, conducting feasibility testing on various control and treatment methods, and sensitizing customers to pork zoonoses. Community-led total sanitation has reported success in reducing cysticercosis in other countries, but must be maintained over an extended period of time [22].
    - Policy: One study found that "policy development in Uganda and Nigeria's public health sectors are highly influenced by external donors,

the prevailing political economy and lack of evidence for funding many alternative disease options" (p. 805), and may "overlook national and regional zoonoses policies" [25]. Changing, updating, and enforcing policies related to veterinary public health and parasite-related issues, including cysticercosis, could be an opportunity to limit the impact of *T. solium* [29].

- Vaccination: The TSOL18 vaccine has been successful in experiments in other countries but is not yet used in Uganda [22]. However, GALVmed is undertaking a large pilot study in the Kumi/Bukedea Districts of Uganda [4].
- Therapeutic/Anthelmintic: A study of 1096 Ugandan households in Masaka, Mukono, and Kamuli Districts found that "more farmers reported that they dewormed pigs (94.1%) than reported deworming themselves or their family members (62.0%)", and that albendazole was the most commonly used anthelmintic (or dewormer) for both groups [13]. Oxfendazole and praziquantel are both possible control strategies for treatment in pigs and humans, respectively, but must be used together to reduce infections and have not been successful yet in Uganda [21]. GALVmed is undertaking a large study on the use of anthelmintics in Uganda, which will fill the current gap in the literature [4].

5. *Diagnostic Tools:* For the studies identified in this literature review, lingual examination, serological testing, and post-mortem necropsy were the diagnostic methods used for cysticercosis in pigs. In humans, taeniasis was identified via coprology, and NC was identified through serology and staining on slides. Sensitivity and specificity of some of these methods, as found in the literature, are listed in Table 13.

Table 13. Estimates of the characteristics of the three diagnostic tests for the detection of *Taenia solium* taeniasis

Diagnostic test	Sensitivity (% CI)	Specificity (% CI)	Reference
HP10 Ag-ELISA	53.9% (10.01 – 100%)	97.0 % (95.9 – 100%)	[12]
HP10 ELISA	70.4% (52.7 – 84.7%)	66.1% (44.6 – 85.1%	[24]
ApDia Ag-ELISA	20.2% (1.5 – 47.7%	92.2% (90.5 – 93.9%)	[12]

CI: Credibility Interval

This literature review section reflects a significant body of published data related to *T. solium* PC, HuT, human NC and control in Uganda.

Questionnaire analysis

Pig farmer analysis

The pig farmer questionnaire was designed to quantify the demographics of each target country's pig farmers, their pig husbandry practices, the environmental factors which impact the prevalence of cysticercosis in their pigs (i.e., presence and use of latrines, etc.), and knowledge about tapeworm infection (taeniasis) and NC in humans in these communities. Simple contingency table is in Appendix 11. The results from 862 questionnaires are compared with Kungu et al. (2017b) results (n=1096).

A summary of the results of the questionnaire conducted with Ugandan pig farmers (n=862) is below:

Demographics
• Respondents were 60% male and 40% female, similar to 68% and 32%, respectively, in the Kungu et al. (2017b) study.
Pig management/husbandry awareness
• Farmers most often tethered their pigs for part of the day (57%), followed by free ranging (21%), penned for part of the day (14%), and confined (8%). In Kungu et al. (2017b), pigs were most often tethered for part of the day (53%) or confined (46%). • Most (52%) farmers fed a mixture of different feeds, with 35% feeding household food scraps and 11% using commercial feed. Only 1% used farm waste. • 87% kept pigs for sale, 14% for breeding, and only 3% for home consumption. 12% of farmers kept pigs for multiple uses. • The most common pig health problem was worms (89%), followed by anorexia (29%), cysticercosis (18%), and lice/mange/mites (10%). African swine fever and cough were listed by a few respondents as "other" health problems. • 85% of farmers or members of their families consume pork, and only 8% slaughtered pigs at home. • Unfortunately, 97% of the meat was not inspected by meat inspectors, compared to 78% of meat uninspected in the Kungu et al. (2017b) study.
Knowledge about tapeworm infection
• 62% of respondents had not heard of tapeworm infection. When asked how tapeworm infections were acquired, 48% chose "eating infected meat" and 48% chose "I don't know". Drinking unclean water and eating raw pork or unwashed vegetables were chosen by 1% of respondents as ways to acquire tapeworm infections. • 72% of respondents have heard of someone in their village complaining of epilepsy. • 51% of respondents had observed "measles" in pig meat before. 81% did not know what the "measles" were.
Environmental factors
• Only 54% of farmers had a latrine present that was used; 18% did not have access to a latrine. 27% of farmers had a latrine that was occasionally used.

- Boreholes were the main source of drinking water for 57% of respondents, 12% got water from natural sources, 7% from taps, and 24% from other sources. 64% of the sources were closed.

Pig trader analysis

Approximately 49 Ugandan pig traders completed the questionnaire. The simple contingency table of results is available in Appendix 12. A summary of the results of the questionnaire conducted with Ugandan pig traders is below:

Demographics
• Respondents were 90% male. • Respondents aged from 20-60 years, with the most (43%) ranging from 31-40 years. • For 63%, primary education was the highest level of education attained. 20% had completed secondary education/high school, and only 6% had completed some tertiary schooling.
Knowledge
• 59% had heard of tapeworm infection, and 33% had heard of or met someone complaining of having tapeworm infection. • When asked how one knows they have a tapeworm infection, 41% said “seeing tapeworm in stool” and 20% did not know. • When asked how people acquire tapeworm infections, 33% said “eating infected meat”, and 27% said “I don’t know”. Of the 10% that reported “other”, respondents were evenly split among eating dirty fruits, eating dirty items, and through water. • 98% had observed “measles” in pig meat, but 35% did not know what those measles were. • When traders saw measles in meat, 86% said they did not eat it, and 80% said they do not sell it. • 59% of traders did not know about the disease; 4% had learned about this disease from school, and 35% from an animal health office.
Practice
• When asked to identify main activities, respondents reported involvement in the following activities: 86% selling farm produce, 82% crops, 76% livestock, 76% business, and 51% other. • Sale of pork was the main income for 15% of respondents, and trade in pigs was the main income for 41%. • 67% of respondents said that people should go to the hospital if they have tapeworm infections. • 63% of respondents had heard of someone complaining of epilepsy. 22% had heard complaints of headaches, 6% of “madness”, and 4% of skin nodules. • 98% do purchase pigs among backyard piggery farmers, and 84% said they were aware of the disease “porcine cysticercosis” among backyard piggeries.

- 100% of those aware of PC among backyard piggeries checked tongues and meat at slaughter to determine if pigs were affected.
- If traders saw PC in a pig, 86% would reject the pig. 4% would reduce the price and 6% would trim the affected part of the pig. Of those that reduced the price, the reduction was 50%.

Policy maker analysis

The policy maker analysis is presented below with results from 30 Ugandan policy makers. The simple contingency table with details of these results is available in Appendix 13.

Demographics
• Respondents were 83% male and 17% female and aged 31-70 years. • Median number of years in role was 6.0 (range from 0.3 to 28). • Respondents were involved in academia, veterinary services, agriculture, human and public health, and other organizations.
Knowledge
• 77% reported that *T. solium* taeniasis was not a notifiable disease, but 13% reported that it was. 10% did not know if taeniasis was a notifiable disease. • A similar discord was present for neurocysticercosis notification: 13% agreed that it is notifiable, but 73% said that it was not. 13% did not know. • 50% agreed that Uganda engaged in health education for *T. solium* control. Some respondents added that this education was part of the duties of researchers, field veterinary officers, or public health education companies. • 57% of respondents said that improvements have not been made to the meat inspection service in the last 10 years, but 20% said that improvements had been made. • 53% of respondents were aware of a vaccine for *T. solium* control, and 50% of respondents also agreed that Uganda is currently engaged in anthelmintic treatment for pigs. Only 40% agreed that Uganda was involved in a sanitation improvement program to control *T. solium*.
Practice
• Respondents generally disagreed (43%) or were unaware (43%) that Uganda is currently involved in *T. solium* control strategies. • 70% of policy makers reported that Uganda does not currently undertake mass drug administration (MDA) for taeniasis. However, 23% said that Uganda does participate in MDA for taeniasis. • 27% said that Uganda does engage in active identification and treatment of taeniasis cases, but 70% disagreed with that statement. • Overall, respondents disagreed on the pig parts that were examined for cysts. The most agreement (50%: yes) was for masseter muscle examined by eye, masseter muscle incised (47%: yes), and tongue incised (47%: yes). Respondents also noted that meat inspection was limited with most slaughters not inspected.

Summary of findings

In the last 10 years, Uganda's pig population increased to 3 million as compared to 1.0-1.6 million for the other three countries in this report. Uganda has undertaken and published research of PC/HuT/NC statistics in peer reviewed scientific journals which demonstrates the high prevalence levels in humans and pigs in production areas. With this impetus, national government programs for regulation, education, prevention, and control of PC, HuT and human NC are advancing.

Some findings include:

- Demographic data confirm that the majority of pig farmers, pig traders and policy makers are male (60-90%).
- Pig management/husbandry figures confirm that 87% keep pigs primarily for sale, 97% of meat is not inspected, and 85% of farmers and their families consume pork, with few slaughtering pigs at home.
- Regarding PC awareness, 38% of pig farmers and 59% of pig traders had heard of human tapeworm infection, 72% of pig farmers and 63% of pig traders have heard of epilepsy in their village, 81% of pig famers did not recognize measles, but 98% of pig traders with and only 35% knew what these were.
- Regarding practices, 54% of pig farmers have latrines.
- In terms of economics, pork represents 41% of pig traders' income.
- In terms of policy makers' awareness, 77% reported that taeniasis and 73% that NC are not notifiable, 53% are aware of a *T. solium* vaccine, and 57% state that no improvements have been made to the meat inspection service in the last 10 years.

Recommendations

This report has reviewed PC, HuT and NC across Uganda, and the following strategies are recommended to control and prevent this disease:

- Education: Efforts to create awareness through education at primary, secondary and tertiary levels, and across all communities of all provinces across Uganda. Educational programs in localized areas such as the Kumi and Kamuli districts have been successful.
- Pig Management and Husbandry: Extension specialists to improve pig management to create safer pork and decrease transmission to pigs and humans in the environment. This will require increased awareness of transmission, and an understanding of how improved pig management will lead to increased safe pork and improved public health.
- Interventions to Impact Disease: Improve interventions through prevention and control steps such as regular diagnostics, prevention of infection, and regular vaccine and anthelmintic treatments.
- One Health Approach: Uganda's published research and prevention and control programs for PC, HuT and NC includes collaborative interdisciplinary teams who represent a broad range of disciplines. These include medical, agricultural, zoonotic expertise, educationists, government and policy makers, researchers and field and lab veterinarians. This integrated team continues to demonstrate the ability to effectively prevent and control this parasitic disease through surveillance and

diagnostic capacity. The policy makers who completed the questionnaires for this landscape study also represented a wide range of disciplines including veterinary, medical, agriculture, policy and industry sectors.

Zambia

Methodology

Literature review

The aim of this literature review was to examine the extent of porcine cysticercosis (PC) and human taeniasis/human cysticercosis (HuT/NC) and its control in Zambia. This review includes a brief introduction to the disease; summary of the prevalence of PC, HuT, human NC and their control; and diagnostic tools. The peer-reviewed scientific journal literature as well as "grey literature" sources (e.g., reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for Zambia from 1996 to 2017.

This literature review was created using the following steps: identification of information resources to search for appropriate literature, searching, screening results, and inclusion.

First, based on the scope of the literature review, appropriate information resources were identified. PubMed, Embase, Web of Science, and Scopus were identified as resources to search for primary and secondary peer-reviewed literature. CAB Abstracts, AGRIS, FAOSTAT, GIDEON, Global Health, Global Health Observatory (GHO) Data, and Google Scholar were identified as resources to search for primary and secondary, peer-reviewed and non-peer-reviewed, and grey literature.

