

Taeniasis-cysticercosis has no borders in Sub-Saharan Africa: pig traders' knowledge, attitudes, and practices regarding *Taenia solium* in the cross-border pig food chain between Zambia and the Democratic Republic of Congo.

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Research Article

Keywords: *Taenia solium*, zoonosis, knowledge, attitudes, and practices

Posted Date: October 11th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10893266/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background

In sub-Saharan Africa, studies have examined stakeholder knowledge, attitudes, and practices in the pig value chain alongside porcine cysticercosis occurrence. However, cross-border pig traders' understanding of, and responses to, the *Taenia solium* complex remain understudied. This gap can limit understanding of other factors facilitating parasite spread and hamper effective control strategies in endemic areas. This research assessed stakeholder knowledge, attitudes, and practices in the cross-border pig food chain between Zambia (a southern African country and pig exporter) and the Democratic Republic of Congo (a central African country, pig importer and consumer) regarding *T. solium*.

Method

From September 2023 to January 2025, this study employed semi-structured interviews with 70 Congolese stakeholders and observations across Kasenga, Kasumbalesa, Kipushi, Sakania (border), and Lubumbashi. The 41-question survey evaluated sociodemographics, knowledge, attitudes, practices, and economic impacts of porcine cysticercosis, while observations examined how stakeholders handled infected carcasses.

Results

Most participants were male (6:4 ratio), aged 14–60 years (average: 35 ± 10), with 2 months to 35 years of experience. They included live pig traders, buyers/sellers, slaughterers, slaughterer-sellers, and pork grill vendors. *Taenia solium* complex knowledge scores ranged from 2.5 to 19.5 out of 24 (median: 9), indicating moderate understanding of its zoonotic aspects; porcine cysticercosis knowledge varied from insufficient to good. Human taeniasis and cysticercosis scores ranged from 0 to 5 out of 6 (median: 0), with 57.1% (40/70) scoring zero. Attitude and risk-practice scores ranged from 1 to 6.5 out of 9, reflecting low to very high public health risks, including importing and distributing infected pigs. Professional experience was associated with porcine cysticercosis knowledge scores and the disease's zoonotic dimension. Attitude and practice scores did not differ by gender, age, profession, workplace, or experience. Inconsistent pig sanitary control across the food chain (Zambian sources, DRC borders) allowed infected carcasses to reach consumers' plates in Haut-Katanga.

Conclusion

The reported knowledge gaps and risky practices indicate that infected pigs from Zambia could be reaching consumers in the DRC. This poses a public health risk and underscores the importance of coordinated “One Health” strategies that target, collaborate, and engage stakeholders to achieve effective parasite control.

Introduction

Taenia solium is a neglected foodborne zoonotic parasite with a life cycle involving humans as the definitive host (taeniasis) or accidental hosts (human cysticercosis), characterized by the presence of *T. solium* cysticerci in the body (Garcia et al., 2020). When cysticerci settle in the nervous system, the condition is called neurocysticercosis, which accounts for 30% of neurological disorders in epileptic populations in endemic regions (Ndimubanzi et al., 2010; De Margerie-Mellon & Levi, 2025). Adult *Taenia* inhabits the human intestine after ingestion of cysticerci from

undercooked or raw pork (Dixon et al., 2021). Humans can contaminate the environment with eggs through feces, especially in areas with poor hygiene and sanitation. Pigs, especially free-range ones, can become infected with *T. solium* cysticerci (porcine cysticercosis) by ingesting human waste or contaminated food and water (Dixon et al., 2021).