Second, these resources were searched using the indicated interfaces. Searches were conducted and updated between September 2016 and May 2017. Searches included no restrictions for language or date. Searches were conducted in English. Sources searched included: PubMed, Embase (through the OVID interface), Web of Science (through the Thomson Reuters interface), Scopus (through the Elsevier interface), CAB Abstracts (through the OVID interface), AGRIS (through both the native FAO interface and the OVID interface), FAOSTAT (through the native interface), GIDEON (through the EBSCO interface), Global Health (through the OVID interface), Global Health Observatory (GHO) Data (through the WHO interface), and Google Scholar.

Search terms represented the primary concepts for the literature review: parasite, intervention, and location. Searches combined the concepts for the parasite and associated diseases (*Taenia solium, T. solium*, porcine cysticercosis, swine cysticercosis, taeniosis, taeniasis, cysticercosis, cardiocysticercosis, neurocysticercosis, cysticercal meningitis, cysticercosis cellulosae), interventions (control, control*, vaccine, vaccines, vaccination, vaccin*, diagnosis, diagnostic, diagnos*, therapy, therapies, therapeutic, therap*, anthelmintic, anthelmintic*, educate, educate*, education, education*, sanitary, sanitation, sanita*), and country. Resources were searched both using terms from all three

concepts and, also just parasite and country. Results were exported to, and managed in a group library in Zotero.

During screening, titles and, if available, abstracts from the results were evaluated according to the following criteria: date (1996-2017 inclusive), country, and parasite. Items were not excluded due to publication type or language. Results for additional parasites, e.g., *Taenia saginata* were excluded unless they also included relevant information about *T. solium*. Additionally, key publications were used to identify additional references through both backward and forward citation searching (identifying works cited in the key publication); these were screened using the criteria above. Remaining items were reviewed for relevance.

Finally, in the inclusion phase, the authors extracted data on porcine cysticercosis, human cysticercosis, taeniasis, neurocysticercosis, control methods for *T. solium*, and diagnostic tools for *T. solium* from identified publications to include in this literature review.

Questionnaires

Pig Farmers: Sections of this questionnaire include: demographics, pig management, and human health. A standard questionnaire was prepared to interview 271 pig farmers to explore and analyze the current situations of pig production and husbandry, and understand knowledge, attitudes and practices regarding PC/NC among the respondents. These questionnaires were completed in 2015.

Pig Traders: A standard questionnaire was prepared to interview 6 pig traders to explore and analyze the current situations of pig production and husbandry, and understand knowledge, attitudes and practices regarding PC/HuT/NC among the respondents. Sections of this questionnaire include: demographics, human health, awareness of cysticercosis in pigs, and pig trade related. The questionnaire is included in this report as Appendix 2.

Policy Makers: A standard policy maker questionnaire was prepared to interview experts across One Health disciplines to understand and collect their views/suggestions towards designing a vision for control of taeniasis/cysticercosis in humans and pigs in Zambia. Sections of the policy maker questionnaire include: demographics and current *T. solium* strategies. Sixteen respondents represented the medical area, and 7 represented the veterinary area. The questionnaire is included in this report as Appendix 3.

Each policy maker was contacted by email to invite their participation via completion of a survey specific to their country; policy makers were contacted no more than four times and could opt-out of the survey if desired at any time. The surveys were provided in a fillable PDF form and in a Word document format, and participants returned completed questionnaires via email. Participants were also provided with the option to complete the survey by phone or in person with an interviewer if desired. Data from the surveys was compiled into a spreadsheet for analysis. A list of respondents with contact details is available in Appendix 7.

Data analysis methodology

For questions with categorical responses, binomial and multinomial proportions (expressed as percentages) were generated and presented as simple contingency tables. The simple contingency tables are available in Appendices 16-18 and are comprised of three columns: one for the question asked, followed by a second column for the possible set of responses (answers), and the third column for the percentages of respondents who selected a particular response. All analyses were performed using SAS version 9.4 (Cary, NC, USA).

Results and discussion

Disease and control status in scientific literature

The aim of this section is to examine the extent of porcine cysticercosis (PC) and human taeniasis/human cysticercosis (HuT/NC) and its control in Zambia. This section includes demographic data, a summary of the prevalence of PC, HuT, human NC, control; diagnostic tools, and a bibliography. The peer-reviewed scientific journal literature as well as "grey literature" sources (e.g., reports, letters to the editor, newspaper or magazine articles, websites, etc.) is reviewed for the Zambia from 1996 to 2017. The bibliography for Zambia is on pages 58-61.

a. Demographic Data

As of 2015, the human population of Zambia was 16 million [40]. The population of pigs was over 1 million as of 2013 [8].

b. Prevalence and Control (vaccine, therapeutic, education/sanitation) of PC, HuT, and Human NC

1. *PC Prevalence*: The incidence of porcine cysticercosis in Zambia ranges from 20.6-56.6% in Lusaka, the capital of Zambia and decreases in studies carried out in the Eastern and Southern Provinces, ranging from 8.2-20.9%. In two comprehensive reviews of the literature in Eastern and Southern Africa, Phiri et al. [24] summarized prevalences in pigs in sub-Saharan African countries, including Zambia (see Table 14 below). Assana et al. [2] focuses on the intervention of vaccination, which has given much promise in recent years.

Table 14. Zambian prevalence rates and surveys, from "Results of prevalence studies on porcine cysticercosis conducted in Eastern and Southern Africa countries" [23]

PC prevalence (%)	Number of pigs surveyed	Type of survey[a]	Area surveyed	Reference
20.6 – 56.6	1316	S, P	Lusaka	[22]
8.2 – 20.8	249	L, S	Eastern and Southern Provinces	[23]

[a] P=post-mortem, L = lingual examination, S = serological.

Table 15 is a summary of PC prevalence studies in Zambia. Along with these results, researchers compared inspection methods in some studies. The results of using only one inspection method can have "serious shortcomings", with tongue palpation and meat inspection failing to identify infection in 83.9% and 61.3% of 65 village pigs [26]. Several risk factors were associated with higher prevalences of PC, including "lack of pork inspection at slaughter (96.7%), consumption of pork with cysts (20.1%), selling of pork infected with *T. solium* cysticerci (18.3%), free-range husbandry system (83.2%) and absence of latrines (58.0%). Free-range husbandry system (OR=1.68; 95% CI=1.36-2.07) was a significant risk factor for porcine cysticercosis in the surveyed areas" [29].

Table 15. Results of porcine cysticercosis prevalence studies conducted in Zambia

PC prevalence (%)	Number of pigs surveyed	Diagnostic tool used	Area surveyed	Reference
20.6	1316	Meat inspection	Lusaka, Southern and Eastern Provinces	[23]
11 – 54.8	1416	Ag-ELISA, Lingual exam	Lusaka, Southern and Eastern Provinces	[24, 25]
0.642	868	Lingual exam, Meat inspection, Ab-ELISA, Ag-ELISA	Lusaka	[7]
0.48	65	Dissection	Data not available.	[3]
42.4	66	Dissection	Unspecified villages	[1]
10.8 – 23.3	1691	Lingual exam, serum test	Katete, Petuake, Gwembe, Monze & Mongu Provinces	[31]
3.27	367	Lingual exam	Gwembe, Katete & Mongu Provinces	[28]

2. *HuT Prevalence:* In a 2015 review, African countries reported "The highest apparent prevalences of active [cysticercosis] infections" [5]. Historically, surveys of human taeniasis have been limited when compared to occurrences in pigs [10]. One challenge in testing for HuT is that the type of diagnostic test used can affect results due to similarities between parasites [27]. Table 16 below summarizes HuT prevalence rates reported in the literature.

Table 16. Results of human taeniasis and cysticercosis studies in Zambia

HuT and cysticercosis prevalence (%)	Number of humans surveyed	Diagnostic tool used	Area surveyed	Reference
0.3 – 6.3	718	Copro-Ag ELISA	Petuake District	[16]
11.	867	Copro-Ag ELISA	Katete District	[17]
0.6 – 1.2	817	Copro-PCR, Bayesian analysis	Petuake and Katete District	[27]
0.9	403	Coprology	Kafue District	[34][a]
1.6	378	Coprology	Lusaka	[20][a]

[a] Note: Results in this study did not specify *Taenia* spp.

3. *NC Prevalence:* Compared to PC, literature on NC is sparse. Mafojane et al. [13] reviewed all available published data for sub-Saharan Africa and reported little evidence for human neurocysticercosis in Zambia. This paper did observe that NC seems to be "the single most important cause of epilepsy" for humans in an endemic area of Zambia [18]. Neurological maladies caused by *T. solium* in pigs, can include "extensive astrogliosis, neuronal and mostly axonal damage…[and] loss of the blood-brain barrier" [32]. Humans also suffer neurological maladies. Human NC can be tested with a serum Ag-ELISA test or a urine Ag-ELISA test, with the less invasive urine test identifying more positive samples (24.3%) than serum (5.9%) in a group of 748 samples [15]. The researchers for that study recommended improvements to the urine test. One case study of a female child with seizures caused by neurocysticercosis who had spent a long period in a Zambian refugee camp has been described in the literature [12].

4. *Control*: Current control methods of *T. solium* infections for humans and pigs include: "community health education, improvements in hygiene and sanitary conditions, proper meat handling at household and community level, improved standards of meat inspection, pig management, and treatment of individual patients, human populations, and pig populations".
   - Education/Sanitation: An additional limiting factor to control is to do with community knowledge, attitudes and practices, which limit pig confinement due to socioeconomic reasons, knowledge, and gender [38], and cultural taboos associated with latrine use [37]. In 9 villages in Katete District in Eastern Province of Zambia, "Community-Led Total Sanitation…did not significantly improve *T. solium* infections in pigs", with a corresponding lack of change in "sanitation practices and awareness of cysticercosis" [4]. Prevalence levels in Katete have been identified as slightly higher than Petuake in a study of 680 households from 53 villages [19].

- Policy: No information available.
- Vaccination: Although vaccination of pigs may affect infection levels in humans, a study found variation in piglet sera antibodies, possibly due to "variable infection levels in the sows" [33].
- Therapeutic/Anthelmintic: Treatment of populations can include "preventative chemotherapy…anthelmintic treatment of pigs, and vaccination of pigs" [36]. Multiple methods should be used to combat this issue, with solutions chosen to reflect the needs of each community [9]. Unfortunately, control efforts may have limited efficacy in sub-Saharan Africa based on transmission model simulations developed with Latin American data [11]. A study of the effects of oxfendazole on *T. solium*-infected pigs reported that this was effective against muscular but not cerebral cysticerci, though it took 26 weeks post treatment to clear dead cysticerci [30]. *T. solium* cysts can be prepared through simple field methods for testing and yield the "high quality material" needed for diagnoses and research [28].

5. *Diagnostic Tools:* Veterinarians, health professionals, and government workers have multiple diagnostic tools to choose from for *T. solium* cysticercosis in pigs and humans. Most of these have already been mentioned, and in pigs include lingual (tongue) inspection, post-mortem meat inspection/dissection, and various tests utilizing blood or feces samples (e.g., Ag-ELISA, Ab-ELISA, copro-Ag ELISA, coprology, PCR). Use of biomarkers to identify infected pigs is a possible diagnostic tool, but this technology has not been refined adequately [6]. Coprology, coproantigen ELISA (copro-Ag ELISA) and real-time PCR are all possible diagnostic tools using human fecal samples, and results of a Bayesian test to determine their sensitivity and specificity are in Table 17 [27]. The copro-Ag ELISA test for fecal samples, although a reliable test for "established patent infections of *T. saginata*", may not be reliable during the infection phase prior to proglottid release [35]. Additional testing and development is necessary to further refine these more technological tests.

Table 17. Estimates of the characteristics of the three diagnostic tests for the detection of *Taenia solium* taeniasis [27]

Diagnostic test	Sensitivity (95% CI)	Specificity (95% CI)
Coprology	0.525 (0.111 – 0.965)	0.999 (0.995 – 1.000)
Coproantigen ELISA	0.845 (0.619 – 0.980)	0.920 (0.900 – 0.938)
Copro-PCR	0.827 (0.570 – 0.976)	0.990 (0.982 – 0.996)

CI, Credibility Interval; Coprology, microscopic identification of *Taenia* spp. Eggs in feces; copro-Ag ELISA, Enzyme-Linked Immunosorbent Assay for the detection of *Taenia* spp. Antigens in feces; copro-PCR, polymerase chain reaction assay for the detection of *T. solium* DNA in feces.

This literature review section reflects a significant body of published data related to *T. solium* porcine cysticercosis, human taeniasis, human neurocysticercosis and control in Zambia.

Questionnaire analysis

Pig farmer analysis

The pig farmer questionnaire was designed to quantify the demographics of each target country's pig farmers, their pig husbandry practices, the environmental factors which impact the prevalence of cysticercosis in their pigs (i.e., presence and use of latrines, etc.), and knowledge about tapeworm infection (taeniasis) and NC in humans in these communities (n=271). These results were compared with Sikasunge et al.'s (2007, n=788) study, and a simple contingency table of results is available in Appendix 14.

A summary of the results of the questionnaire conducted with Zambian pig farmers (n=271) is below:

Demographics
• All respondents were from the Katete district.
Pig management/husbandry awareness
• Respondents generally had only a few pigs, with only 16% having more than seven pigs, and 35% with only one pig. • 66% of farmers used a free-range system, compared to 83% using a free range system in the Sikasunge et al. (2007) study. 33% penned their pigs for part of the day. No pig owners reached in this survey confined their pigs. • 100% of farmers agreed that they fed maize bran ("gaga") to their pigs, while no pigs were fed commercial feed or free-ranged without supplement feed.90% fed their pigs seasonal fruits, 53% fed kitchen leftovers, and 15% fed crop residues. Only 12% fed maize grain. • If measles were found in the pigs, farmers reported various degrees of loss: a 75-100% loss was reported by 36% of farmers, and a 50-75% loss was reported by 29% of farmers.
Knowledge about tapeworm infection
• 94% of respondents said that they do not sell the meat when they see measles in it, compared to 82% that would not sell in the Sikasunge study.
Environmental factors
• 92% of respondents said that a latrine was present and used. 7% noted that latrines were absent. • For 70% of respondents, the tap is their main source of drinking water. Boreholes (25%) and natural sources (5%) were other water sources used. 95% of all water sources were closed/not natural.

Pig trader analysis

Six pig traders from Zambia completed the questionnaire, and results were analyzed. The simple contingency table of results is available in Appendix 16.

Demographics
• All respondents were male. 67% were aged 31-40, and 33% aged from 40-50. • 50% of respondents had completed secondary education (e.g., high school), and 33% had only completed primary education. 17% had no formal education.
Knowledge
• All respondents had heard of tapeworm infection and had heard of or met someone complaining of tapeworm infection. • When asked how people know they have a tapeworm infection, 33% said "seeing tapeworm in stool". The other 67% chose "other" and reported stomach pains, unusual gastrointestinal feelings, or a combination of the two. All respondents agreed that people with tapeworm infections should go to the hospital. • When asked how people acquire tapeworm infections, 33% said eating infected meat, 33% did not know, and 33% said by eating vegetables or from bad water. • 83% had heard of someone complaining of epilepsy, and 17% for chronic headaches. • 67% of pig traders had observed "measles" in pig meat, and respondents were evenly split on if they knew what the measles were. • All respondents said that they do not know how pigs acquire the infections, but would not eat or sell the meat. • 83% said that they learned about the disease from an animal health office, and 50% from an environment health office.
Practice
• When asked what their main activities were, all agreed that crops and "pig business especially in dry season" were main activities. 83% reported selling farm produce, 50% livestock, and 33% chose "other" or business. • 100% reported that they buy pigs from backyard piggery farmers and are aware of the disease "porcine cysticercosis" among these piggeries. • 75% identified infected pigs by a check of tongue and meat at slaughter, and 25% would identify pigs who were growing thin and potbellied. • All respondents reported that they would reject pigs infected with PC.

Policy maker analysis

The policy maker analysis is presented below with results from 23 Zambian policy makers. The simple contingency table with details of these results is available in Appendix 16.

Demographics
• Respondents were mostly (78%) male and 22% female and aged 20-70 years. • Median number of years in role was 6.5 (range from 0.25 to 32). • Respondents worked in academia, the Ministry of Health, and the Ministry of Veterinary Services.
Knowledge
• Most agreed that taeniasis (68%) and NC (73%) are not notifiable diseases in Zambia. • 57% agreed that Zambia engages in some type of health education for *T. solium* control.

- Only 38% of respondents were aware that a vaccine for *T. solium* control was available. 40% agreed that Zambia was currently engaged in anthelmintic treatment of pigs for *T. solium*.
- Respondents were divided (48% agreed, 29% disagreed, 24% did not know) on whether Zambia engages in active identification and treatment of taeniasis cases.
- 48% agreed that Zambia currently engages in at least one *T. solium* control strategy, but 86% reported that Zambia did use mass drug administration.
- 52% of respondents did not know if improvements specific to *T. solium* had been made to the meat inspection service in the last 10 years.

Practice
• Respondents did not agree if Zambia was not engaged in a program to improve sanitation for *T. solium* control (38% yes, 38% no, 24% did not know). • Respondents did not agree on which pig parts were inspected for cysts during slaughter. 52% agreed that tongue muscles (visually) were inspected. 48% agreed that the master muscles (visually), tongue (palpation and incised), and masseter muscles (incised were inspected for cysts.

Summary of findings

Zambia has produced leading research in the diagnostics of this parasite in humans and pigs, resulting in an understanding of distribution geographically in pigs and humans in this country. National government programs in PC, HuT and NC including regulations, education and prevention and control are developing.

Some findings include:

- Demographic data confirmed that 67-83% of pig farmers, pig traders and policy makers are male.
- Pig management/husbandry figures confirm that 66% of farmers keep pigs free-range which agrees with 83% in the Sikasunge et al. (2007) study. All surveyed pig farmers reported feeding maize and crops, with 53% feeding kitchen leftovers.
- Regarding PC awareness, 100% of pig traders had heard of tapeworm infection, 83% of pig traders have heard of epilepsy in their village.
- Regarding practices, 92% of pig farmers have latrines.
- In terms of economics, 100% pig famers recognize measles and understand the decreased loss of value to the carcass depending on the presence of measles.
- In terms of policy makers' awareness, 68% reported that taeniasis and 73% neurocysticercosis not notifiable, 38% are aware of a *T. solium* vaccine, and 38% state no improvements have been made to the meat inspection service in the last 10 years.

Recommendations

This report has reviewed PC, HuT and human NC across Zambia and the following strategies are recommended to control and prevent this disease:

- Education: Efforts to create awareness through education at primary, secondary and tertiary levels, and across all communities of all provinces across Zambia.

Educational programs in localized areas such as the Katete districts have been successful.

- Pig Management and Husbandry: Pig management to create safer pork and decrease transmission in the environment and to pigs and humans should be implemented. This will require increased awareness of transmission, and an understanding of how this intervention will lead to increased safe pork and improve public health.
- Interventions to Impact Disease: Improve interventions through steps such as regular diagnostics, prevention of infection, vaccine and anthelmintic treatments.
- One Health Approach: This approach requires an integrated team of medical, veterinary, agricultural, educational and policy disciplines to effectively prevent and control PC, HuT and NC including surveillance and diagnosis capacity in pigs and humans. The policy makers in Zambia who completed questionnaires for this landscape analysis represented medical, veterinary and policy disciplines. This interdisciplinary effort that includes animal, human and environmental specialists will prevent and control this disease.

Summary of findings, recommendations and conclusions

Summary of findings

This Landscape Analysis Report summarizes the current status of *T. solium* disease and prevention in South Africa, Tanzania, Uganda and Zambia in Eastern and Southern Africa and how each uniquely approaches PC, HuT and NC prevention and control. In preparation to introducing the PC interventions being tested, this Report summarizes the knowledge, attitudes and practices amongst pig farmers, pig traders and policy makers across four target countries. An additional purpose of this report is to assess the current status of the disease, identify gaps and opportunities and the existing framework for prevention and control.

Several objectives were outlined for this report and have been achieved:

6. Identifying the stakeholders and key opinion leaders with a view to maintaining regular contact and exchange of information. This objective was realized through questionnaires implemented to pig farmers, pig traders and policy makers across four countries.
7. Providing disease and control status of taeniasis/cysticercosis, current knowledge, attitudes and practices of key stakeholder communities for each country through analysis of questionnaires implemented to the public sector (government officials representing veterinary, medical, public health, environment, agriculture, education, etc.), pig farmers and traders, and industry, etc. This objective was achieved through questionnaires, contact and exchanges with stakeholders and an extensive review of the peer reviewed scientific literature. This resulted in identifying each country's unique achievements to prevent and control the disease.

8. Providing a landscape analysis for taeniasis/cysticercosis control in each of the target countries. This report outlines the landscape analysis for each of the four countries.
9. Identifying potential partners for Phase 2 PC control tools. Throughout this project, this goal was achieved by engaging and building trust and confidence with stakeholders ranging from on-the-ground pig farmers and pig traders to policy holders with broad experience in government, academic and industry players.
10. Identify gaps in policy and reasons for indifference towards PC and implications for and recommendations to GALVmed. Gaps in policy and reasons behind indifference towards PC and the implications have been identified in the summaries and recommendations for each country and in the final summary.

Policy recommendations

Based on this report's findings the following policy recommendations apply across the four countries:

- Education:
  - "Knowledge is power". Efforts to create awareness through education at primary, secondary and tertiary levels across all communities of all provinces should continue and embrace wider modalities of communication. Each country has demonstrated individual excellence in PC research, education, outreach and advocacy. This is an opportunity for each to share their prowess.
- Pig Management and Husbandry:
  - Improved pig management and extension will build awareness of the disease and empower communities from the resource-poor to the resourced. Pig farmers and pig traders could become the champions of spreading the message of life cycle, prevention and control and result in breaking the life cycle, leading to reducing infected pigs and reducing PC, HuT and NC.
- One Health Approach:
  - "One Health is the collaborative interdisciplinary approach to optimal health for animals, humans and environment" [5, 6 General]. This approach has been demonstrated in the four target countries. This project has the potential to bring these PC, HuT and NC teams closer together to share their successes with each other, and identify solutions together through implementation.
- Treatment and Prevention:
  - This includes mass drug administration of humans and pigs. The intervention combination oxfendazole and vaccine for pigs has proven effective.
  - Meat inspection educational tools which are available to be implemented at all levels of extension, abattoirs, animal health and veterinary programs, public health and medical programs and agricultural livestock.

Conclusions

GALVmed's commitment to identify gaps and create solutions that address sustainable poverty alleviation by making available and accessible animal health products (vaccines,

medicines and diagnostics) to livestock keepers in the developing world has been achieved through this Landscape Analysis Study. This Global One Health approach focuses on the societal need for solutions to PC, HuT and NC infections. GALVmed is currently implementing field testing of a vaccine (TSOL18) against PC co-administered with Oxfendazole (OFZ) as a control strategy for *T. solium* (pork tapeworm). This intervention that will reduce PC prevalence has been planned for an extended time and now is within reach. Ultimately, it will also decrease the prevalence of human taeniasis and neurocysticercosis.

The evaluation of how PC control integrates multiple (agricultural, veterinary, medical, food safety, public health, educational and sociological) frameworks of each of the four target countries embraces a Global One Health approach. There is also a need to evaluate how the Global One Health approaches at the research level is implemented as part of national control programs in the target countries of South Africa, Uganda, Tanzania, and Zambia. To gain an understanding of potential issues and concerns, this Landscape Analysis Report commissioned by GALVmed contributes to the evaluation package that will support advocacy activities and engagements with other partners and donors.

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References

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Appendices

- **Appendix 1:** Questionnaire for Taeniasis/Cysticercosis Landscaping Analysis of Stakeholders: Pig Farmers
- **Appendix 2:** Questionnaire for Taeniasis/Cysticercosis Landscaping Analysis of Stakeholders: Pig Traders
- **Appendix 3:** Questionnaire for Taeniasis/Cysticercosis Landscaping Analysis of Stakeholders: Policy Makers
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- **Appendix 15:** Zambia: Pig Traders Simple Contingency Table
- **Appendix 16:** Zambia: Policy Makers Simple Contingency Table

Appendix 1

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District.
Village.
HH.

Questionnaire for Taeniasis/Cysticercosis Landscaping Analysis of Stakeholders in Uganda: Farmers

Background

GALVmed's aim is to create solutions that address sustainable poverty alleviation by making available and accessible animal health products (vaccines, medicines and diagnostics) to livestock keepers in the developing world. As part of the programme "Protecting livestock, improving human life" funded by the Bill and Melinda Gates Foundation and UK Department for International Development (DFID), GALVmed is implementing activities related to Field Testing of a vaccine (TSOL18) against Porcine Cysticercosis (PC) co-administered with Oxfendazole (OFZ) as a control strategy for *Taenia solium*. In order to assess the potential for controlling taeniasis/ cysticercosis and how the disease is affecting people, the survey will seek responses on the knowledge, attitudes and practices of pig farmer stakeholder groups.

The information you provide will be handled with utmost confidentiality.

Please answer all questions relevant to the current situation in your county.

Section A: Demographics

1. **Date:** (dd/mm/yyyy)

2. **Interviewer Name**

3. **District**

☐ District a ☐ District b

☐ District c

Appendix 2

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Questionnaire for Taeniasis/Cysticercosis Landscaping Analysis of Stakeholders in Uganda: Traders

Background

GALVmed's aim is to create solutions that address sustainable poverty alleviation by making available and accessible animal health products (vaccines, medicines and diagnostics) to livestock keepers in the developing world. As part of the programme "Protecting livestock, improving human life" funded by the Bill and Melinda Gates Foundation and UK Department for International Development (DFID), GALVmed is implementing activities related to Field Testing of a vaccine (TSOL18) against Porcine Cysticercosis (PC) co-administered with Oxfendazole (OFZ) as a control strategy for *Taenia solium*. In order to assess the potential for controlling taeniasis/ cysticercosis and how the disease is affecting people, the survey will seek responses on the knowledge, attitudes and practices of trader stakeholder groups.

The information you provide will be handled with utmost confidentiality.

Please answer all questions relevant to the current situation in your county.

Section A: Demographics

1. **Date:** (dd/mm/yyyy)

2. **Interviewer Name**

3. **District**

☐ District a ☐ District b

☐ District c

Page 1 of 6

Appendix 3

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Questionnaire for Taeniasis/Cysticercosis Landscaping Analysis of Stakeholders in Uganda: Policy Makers

Background

GALVmed's aim is to create solutions that address sustainable poverty alleviation by making available and accessible animal health products (vaccines, medicines and diagnostics) to livestock keepers in the developing world. As part of the programme "Protecting livestock, improving human life" funded by the Bill and Melinda Gates Foundation and UK Department for International Development (DFID), GALVmed is implementing activities related to Field Testing of a vaccine (TSOL18) against Porcine Cysticercosis (PC) co-administered with Oxfendazole (OFZ) as a control strategy for *Taenia solium*. In order to assess the potential for controlling taeniasis/ cysticercosis and match the legislation to the practice we would like to evaluate the policy landscape by assessing the current practices used by your country in controlling taeniasis/ cysticercosis.

The information you provide will be handled with utmost confidentiality.

Please answer all questions relevant to the current situation in your county.

Section A: Demographics

1. **Date:** (dd/mm/yyyy)

2. **Interviewer Name**

3. **District**

☐ District a ☐ District b

☐ District c

Appendix 4
Policy maker respondents from South Africa

Name	Organization	Details	Address	Address2	Address3	Telephone	Email
Dr. Rosemary Peter	GALVmed (Global Alliance for Livestock Veterinary Medicines)	Programme manager: Animal African Trypanosomosis	Doherty Building, Pentlands Science Park	Bush Loan	Edinburgh EH26 0PZ United Kingdom	27 118831389	rose.peter@galvmed.org
Dr. Msawenkosi Sithole	Department of Agriculture, Forestry, and Fisheries	Control Veterinary Public Health Officer	P/ag X138	Pretoria 0001	South Africa	+2712 319 7515	MsawenkosiS@daff.gov.za
Dr. A.M. Tsotetsi-Khambule	Agricultural Research Council Onderstepoort Veterinary Institute		Private Bag X13, Phuthaditjhaba, 9866		South Africa		tsotetsiA@arc.agric.za
Dr. Hannes van Niekerk	Department of Agriculture - Veterinary Services	State Vet - Veterinary Public Health	Port Elizabeth		South Africa	041 4026252	hannes.vanniekerk@drdar.gov.za

Appendix 5
Policy maker respondents from Tanzania

Name	Organization	Details	Address	Address 2	Address 3	Telephone	Email
Justine Assenga	Ministry of Agriculture, Livestock and Fisheries	Principal Veterinary Officer				+255753860704	assengakanda@yahoo.com
Dr. Jelly Senyagwa Chang'a	Centre for Infectious Diseases and Biotechnology, Tanzania Veterinary Laboratory Agency	Manager	PO Box 9254	Dar es Salaam	Tanzania	+255 22 2861152	jelhas2002@yahoo.co.uk
David ED	Ministry of Education	Teacher					
Dr. Komba Erick							babagrid@yahoo.com
Esther	Ministry of Regional Administration and Local Government	Councillor				Missed	
Ally Fupi	Ministry of Health	Clinical Officer				+255655829903	jfwoma2005@yahoo.com
Joseph Guulo	Ministry of Regional Administration and Local Government	Councillor					guuloj@gmail.com
Shabani Halfani	Ministry of Health	Environmental Health Officer					shabanikra@gmail.com
Shaka Ibrahim	Ministry of Health	Environmental Health Officer					shakaibra11@gmail.com

Mary Kitambi	Ministry of Health	Principal Medical Officer				+255754222269	nkasakitambi@gmail.com
Arthur Komba	Ministry of Health	Environmental Health Officer				+255786995587/ 762982512	artben09@yahoo.com
Alex Magufwa	Ministry of Health	Medical Officer					magufwa_a@yahoo.com
Dr. Henry Budodi Magwisha	Tanzania Veterinary Laboratory Agency; Commonwealth Veterinary Association; Tanzania Veterinary Association		Veterinary Complex, 131 Nelson Mandela Road	PO Box 9254, 15487 Dar es Salaam	Tanzania	255 22 2861152	hbudodi@yahoo.com
Joseph Malakalinga	Tanzania Bureau of Standards	Quality Assurance Officer in Biotechnology and Molecular Biology				+255757915097	malakalingajoseph@yahoo.com
Zakaria Manya	Ministry of Health	Nursing Officer				255788525971.00	
Justina Margwe	Ministry of Health	Nursing Officer					justinamargwe1@gmail.com
Dr. Daniel Mdetele	Sokoine University of Agriculture		PO Box 3015	Chuo Kukuu Morogoro	Tanzania		mdeteled@yahoo.com
Dr. Issac Joseph Mengele	Tanzanian Veterinary Laboratory		PO Box 1752	Dodoma	Tanzania		mengele13@yahoo.com
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Dr. Roggers Mosha	Open University of Tanzania; GALVmed					255-784-522208	moochamotesha@hotmail.com
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Dr. Kabululu Mwemezi	TALIRI		TALIRI-Uyole, PO Box 6191, Mbeya	Sokoine University of Agriculture, PO Box 3019, Morogoro	Tanzania		mwemezie@yahoo.com
Sylvester Mwidunda	Tanzania Food and Drugs Authority (TFDA)	Drug Inspector					mwidunda6@yahoo.com
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Dr. Helena Ngowi	Sokoine University of Agriculture					+255 (754) 374 839	h_ngowi@yahoo.com
Dr. Bernard Ngowi	National Institute for Medical Research		National Institute for Medical Research, Muhimbili Medical Research Centre	Dar es Salaam	Tanzania		b_ngowi@yahoo.co.uk

Grace Quntine	Ministry of Education	Teacher				255768622 952.00	
Dr. Makungu Selemani	Ministry of Livestock and Fisheries Development, Dept. of Veterinary Services	PVO Epidemiology	PO Box 2870	40487 Dodoma	Tanzania	255 685 512 765	makungu57@gmail.com
Pellagio Shirima	Ministry of Health	Nursing Officer					pellagiashirima@yahoo.com

Appendix 6

Policy maker respondents from Uganda

Name	Organization	Details	Address	Address2	Address3	Telephone	Email
Dr. Chrisostom Ayebazibwe	NADDEC	Diagnostic and Epidemiology Centre	PO Box 513	Entebbe	Uganda	256 041 320 627	cayebazibwe@gmail.com
Dr. Sylvia Baluka	Uganda Veterinary Association	President				256700540415	sbaluka3@gmail.com
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Aggrey Batesaki	Ministry of Health, Kamuli district	District health officer				+256-785 984 812	abateaski@gmail.com
Dr. Fred Bisso	Uganda Medical Association	President				756837451	bissofred@gmail.com
Dr. Alysius Bukenya	Minister of Agriculture, Animal Industry and Fisheries		MAAIF Bukedea District				aloysbukenya@hotmail.com

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Dr. Francis Ejobi	Makerere University	Professor of public health				256-41-586938	ejobifrancis@yahoo.com
Stephen Ikodet	Ministry of health, Bukedea district	District health officer				+256-772535688	smccouncil@yahoo.com
Josephat Jombwe	Ministry of Health	Consultant Surgeon				+256 418 071	jombwe@gmail.com
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Robert Kagwire	Ministry of Health	Acting District health officer				+256 782 451 532	kagwirerobert@yahoo.com
Peter Kalyebi	Ministry of health	Senior Public Health Inspector				+256-772 459 098	bpkalyebi@gmail.com
Dr. Joseph Kungu	National Livestock Resources Institute		PO Box 96	Tororo	Uganda	256 78204 3931	kungu@live.com
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Dr. Kenneth Mugabi	Minister of Agriculture, Animal Industry and Fisheries	Senior Veterinary Officer	PO Box 513	Entebbe	Uganda	256 772 446 478	kmugabi@gmail.com
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Edridak Muheki Tukahebwa	Ministry of Health, vector control division	Assistant commissioner				+256 772 443 659	edmuheki@gmail.com
Dr. Fred Mukulu	Ministry of Agriculture, Animal Industry and Fisheries	Mukono District Production Officer				256-702-418384	mukonoproduction@gmail.com
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Dr. Robert Mwebe							rmwebe@gmail.com
Dr. Noelina Nantima	Ministry of Agriculture, Animal Industry and Fisheries	Assistant Commissioner, Animal Disease Control	PO Box 513	Entebbe	Uganda	256 772 515962	noelinanantima@yahoo.com
Dr. Kauta Nicholas	Ministry of Agriculture, Animal Industry and Fisheries	Chief Veterinary Officer					kauta.nicholas83@gmail.com
Dr. Zachary Nsadha	Makerere University						znsadhansadha@gmail.com
Suzan Okwakol	Ministry of Health, Kumi District	Assistant District Health Officer				+256 772 537 770	suzieokwakol@yahoo.com
John Opolot	Ministry Of Health, Kumi District	District Health officer				+256 772 416 795	johnopolot@gmail.com
Jokar Oryema	Ministry of Health	District health officer				+256 772 619 078	jakororyem410@gmail.com
Oundo G. Bwire	Retired from Ministry of Health	Retired District Health Officer				+256 772 507 510	gboundo@yahoo.com

Dr. Chris S. Rutebarika	Ministry of Agriculture, Animal Industry and Fisheries	Ag. Assistant Commissioner - Disease Control	PO Box 513	Entebbe	Uganda	256-41-321463	pace@utonline.co.ug
Prof Charles Waiswa	Ministry of Agriculture, Animal Industry and Fisheries		MAAIF COCOTU Project			256-772-501274	cwaiswa@yahoo.co.uk

Appendix 7
Policy maker respondents from Zambia

Name	Organization	Details	Address	Address2	Address 3	Telephone	Email
Prof. Dr Sekelani S. Banda	Ministry of Health Headquarters	Director Human Resources, Planning and Development				260966758833	
Dr. Patricia Mupeta Bobo	Ministry of Health Headquarters	Assistant Director-Child Health				260955154584	
Dr. Francis Bwalya	Ministry of Health Headquarters	Medical Officer					bwalyachiza@yahoo.com
Michelo Choopa	Ministry of Health	Consultant				260967024277	
Dr. Sarah Gabriel	Institute of Tropical Medicine	Department of Veterinary Public Health and Food Safety, Faculty of Veterinary Medicine, Ghent University	Salisburylaan 133	9820 Merelbeke	Belgium	+32 484050387	Sarah.Gabriel@UGent.be
Dr. Matthews Nakozi Kabeta	Ministry of Fisheries and Livestock	Head, Public Health				260979696633	
Dr. Chrispin Muyangana	Ministry of Health, University Teaching Hospital	Registrar Medical Doctor				260962492282	
Dr. John Mvula	Ministry of Health, University	Registrar Medical Doctor				26096549188	

	Teaching Hospital						
Dr. Tendai Mwale	Ministry of Health	Medical Care Giver				260979305302	
Dr. James Mwansa	Retired Ministry of Health	Senior Lecturer/Researcher					
Dr. Titele Mwansa	Ministry of Health	Medical Officer					titelemwansa@gmail.com
Mr. Syndey Mwanza	Ministry of Health.	Public Health Researcher					
Dr. Kabemba Evans Mwape	University of Zambia	School of Veterinary Medicine, Dept. of Clinical Studies	PO Box 32379	Lusaka	Zambia	+260 211291515	kemwape@yahoo.com
Dr. Maxwell Mwase	University of Zambia	Senior Lecturer and Pathologist	School of Veterinary Medicine, The University of Zambia	Lusaka	Zambia		mmwase@unza.zm
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Prof. I.K. Phiri	University of Zambia		School of Veterinary Medicine, The University of Zambia	Lusaka	Zambia	+260-211-291515	igkphiri@unza.zm
Frank Shamilimo	Ministry of Health	Chief CD/Neglected Tropical Diseases					
Dr. Joseph Siame	Ministry of Health	Medical Doctor				260955469893,	josephsiame11a@mail.com

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Dr. Namasiku Siyumbwa	Ministry of Health Headquarters	Medical Officer					namasikusiyumbwa@gmail.com
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Dr. Stanley Zulu	Ministry of Health	Medical Officer				260977464620	

Appendix 8: South Africa
Policy makers simple contingency table

Question	Answer	Percent
Country	South Africa	100%
Sex	Female	50%
	Male	50%
Age	41 - 50 yrs	50%
	51 - 60 yrs	50%
Designation	Chief State Veterinarian	33%
	Consultant	33%
	Senior Researcher	33%
Organization name	Agricultural Research Council-Onderstepoort	25%
	Department of Agriculture, Forestry and Fisheries	25%
	GALVmed	25%
	State Veterinary Services	25%
Designation and organization name	Chief State Veterinarian at State Veterinary Services	25%
	Consultant at GALVmed	25%
	Department of Agriculture, Forestry and Fisheries	25%
	Senior Researcher at Agricultural Research Council-Onderstepoort	25%
Role in organization	Conducts Research in Veterinary Parasitology	25%
	Control Veterinary Public Health Practitioner	25%
	Trypanosomosis Programme Leader	25%
	Veterinary Public Health	25%
Which sector do you work in?	Department of Veterinary Services	50%
	Non-Governmental Organisation	25%
	Other	25%
Other sector details	N/A	N/A
Does your country currently engage in ANY *T. solium* control strategies?	Yes	50%
	No	50%

Notification of Taeniasis: Is *T. solium* taeniasis a notifiable disease in your country?	No	100%
Notification of Neurocysticercosis: Is Neurocysticercosis a notifiable disease in your country?	Yes	25%
	No	50%
	I don't know	25%
Mass drug administration: Does your country currently undertake mass drug administration (MDA) for taeniasis?	No	75%
	I don't know	25%
Drug name	N/A	N/A
Identification and treatment of taeniasis cases: Does your country engage in active identification and treatment of taeniasis cases?	No	100%
Health Education: Does your country engage in ANY specific health education for the control of *T. solium*?	Yes	25%
	No	75%
Health education name	Extension work	100%
Heart examined by eye for cysts	Yes	50%
	No	50%
Masseter muscles examined by eye for cysts	Yes	50%
	No	50%
Tongue muscle examined by eye for cysts	Yes	50%
	No	50%
Diaphragm examined by eye for cysts	Yes	100%
Tongue palpated for cysts	Yes	25%
	No	75%
Heart incised to look for cysts	Yes	100%
Masseter muscle incised to look for cysts	Yes	100%
Tongue incised to look for cysts	Yes	25%
	No	75%
Other	Yes	50%

	No	50%
Other meat inspection details	Incisions in the distal Triceps brachii	50%
	Triceps muscles	50%
Improvements to the meat inspection service: Within the last 10 years have any specific improvements been made to the meat inspection service in your country for the specific control of *T. solium*?	No	100%
Vaccination of Pigs: Are you aware that vaccine for control of *T. solium* is now available?	Yes	75%
	No	25%
Anthelmintic treatment of pigs: Is your country currently engaged in the treatment of pigs with anthelmintic for the control of *T. solium*?	No	100%
Improvement of sanitation: Is your country currently engaged in a program to improve sanitation for the specific control of *T. solium*?	Yes	25%
	No	50%
	I don't know	25%
Other control strategies for *T. solium*: Is your country currently engaged in any activities for the control of *T. solium* not mentioned so far please describe them to us	Yes	50%
	No	50%
Other control strategies - description: If your country is currently engaged in any activities for the control of *T. solium* not mentioned so far please described them to us	Development	33%
	None	33%
	We currently busy with research on human and environmental factors that contribute to the prevalence of porcine cysticercosis in some part of the Eastern Cape Province	33%
There is a legal requirement to do so	No	100%
This was selected as the most effective strategy for *T. solium* control	Yes	25%
	No	75%
There was a close fit with other ongoing public health campaigns	Yes	25%
	No	75%
It was the most appropriate strategy within our current budget	No	100%

This was the most acceptable *T. solium* control strategy to the target population	No	100%
I do not know	Yes	25%
	No	75%
Other	No	100%
Other control reason details	N/A	N/A

Appendix 9: Tanzania
Pig farmers simple contingency table

Variable	Category	Percentage
Demographics		
District	A	66%
	B	34%
Village	Iganya	13%
	Isangati	11%
	Itepula	13%
	Iyunga mapinduzi	4%
	Izuo	4%
	Magamba	13%
	Mjele	8%
	Msanyila	14%
	Mshewe	8%
	Njelenje	9%
	Shuwa	4%
Sex	Female	34%
	Male	66%
Pig Management/Husbandry Awareness		
Husbandry systems	Confined	57%
	Free range	19%
	Penned for part of the day	8%
	Tethered for part of the day	16%
Type of feed	Commercial	59%
	Household scraps	9%
	Mixture	31%
	Other	2%
Keep pigs for sale	Yes	99%
Keep pigs for home consumption	Yes	1%
Pig health (main problems encountered)		
Anorexia	Yes	7%
Worms	Yes	94%
Cysticercosis	Yes	3%
Other (e.g. ASF)	Yes	11%
Pig slaughter/inspection		
Slaughter pigs at home	No	98%

	Yes	2%
Meat Inspected	No	62%
	Yes	38%
Environmental factors impacting human and animal health		
Presence of latrine	Absent	6%
	Other	1%
	Present	93%
Presence and use of latrine	Absent	6%
	Other	1%
	Present and sometimes used	0%
	Present and used	93%
Source of water	Borehole	41%
	Natural sources	39%
	Other (mixture)	6%
	Taps	14%
Source of water	Closed sources	55%
	Natural source	39%
	Other	6%
Knowledge about human tapeworm infection		
Ever heard of tapeworm infection?	No	81%
	Yes	19%
How do people acquire tapeworm infection?	Don't know	40%
	Infected meat	46%
	Other (unclean water, unwashed vegetables)	14%
Ever heard of any one with epilepsy	Yes	55%
Have you observed “measles” (*Cysticercus cellulose*) in pig meat?	No	58%
	Yes	42%

Appendix 10: Tanzania
Policy makers simple contingency table

Question	Answer	Percent
Mandate	Medical policy maker	67%
	Veterinary policy maker	33%
Sex	Female	27%
	Male	73%
Age	20-30	7%
	31 - 40 yrs	30%
	41 - 50 yrs	43%
	51 - 60 yrs	20%
Designation	Councillor	3%
	Clinical Officer	3%
	Councillor	3%
	District Medical Officer	3%
	Drug Inspector	3%
	Environmental Health Practitioner	3%
	Environmental Health Officer	10%
	Epidemiologist	3%
	Medical Officer	3%
	Nursing Officer	13%
	Principal Medical Officer	3%
	Principal Veterinary Officer	10%
	Principal researcher	3%
	Quality Assurance Officer in Biotechnology and Molecular Biology	3%
	Senior Lecturer	7%
	Senior Lecturer/Researcher	3%
	Senior Veterinary Research Officer	7%
	Teacher	7%
	Veterinary Officer	3%
	Veterinary Research Officer	3%
Organization name	Local government authority	3%
	Ministry of Agriculture Livestock and Fisheries	3%
	Ministry of Agriculture, Livestock and Fisheries	3%
	Ministry of Agriculture, Livestock and Fisheries; Tanzania Livestock Research Institute (TALIRI) Uyole	3%
	Ministry of Education	7%
	Ministry of Health	40%
	Ministry of Regional Administration and Local Government	7%
	Ministry of Health	3%
	National Institute for Medical research Tanzania	3%
	Sokoine University of Agriculture	7%

	Tanzania Bureau of Standards	3%
	Tanzania Food and Drugs Authority (TFDA)	3%
	Tanzania Veterinary Laboratory Agency	10%
	The Open University of Tanzania, Babati Tanzania	3%
Designation and organization name	Councillor at Ministry of Regional Administration and Local Government	3%
	Clinical Officer at Ministry of Health	3%
	Councillor at Ministry of Regional Administration and Local Government	3%
	District Medical Officer at Ministry of Health	3%
	Drug Inspector at Tanzania Food and Drugs Authority (TFDA)	3%
	Environmental Health Practitioner at Ministry of Health	3%
	Environmental Health officer at Ministry of Health	10%
	Epidemiologist at Ministry of Health	3%
	Medical Officer at Ministry of Health	3%
	Nursing Officer at Ministry of Health	10%
	Nursing Officer at Ministry of Health	3%
	Principal Medical Officer at Ministry of Health	3%
	Principal Veterinary Officer at Ministry of Agriculture Livestock and Fisheries	3%
	Principal Veterinary Officer at Ministry of Agriculture, Livestock and Fisheries	3%
	Principal Veterinary Officer at Tanzania Veterinary Laboratory Agency	3%
	Principal researcher at National Institute for Medical research Tanzania	3%
	Quality Assurance Officer in Biotechnology and Molecular Biology at Tanzania Bureau of Standards	3%
	Senior Lecturer at Sokoine University of Agriculture	3%
	Senior Lecturer at The Open University of Tanzania, Babati Tanzania	3%
	Senior Lecturer/Researcher at Sokoine University of Agriculture	3%
	Senior Veterinary Research Officer at Tanzania Veterinary Laboratory Agency	7%
	Teacher at Ministry of Education	7%
	Veterinary Officer at Local government authority	3%
	Veterinary research officer at Ministry of Agriculture, Livestock and Fisheries; Tanzania Livestock Research Institute (TALIRI) Uyole	3%
Role in organization	Administration	13%

	Animal disease control	3%
	Coordinate provision of Quality Health services during emergencies and disasters	3%
	Coordination of One Health Activities in the country	3%
	Councillor	7%
	Diagnosis, Research and Development	3%
	Director of Surveillance and Diagnostic Services	3%
	Disease surveillance and outbreak response	3%
	District Reproductive and child health	3%
	District Cultural Officer	3%
	District Health Officer	3%
	Drug inspection	3%
	Environmental Health Officer	7%
	Epidemiologist	3%
	Human Resource Development - Coordinator for Distance Education for Nursing	3%
	Manager- Centre for Infectious Diseases and Biotechnology	3%
	Medical Doctor	3%
	Microbiological analysis of food samples	3%
	Public Health Promotion Officer / Tutor	3%
	Reaching/Research/Outreach	3%
	Researcher	3%
	Teacher	3%
	Teaching, Research, Consultancy, Extension Services	7%
	conducting research and training on animal health aspects	3%
Which sector do you work in?	Academia	15%
	Academia; Private veterinary services; Other	4%
	Department of Veterinary Services	11%
	Ministry of Health	44%
	Ministry of Health, Academia	4%
	Ministry of Health, Academia, Primary Health Care	4%
	Ministry of Health; Academia	4%
	Ministry of Veterinary Services	4%
	Other	11%
Other sector details	Government Agency	11%
	Local Government Authority	11%
	Ministry of Industry and Trade	11%
	National One Health focal point	11%
	Political sector	22%
	Private company: Ilunde Agrovet and Research Solutions	11%

	TFDA (Government agency under Ministry of Health)	11%
	TVLA is a Government Agency	11%
Does your country currently engage in ANY *Taenia solium* control strategies?	Yes	67%
	No	30%
	I don't know	3%
Notification of Taeniasis: Is *T. solium* taeniasis a notifiable disease in your country?	No	100%
Notification of Neurocysticercosis: Is Neurocysticercosis a notifiable disease in your country?	Yes	3%
	No	97%
Mass Drug Administration: Does your country currently undertake mass drug administration (MDA) for taeniasis?	Yes	53%
	No	40%
	I don't know	7%
Drug name	Broad spectrum anthelmintic	7%
	MDA for helminth control in general but not specifically focused to taeniasis.	7%
	Praziquantel	87%
Identification and treatment of taeniasis cases: Does your country engage in active identification and treatment of taeniasis cases?	Yes	7%
	No	90%
	I don't know	3%
Health education: Does your country engage in ANY specific health education for the control of *T. solium*?	Yes	57%
	No	40%
	I don't know	3%
Health education name	Anthelmintic treatment of pigs, Importance of meat Inspection in Detection of *Taenia solium*, Proper use of Latrines	20%
	College (especially vet) students. Also, education to communities during surveys	20%
	Education on use of latrines and on thorough cooking of pork	20%
	Primary School Education	20%

	Sensitization on hygiene and responsible pig husbandry	20%
Heart examined by eye for cysts	Yes	95%
	No	5%
Masseter muscles examined by eye for cysts	Yes	65%
	No	35%
Tongue muscle examined by eye for cysts	Yes	80%
	No	20%
Diaphragm examined by eye for cysts	Yes	50%
	No	50%
Tongue palpated for cysts	Yes	60%
	No	40%
Heart incised to look for cysts	Yes	75%
	No	25%
Masseter muscle incised to look for cysts	Yes	90%
	No	10%
Tongue incised to look for cysts	Yes	75%
	No	25%
Other	Yes	47%
	No	53%
Other meat inspection details	Don't know	71%
	Psoas and longissimus dorsi muscles examine by eye, palpate and incise for cysts.	7%
	Shoulder (triceps brachii) and diaphragm muscles are incised and inspected. Lips and gums are visualized.	7%
	Triceps and biceps muscles incised	7%
	intercostal muscles and biceps muscles incised	7%
Improvements to the Meat Inspection Service: Within the last 10 years have any specific improvements been made to the meat inspection service in your country for the specific control of *T. solium*?	Yes	20%
	No	40%
	I don't know	40%
Vaccination of Pigs: Are you aware that vaccine for	Yes	30%
	No	33%
	I don't know	37%

control of *T. solium* is now available?		
Anthelmintic treatment of pigs: Is your country currently engaged in the treatment of pigs with anthelmintic for the control of *T. solium*?	Yes	17%
	No	50%
	I don't know	33%
Improvement of Sanitation: Is your country currently engaged in a program to improve sanitation for the specific control of *T. solium*?	Yes	27%
	No	33%
	I don't know	40%
Other Control Strategies for *T. solium*: Is your country currently engaged in any activities for the control of *T. solium* not mentioned so far? Please describe them to us.	Yes	21%
	No	41%
	I don't know	38%
Other control strategies - description: If your country is currently engaged in any activities for the control of *T. solium* not mentioned so far, please described them to us	Although the disease is in the national priority	6%
	Don't know	33%
	Education in improved pig husbandry	6%
	Few among them are like, Education on thorough cooking of pork, Improving farm management, Control of pig marketing systems	6%
	General water and sanitation campaigns ongoing	6%
	I can only mention here that control of *T. solium* in Tanzania can benefit from other strategies. For example, there is ongoing mass drug administration targeting soil-transmitted helminths and schistosomiasis. In addition, WASH and SWASH programmes.	6%
	Individual research activities such as those carried out by some researchers from Sokoine University of Agriculture.	6%
	None	17%
	Public education on Proper use of latrines, Pig management system (intensive, proper cooking of pork, etc.)	6%
	I don't know	6%

	sensitization for Pigs zero grazing, construction and uses of latrine, Health Education on control of *Taenia solium* among primary school children.	6%
There is a legal requirement to do so	Yes	15%
	No	85%
This was selected as the most effective strategy for *T. solium* control	Yes	8%
	No	92%
There was a close fit with other ongoing public health campaigns	Yes	31%
	No	69%
It was the most appropriate strategy within our current budget	No	100%
This was the most acceptable *T. solium* control strategy to the target population	Yes	8%
	No	92%
I do not know	Yes	61%
	No	39%
Other	No	100%
Other control reason details	N/A	N/A

Appendix 11: Uganda
Pig farmers simple contingency table

Question	Answer	Percent (2017 data)	Percent (Kungu et al 2017)
Demographics			
District	A	29%	N/A
	B	22%	
	Kamuli	49%	
Village	A	22%	
	Bantusi	0%	
	Bugemya	0%	
	Bukaya	0%	

	Bukuluba	1%	
	Bulange	13%	
	Buleebi	1%	
	Buleeta	1%	
	Bulongo	0%	
	Busamo	2%	
	Busuulu	1%	
	Busuuyi	1%	
	Butansi	15%	
	Butatya	0%	
	Butatyama	1%	
	Buyoga	0%	
	C	1%	
	D	23%	
	E	5%	
	Namwendwa	13%	
Sex	Female	40%	32%
	Male	60%	68%
Pig Management/Husbandry			
Husbandry system	Confined (zero foraging)	8%	46%
	Free ranging	21%	1%
	Penned for part of day	14%	
	Tethered for part of day	57%	53%
What do you feed your pigs?	Commercial feed	11%	N/A
	Farm waste	1%	
	Household food scraps	36%	
	Mixture	52%	
Pigs kept for sale	Yes	87%	N/A
Pigs kept for home consumption	Yes	3%	N/A
Pigs kept for breeding	Yes	14%	N/A
Pigs kept for a mixture of uses	Yes	12%	N/A
Pig Health (main problems encountered)			
Pig problem: anorexia	Yes	29%	N/A
Pig problem: worms	Yes	89%	N/A
Pig problem: cysticercosis	Yes	18%	N/A
Pig problem: lice/mange/mites	Yes	10%	N/A

Pig problem: other	Yes	42%	N/A
Pig problem: other in detail	ASF	90%	N/A
	ASF, Cough	1%	
	Cough	9%	
	Doesn't know	0%	
Pig Slaughter/Inspection			
Do you or any member in the family consume pork?	No	15%	N/A
	Yes	85%	N/A
Have you slaughtered pigs at home?	No	92%	89%
	Yes	8%	11%
Was the meat inspected by a meat inspector	No	97%	78%
	Yes	3%	22%
Environmental Factors Impacting Human and Animal Health			
Presence and usage of latrine	Absent	18%	N/A
	Other	1%	
	Present & Sometimes Not Used	27%	
	Present & Used	54%	
Presence of latrine	Absent	18%	56%
	Other	1%	N/A
	Present	81%	44%
What is the main source of drinking water?	Borehole	57%	N/A
	Natural sources	12%	
	Other	24%	
	Taps	7%	
What is the main source of drinking water (aggregated)?	Closed sources	64%	62%
	Natural source	12%	38%
	Other	24%	N/A
Other source of drinking water in detail	Mixture	98%	N/A
	Not used	2%	
Knowledge about human tapeworm infection			
Have you heard of tapeworm infection?	No	62%	N/A
	Yes	38%	
How do people acquire tapeworm infection?	Drinking unclean water	1%	N/A
	Drinking unclean water; Eating raw pork; Eating unwashed vegs	1%	

	Drinking unclean water; Eating undercooked beef; Eating unwashed vegs	0%	
	Eating infected meat	48%	
	Eating unwashed vegs	0%	
	I do not know	48%	
	Other	2%	
Other ways to acquire tapeworm infection	Drinking raw milk, Drinking unclean water	3%	N/A
	Drinking raw milk, Drinking unclean water, Eating unwashed vegs	63%	
	Drinking unclean water	16%	
	Drinking unclean water, Eating unwashed vegs	8%	
	Drinking unclean water; Eating unwashed vegs	1%	
	Eating unwashed vegs	10%	
Have you heard of anyone saying or complaining in the village of epilepsy?	No	14%	N/A
	Yes	72%	
Have you observed "measles" *(Cysticercus cellulose)* in pig meat?	No	49%	N/A
	Yes	51%	
Do you know what these measles are?	No	81%	N/A
	Yes	19%	

Appendix 12: Uganda

Pig traders simple contingency table

Question	Answer	Percent
District	A	37%
	B	41%
	C	22%
Sex	Female	6%

	Male	90%
Age	20-30	20%
	31-40	43%
	40-50	24%
	51-60	12%
Highest education level in household/individual	No formal education	10%
	Primary education	63%
	Secondary education/high school	20%
	Tertiary	6%
Main activity: Livestock	Yes	76%
Main activity: Crops	Yes	82%
Main activity: Business	Yes	76%
Main activity: Other	Yes	6%
Main income: Selling farm produce	Yes	86%
Main income: Other	Yes	51%
Main income: Other in detail	Business	44%
	Business - Sale of pork	15%
	Trade in pigs	41%
Have you heard of tapeworm infection?	No	41%
	Yes	59%
Have you heard or met anyone complaining of having tapeworm infection in the village?	No	35%
	Yes	33%
How does one know that he/she has a tapeworm infection?	I do not know	20%
	Other	6%
	Seeing tape worm in the stool	41%
Other	Checking cysts in tongues of pigs	33%
	Tape worms found in meat/pork	33%
	Seeing tapeworm in dirty water	33%
How do people acquire tapeworm infection?	Eating infected meat	33%
	I do not know	27%
	Other	10%
Other	Eating dirty fruits	33%
	Eating of dirty items e.g. mangoes	33%

	Through water (infected with worm)	33%
What should people do who have tapeworm infection?	Go to the hospital	67%
Have you heard of anyone saying or complaining in the village of the following conditions?	Chronic Headache	22%
	Epilepsy	63%
	Madness	6%
	Skin nodules	4%
Have you observed "measles" (*Cysticercus cellulose*) in pig meat?	No	2%
	Yes	98%
Do you know what these measles are?	No	35%
	Yes	65%
Do you know how a pig acquires this infection?	No	59%
	Yes	41%
In detail	Eating dirty food	6%
	Eating feces of human beings	56%
	Pigs moving around	39%
When you see measles in the meat, do you eat the meat?	No	86%
	Yes	14%
When you see measles in the meat, do you sell the meat?	No	80%
	Yes	18%
Where did you learn about this disease and how to treat, prevent, or manage it? AHO	Animal Health Office (AHO)	35%
Where did you learn about this disease and how to treat, prevent, or manage it? School	School	4%
Where did you learn about this disease and how to treat, prevent, or manage it? I don't know	Do not know about this disease	59%
Do you buy pigs from backyard piggery farmers?	No	2%
	Yes	98%
Are you aware of the disease Porcine Cysticercosis (local term) among backyard piggery?	No	12%
	Yes	84%
If yes, how do you know if the pig is affected with Porcine Cysticercosis	Check tongue and meat at slaughter	100%

In case you find the pig is suffering from Porcine Cysticercosis, what action do you take?	Reduce price	4%
	Reject	86%
	Trim affected part of the pig	6%
Percent reduction in price due to Porcine Cysticercosis	50%	100%

Appendix 13: Uganda
Policy makers simple contingency table

Question	Answer	Percent
Mandate	Medical policy maker	53%
	Veterinary policy maker	47%
Sex	Female	17%
	Male	83%
Age	31 - 40 yrs	10%
	41 - 50 yrs	40%
	51 - 60 yrs	37%
	61 - 70 yrs	13%
Designation	Acting District health officer	3%
	Assistant District Health Officer	3%
	Assistant Commissioner animal disease control	3%
	Assistant commissioner	3%
	Commissioner community Health	3%
	Consultant	3%
	Consultant Surgeon	3%
	District Health officer	3%
	District health officer	10%
	District production and marketing officer	3%
	Executive Director Butabika Mental Hospital	3%
	Executive Director	3%
	Former assistant commissioner for Veterinary Public Health and livestock Marketing	3%
	Lecturer	3%
	President	7%
	Retired District Health Officer	3%
	Retired director of veterinary services	3%
	Senior Public Health Inspector	7%
	Senior Research Officer	3%

	Senior Veterinary Officer	7%
	Senior Veterinary Officer/Principal Investigator	3%
	University Professor	3%
	Vector control officer	3%
	Veterinary Officer	3%
	Research Director	3%
Organization name	ANISOLUTIONS International Ltd.	3%
	COCTU	3%
	Cure Children's Hospital of Uganda Mbale	3%
	Directorate of Animal Resources	3%
	Local gov't	3%
	Makerere University, College of Veterinary Medicine	7%
	Ministry Of Health, Kumi District	7%
	Ministry of Agriculture, Animal Industry and Fisheries	17%
	Ministry of Health	13%
	Ministry of Health, vector control Division	3%
	Ministry of health	7%
	Ministry of health Kayunga District	3%
	Ministry of health, Bukedea district	3%
	Mukono District local government	3%
	National Livestock Resources Research Institute	3%
	Retired from Ministry of Health	3%
	Uganda Medical Association	3%
	Uganda Veterinary Association	3%
	Ministry of Health	3%
	Ministry of Health, Kamuli District	3%
Designation and organization name	Acting District Health Officer at Ministry of Health	3%
	Assistant District Health Officer at Ministry Of Health, Kumi District	3%
	Assistant Commissioner Animal Disease Control at Ministry of Agriculture, Animal Industry and Fisheries	3%
	Assistant Commissioner at Ministry of Health, vector control Division	3%
	Commissioner Community Health at ministry of Health	3%
	Consultant Surgeon at Ministry of Health	3%

	Consultant at ANISOLUTIONS International Ltd.	3%
	District Health officer at Ministry Of Health, Kumi District	3%
	District Health Officer at Ministry of Health	3%
	District Health Officer at Ministry of health, Bukedea district	3%
	District Health Officer at ministry of health, kamuli district	3%
	District Production and Marketing Officer at Mukono District local government	3%
	Executive Director Butabika Mental Hospital at Ministry of Health	3%
	Executive Director at COCTU	3%
	Former assistant commissioner for Veterinary Public Health and livestock Marketing at Ministry of Agriculture, Animal Industry and Fisheries	3%
	Lecturer at Makerere University, College of Veterinary Medicine	3%
	President at Uganda Medical Association	3%
	President at Uganda Veterinary Association	3%
	Retired District Health Officer at Retired from Ministry of Health	3%
	Retired director of veterinary services at Directorate of Animal Resources	3%
	Senior Public Health Inspector at Ministry of Health	3%
	Senior Public Health Inspector at Ministry of health	3%
	Senior Research Officer at National Livestock Resources Research Institute	3%
	Senior Veterinary Officer at Ministry of Agriculture, Animal Industry and Fisheries	7%
	Senior Veterinary Officer/Principal Investigator at Ministry of Agriculture, Animal Industry and Fisheries	3%
	University Professor at Makerere University, College of Veterinary Medicine	3%
	Vector control officer at Ministry of Health Kayunga District	3%
	Veterinary Officer at Local gov't	3%

	Research director at Cure Children's Hospital of Uganda Mbale	3%
Role in organization	Acting Commissioner Animal Production from August 2015 to July 2016 providing over-all policy and technical guidance and support to Animal Production and Marketing stakeholders so as to facilitate improved production and marketing both in quality	3%
	Animal disease outbreak investigation and surveillance, Animal disease reporting	3%
	Assistant District Health officer/ District Nursing officer	3%
	Commissioner	3%
	Coordination of clinical services, Research	3%
	Design and implement control measures for animal diseases	3%
	Director	3%
	Disease control	3%
	Disease surveillance	3%
	District health officer	10%
	Executive Director Butabika Mental Hospital	3%
	Head of Association	3%
	Head of health department, Bukedea District	3%
	Head of health department, Kumi District	3%
	Head of vector Control Division	3%
	Health inspection	3%
	Health inspection (Environmental Health)	3%
	Lecturer	3%
	Retired District health officer Busia District	3%
	Running and implementing disease control programmes	3%
	SENIOR VETERINARY OFFICER	3%
	Senior Research Officer	3%
	Senior management	3%
	Teaching, Research, and outreach	3%
	Team Leader	3%
	Vector control officer	3%
	control of tsetse and trypanosomiasis	3%

	Head of department under which veterinary services fall	3%
Which sector do you work in?	Academia	10%
	Department of Veterinary Services	3%
	Ministry of Agriculture	17%
	Ministry of Agriculture; Department of Veterinary Services	7%
	Ministry of Agriculture; Other	3%
	Ministry of Veterinary Services	3%
	Ministry of health	43%
	Non-government organisation	3%
	Other	7%
	Retired District Health officer	3%
Other sector details	Consulting firm on animal industry services	25%
	Tertiary Health care	25%
	Local government	25%
	Specialised Healthcare (pediatric Neurosurgery Centre)	25%
Does your country currently engage in ANY *Taenia solium* control strategies?	Yes	60%
	No	40%
Notification of Taeniasis: Is *T. solium* taeniasis a notifiable disease in your country?	Yes	13%
	No	77%
	I don't know	10%
Notification of Neurocysticercosis: Is Neurocysticercosis a notifiable disease in your country?	Yes	13%
	No	73%
	I don't know	13%
Mass drug administration: Does your country currently undertake mass drug administration (MDA) for taeniasis?	Yes	23%
	No	70%
	I don't know	7%
Drug name	Albendazole in children	14%
	During immunization for children	14%
	Mass deworming during child health days using albendazole	14%
	Mebendazole and ivermectin	14%
	Praziquantel	14%
	Using TSOL18 vaccine and OFZ dewormer under GALVEM project	14%
	Albendazole	14%
Identification and treatment of taeniasis cases: Does your country	Yes	27%
	No	70%

engage in active identification and treatment of taeniasis cases?	I don't know	3%
Health education: Does your country engage in ANY specific health education for the control of *T. solium*?	Yes	50%
	No	47%
	I don't know	3%
Health education name	Also this is mainly be researchers on the subject	7%
	As part of the duties of field veterinary officers	7%
	At health facilities patients are educated on general aspects of control of worms	7%
	Display of posters at health facilities, health education in schools in primary schools	7%
	During deworming, communities are educated on preventive measures such as not defecate in open and eat properly cooked pork	7%
	During the programs of child survival days when education of worm control in children is carried out.	7%
	General health education on intestinal worms	7%
	General program/not very specific	7%
	Health education on prevention of worms (sanitation) and nutrition Promotion	7%
	It is one the clinical diseases medical trainees learn about	7%
	Public Health education campaigns	7%
	Thorough cooking of pork	7%
	Through the veterinary department farmers are sensitized about worm burden	7%
	General health promotion of usage of latrines	7%
	Sensitization on sanitation activities like construction of latrines	7%
Heart examined by eye for cysts	Yes	37%
	No	63%
Masseter muscles examined by eye for cysts	Yes	50%
	No	50%
Tongue muscle examined by eye for cysts	Yes	43%
	No	57%

Diaphragm examined by eye for cysts	Yes	30%
	No	70%
Tongue palpated for cysts	Yes	30%
	No	70%
Heart incised to look for cysts	Yes	27%
	No	73%
Masseter muscle incised to look for cysts	Yes	47%
	No	53%
Tongue incised to look for cysts	Yes	47%
	No	53%
Other	Yes	27%
	No	73%
Other meat inspection details	No	100%
Improvements to the meat inspection service: Within the last 10 years have any specific improvements been made to the meat inspection service in your country for the specific control of *T. solium*?	Yes	20%
	No	57%
	I don't know	23%
Vaccination of pigs: Are you aware that vaccine for control of *T. solium* is now available?	Yes	53%
	No	33%
	I don't know	13%
Anthelmintic treatment of pigs: Is your country currently engaged in the treatment of pigs with anthelmintic for the control of *T. solium*?	Yes	50%
	No	33%
	I don't know	17%
Improvement of sanitation: Is your country currently engaged in a program to improve sanitation for the specific control of *T. solium*?	Yes	40%
	No	43%
	I don't know	17%
Other control strategies for *T. solium*: Is your country currently engaged in any activities for the control of *T. solium* not mentioned so far? Please describe them to us	Yes	14%
	No	43%
	I don't know	43%

Other control strategies - description: If your country is currently engaged in any activities for the control of *T. solium* not mentioned so far please described them to us	No systematic control program in place. Vaccination and deworming done at trial phase	20%
	Public education with emphasis on proper cooking or roasting of pork.	20%
	We are involved in passive surveillance for *Taenia solium*	20%
	Farmer education to improve hygiene and administer anthelmintics and training of meat inspectors	20%
	Vaccine field trial	20%
There is a legal requirement to do so	Yes	4%
	No	96%
This was selected as the most effective strategy for *T. solium* control	No	100%
There was a close fit with other ongoing public health campaigns	Yes	4%
	No	96%
It was the most appropriate strategy within our current budget	Yes	4%
	No	96%
This was the most acceptable *T. solium* control strategy to the target population	No	100%
I do not know	Yes	29%
	No	71%
Other	Yes	11%
	No	89%
Other control reason details	I am aware that some scientists from Australia collaborating with Dr. Chis (FAO/MAAIF) and are currently piloting a vaccine against *T. solium* in Uganda.	25%
	Its only done as part of the routine veterinary extension services, training and research	25%
	Research programme	25%
	Traders inspect pigs at point of purchase to limit losses due to condemnation after slaughter	25%

Appendix 14: Zambia
Pig farmers simple contingency table

Question	Answer	Percent (2015 data)	Percent (Sikasunge et al 2007)
	Demographics		
District	Katete	100%	N/A
Village	Apton farm	1%	
	Chakalamba	1%	
	Chakumba	8%	
	Chamoto	5%	
	Chibweza	1%	
	Chikalema	1%	
	Chikhutu	2%	
	Chikuse	3%	
	Chikutu	0%	
	Chimbalu	5%	
	Chimphafa	3%	
	Chimvira	5%	
	Chimviri	1%	
	Chimwayi	3%	
	Etala	4%	
	Gundamwala	0%	
	Gwawale	0%	
	Gwawale 1	0%	
	Gwawale 2	2%	
	Herode	4%	
	Kabonga	4%	
	Kabongo	3%	
	Kamkulekule	2%	
	Kamlawe	0%	
	Kamvumvuli	2%	
	Kapelepeta	6%	
	Kavunvuli	0%	
	Kayela	3%	
	Madalitso	1%	
	Mkambi	4%	
	Mtalalika	5%	
	Mufunanji	2%	
	Nkhowe	6%	
	Peter farms	1%	
	Robert	3%	
	Safari	4%	
	Sizala farm	1%	
	Zonde	1%	

Pig Management/Husbandry			
Number of pigs	1	35%	N/A
	2	13%	
	3	11%	
	4	6%	
	5	6%	
	6	5%	
	7	8%	
	>7	16%	
Husbandry system	Confined	0%	0%
	Free range	66%	83%
	Penned for part of the day	33%	17%
Do you feed your pigs maize bran (gaga)?	Yes	100%	N/A
Do you feed your pigs maize grain?	Yes	12%	N/A
	No	88%	
Do you feed your pigs crop residues?	Yes	15%	N/A
	No	85%	
Do you feed your pigs kitchen leftovers?	Yes	53%	N/A
	No	47%	
Do you feed your pigs seasonal fruits (water melons, guava, mango, pumpkin)?	Yes	90%	N/A
	No	10%	
Do you feed your pigs commercial feed?	Yes	0%	N/A
	No	100%	
No extra feed, free roaming only	Yes	0%	N/A
	No	100%	
A mixture of feeds	Yes	63%	N/A
	No	37%	
If measles, what is the loss in price due to this disease?	25% - 50%	28%	N/A
	50% - 75%	29%	
	75% - 100%	36%	
	<25%	7%	
Environmental factors impacting human and animal health			
Presence of latrine	Yes	92%	42%
	No	8%	58%

Presence and use of latrine by direct observation	Absent	7%	N/A
	Other	0%	
	Present and sometimes used	1%	
	Present and used	92%	
What is the main source of drinking water?	Borehole	25%	N/A
	Natural sources	5%	
	Other	0%	
	Taps	70%	
What is the main source of drinking water?	Closed sources	95%	N/A
	Natural source	5%	
	Other	0%	
Knowledge about human tapeworm infection			
When you see measles in the meat, do you sell the meat?	No	94%	82%
	Yes	6%	18%

Appendix 15: Zambia
Pig traders simple contingency table

Question	Answer	Percent
District	A	100%
Sex	Male	100%
Age	31-40	67%
	40-50	33%
Highest education level in household/individual	No formal education	17%
	Primary education	33%
	Secondary education/high school	50%
Main activity: Livestock	Yes	50%
Main activity: Crops	Yes	100%
Main activity: Business	Yes	33%
Main activity: Other	Yes	17%

Main activity: Other in detail	Pig business especially dry season	100%
Main income: Selling farm produce	Yes	83%
Main income: Other	Yes	33%
Main income: Other in detail	Get more from pig selling	50%
	Pig business (buying and selling)	50%
Have you heard of tape worm infection?	Yes	100%
Have you heard or met anyone complaining of having tapeworm infection in the village?	Yes	100%
How does one know that he/she has a tape worm infection?	Other	67%
	Seeing tape worm in the stool	33%
Other	Feels some movements in the stomach and some unusual feeling in the anus	20%
	Stomach pains	40%
	Stomach pains and constipation	20%
	Stomach pains with other movements in the stomach	20%
How do people acquire tapeworm infection?	Eating infected meat	33%
	I do not know	33%
	Other	33%
Other	By eating a lot of vegetables	33%
	From vegetables	33%
	From bad water during rainy season	33%
What should people do who have tapeworm infection?	Go to the hospital	100%
Have you heard of anyone saying or complaining in the village of the following conditions?	Chronic Headache	17%
	Epilepsy	83%

Have you observed "measles" (*Cysticercus cellulose)* in pig meat?	No	33%
	Yes	67%
Do you know what these measles are?	No	50%
	Yes	50%
Do you know how a pig acquires this infection?	No	100%
When you see measles in the meat, do you eat the meat?	No	100%
When you see measles in the meat, do you sell the meat?	No	100%
Where did you learn about this disease and how to treat, prevent, or manage it? AHO	Animal Health Office (AHO)	83%
Where did you learn about this disease and how to treat, prevent, or manage it? EHO	Environmental Health Office (EHO)	50%
Do you buy pigs from backyard piggery farmers?	Yes	100%
Are you aware of the disease Porcine Cysticercosis (local term) among backyard piggery?	Yes	100%
If yes, how do you know if the pig is affected with Porcine Cysticercosis	Check tongue and meat at slaughter	75%
	Growing thin, pot bellied	25%
In case you find the pig is suffering from Porcine Cysticercosis, what action do you take?	Reject	100%

Appendix 16: Zambia
Policy makers simple contingency table

Question	Answer	Percent
Mandate	Medical policy maker	70%
	Veterinary policy maker	30%
Sex	Female	22%
	Male	78%
Age	20 - 30 yrs	9%
	31 - 40 yrs	17%
	41 - 50 yrs	43%
	51 - 60 yrs	26%
	61 - 70 yrs	4%
Designation	Assistant Director-Child Health	4%
	Chief CD/Neglected Tropical Diseases	4%
	Chief Veterinary Research Officer	4%
	Consultant	4%
	Director Human Resources, Planning and Development	4%
	Doctor	4%
	Dr. Lecturer and Researcher	4%
	Head, Public Health	4%
	JRMO	4%
	Medical Care Giver	4%
	Medical Officer	17%
	Medical doctor	9%
	Prof, Head of Laboratory	4%
	Professor, Former Permanent Secretary Ministry of Livestock and Fisheries	4%
	Public Health Researcher	4%
	Registrar Medical Doctor	9%
	Senior Lecturer	4%
	Senior Lecturer/Researcher	4%
Organization name	Ghent University, Belgium, Faculty of Veterinary Medicine, Department of Veterinary Public Health and Food Safety	5%
	MOH Ndola DHO	5%
	Ministry of Fisheries and Livestock	5%
	Ministry of Health	32%
	Ministry of Health, University Teaching Hospital	9%
	Ministry of Health.	5%

	Ministry of Health Headquarters	18%
	Retired Ministry of Health	5%
	University of Zambia	9%
	University of Zambia, School of Veterinary Medicine	9%
Designation and organization name	Assistant Director-Child Health at Ministry of Health Headquarters	4%
	Chief CD/Neglected Tropical Diseases at Ministry of Health	4%
	Chief Veterinary Research Officer	4%
	Consultant at Ministry of Health	4%
	Director Human Resources, Planning and Development at Ministry of Health Headquarters	4%
	Doctor at University of Zambia	4%
	Dr. Lecturer and Researcher at University of Zambia	4%
	Head, Public Health at Ministry of Fisheries and Livestock	4%
	JRMO at Ministry of Health	4%
	Medical Care Giver at Ministry of Health	4%
	Medical Officer at Ministry of Health	9%
	Medical Officer at Ministry of Health Headquarters	9%
	Medical doctor at MOH Ndola DHO	4%
	Medical doctor at Ministry of Health	4%
	Prof, Head of Laboratory at Ghent University, Belgium, Faculty of Veterinary Medicine, Department of Veterinary Public Health and Food Safety	4%
	Professor, Former Permanent Secretary Ministry of Livestock and Fisheries at University of Zambia, School of Veterinary Medicine	4%
	Public health researcher at Ministry of Health	4%
	Registrar medical doctor at Ministry of Health, University Teaching Hospital	9%
	Senior Lecturer at University of Zambia, School of Veterinary Medicine	4%
	Senior lecturer/Researcher at retired Ministry of Health	4%
Role in organization	Child health officer	5%
	Conducting research on diseases of public health importance	5%

	Consultant HOD	5%
	Coordinating programme	5%
	Coordination and implementation of child health policies	5%
	District Health Director	5%
	Head of laboratory of foodborne parasitic zoonoses	5%
	Lecturer/researcher	5%
	Medical care giver	5%
	Medical care giver	18%
	Medical officer	5%
	Parasitology research and lecturing at the university	5%
	Planning and coordination of ministry activities	5%
	Senior lecturer and researcher	5%
	Senior resident medical officer	5%
	Teaching and research	5%
	To attend to patients	5%
	Veterinary research and disease investigations	5%
	Veterinary public health	5%
Which sector do you work in?	Academia	17%
	Department of Veterinary Services	9%
	Ministry of Health	4%
	Ministry of Health	57%
	Ministry of Health/Academia	9%
	Ministry of Veterinary Services	4%
Other sector details	Research and teaching	100%
Does your country currently engage in ANY *Taenia solium* control strategies?	Yes	48%
	No	33%
	I don't know	19%
Notification of Taeniasis: Is *T. solium* taeniasis a notifiable disease in your country?	Yes	14%
	No	68%
	I don't know	18%
Notification of Neurocysticercosis: Is Neurocysticercosis a notifiable disease in your country?	Yes	14%
	No	73%
	I don't know	14%
Mass drug administration: Does your country currently undertake mass drug administration (MDA) for taeniasis?	Yes	9%
	No	86%
	I don't know	5%
Drug name	Child Health Week	50%

	Only research related	50%
Identification and treatment of taeniasis cases: Does your country engage in active identification and treatment of taeniasis cases?	Yes	48%
	No	29%
	I don't know	24%
Health education: Does your country engage in ANY specific health education for the control of *T. solium*?	Yes	57%
	No	33%
	I don't know	10%
Health education name	As a pilot research project in Eastern Zambia; community education	9%
	Community sanitation improvement programmes	9%
	Electronic media	9%
	Regular meat inspection both slaughter and butchery	9%
	Routine pig health programme including deworming schedules	9%
	Sanitary improvement	9%
	Sanitary improvement to break the transmission cycle	9%
	Sanitation improvement initiatives	9%
	Community led programmes on sanitation	9%
	Extension services	9%
	Only research related	9%
Heart examined by eye for cysts	Yes	38%
	No	62%
Masseter muscles examined by eye for cysts	Yes	48%
	No	52%
Tongue muscle examined by eye for cysts	Yes	52%
	No	48%
Diaphragm examined by eye for cysts	Yes	33%
	No	67%
Tongue palpated for cysts	Yes	48%
	No	52%
Heart incised to look for cysts	Yes	33%
	No	67%
Masseter muscle incised to look for cysts	Yes	48%
	No	52%

Tongue incised to look for cysts	Yes	48%
	No	52%
Other	Yes	19%
	No	81%
Other meat inspection details	Don't know this is a veterinary portfolio	17%
	Don't know, I am in human health	17%
	I don't know	17%
	Meat inspection is done but I don't know which organs specialist examine	17%
	This is a vet function	17%
	This is officially, but in practice not implemented, and at risk pigs are slaughtered backyard	17%
Improvements to the meat inspection service: Within the last 10 years have any specific improvements been made to the meat inspection service in your country for the specific control of *T. solium*?	Yes	10%
	No	38%
	I don't know	52%
Vaccination of pigs: Are you aware that vaccine for control of *T. solium* is now available?	Yes	38%
	No	29%
	I don't know	33%
Anthelmintic treatment of pigs: Is your country currently engaged in the treatment of pigs with anthelmintic for the control of *T. solium*?	Yes	40%
	No	15%
	I don't Know	45%
Improvement of sanitation: Is your country currently engaged in a program to improve sanitation for the specific control of *T. solium*?	Yes	38%
	No	38%
	I don't know	24%
Other control strategies for *T. solium*: Is your country currently engaged in any activities for the control of T. solium not mentioned so far? Please describe them to us	Yes	10%
	No	35%
	I don't know	55%
Other control strategies - description: If your country is currently engaged in any activities for the control of *T. solium* not mentioned so far please described them to us	As part of NTD control programs	20%
	Ministry of Local Government and UNICEF are currently scaling up Community Led Total Sanitation (CLTS)	20%
	N/A	20%

	Not aware	20%
	Not country based, only research based projects.	20%
There is a legal requirement to do so	Yes	5%
	No	95%
This was selected as the most effective strategy for *T. solium* control	Yes	5%
	No	95%
There was a close fit with other ongoing public health campaigns	Yes	15%
	No	85%
It was the most appropriate strategy within our current budget	Yes	5%
	No	95%
This was the most acceptable *T. solium* control strategy to the target population	Yes	5%
	No	95%
I do not know	Yes	20%
	No	80%
Other	Yes	10%
	No	90%
Other control reason details	N/A	50%
	This is a research in order to find the best combination.	50%

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