Several factors influence the parasite's prevalence and endemicity. In areas where the disease is common, free-ranging pig farming, combined with a lack of latrines, promotes the infection in pigs by increasing their exposure to human feces (Dixon et al., 2021). Poor sanitation worsens this issue, including contaminated water sources, low health awareness (especially about regular handwashing), and the use of untreated human fecal matter, which can contaminate water and vegetables (Ndimubanzi et al., 2010; Bhattarai et al., 2019). Additionally, human migration helps spread human cysticercosis globally, aiding the parasite's movement across regions (Wraige et al., 2003; Van Damme et al., 2021; Ngwili et al., 2023). At a community level, transmission is further driven by the movement of free-roaming pigs and their frequent contact with potentially infectious human feces (Pray et al., 2019; O'Neal et al., 2012; Van Damme et al., 2022). Research shows that the knowledge, attitudes, and practices of stakeholders in the pig value chain, such as pork consumers, are linked to the endemicity and spread of the taeniasis–cysticercosis complex (Minani et al., 2025; Zulu et al., 2023). However, while endemicity has been confirmed in several sub-Saharan African countries, international trade in pigs and related factors has not been documented as a contributor to the spread and transmission of *T. solium*.

The trade in live pigs and carcasses among African communities is widespread, particularly across borders such as those between Zambia and the Democratic Republic of the Congo (DRC), with significant activity through Haut-Katanga Province. As neighboring countries, Zambia and the DRC are closely connected through the Kasumbalesa border, a major trading hub that facilitates the movement of people and goods. These exchanges extend beyond economic transactions to include sociological, anthropological, cultural, and linguistic interactions (Fazili et al., 2020). Despite international trade in food commodities, especially pork, playing an important role in linking surplus-producing areas to deficit regions and contributing to global food security (Poonyth, 2021; FAO, 2024), it may also facilitate the transboundary spread of infectious agents, including zoonotic parasites such as *Taenia solium*. Consequently, managing and controlling these diseases requires substantial resources and coordinated, multidisciplinary efforts. Understanding the knowledge level of stakeholders involved in cross-border pig handling regarding zoonotic diseases such as cysticercosis is essential for identifying factors that facilitate the parasite's spread or endemicity. This knowledge helps develop effective and sustainable control measures. This study assessed the knowledge, attitudes, and practices of those involved in the pig trade and pork food chain between Zambia and DRC (Haut-Katanga province), as well as pork marketers in Lubumbashi, specifically in Kasenga, Kasumbalesa, Kipushi, and Sakania, focusing on the zoonotic aspects of *T. solium*.

1. Materials and methods

1.1. Study area

The study was conducted in the city of Lubumbashi and at border sites in Haut-Katanga province (DRC) near Luapula and Copperbelt provinces in Zambia (Fig. 1). Haut-Katanga is a mining province with subsidiaries rich in copper, zinc, manganese, cobalt, gold, and other minerals, which play an important economic role and attract major mining companies (Kalenga et al., 2018). Its agricultural sector is underperforming, with indicators showing that local production (whether subsistence farming, livestock, or fishing) cannot meet the demands of a growing urban population. In traditional farming, families mainly manage livestock, including small animals such as goats, sheep, and

pigs, as well as fish farming. In rural areas, livestock is mainly for subsistence and is sometimes practiced commercially or to fund social expenses, such as dowries or hosting important guests (Kalenga et al., 2018).

The study sites in Haut-Katanga province include Kasenga, Kasumbalesa, Kipushi, and Sakania (Fig. 1). Stakeholders in the pig/pork food chain operating in Lubumbashi's primary markets (such as Zambia Market, Mzé Kabila Market, Taba Congo Market, Kenya Market, Moïse Market, Rail (Texaco) Market, Kilobelobe Market, Plateau Karavia Market, and RADEM Market), as well as those importing pigs from Zambia, slaughtering pigs and selling pork at home in Lubumbashi and border sites, were identified and included in this study (Tshiasuma et al., 2026).

1.2. Study design and sample size

This research is part of a broader study mapping the pig cross-border food chain and the stakeholders involved, and evaluating the occurrence of *T. solium* at the Zambia-DRC interface (Haut-Katanga province) (Tshiasuma et al., 2026). The DRC serves as the importing country for Zambian pigs within this chain, a source exhibiting a very high documented prevalence of porcine cysticercosis (Chembensofu et al., 2017; Gabriël et al., 2018). To assess the knowledge, attitudes, and practices (KAP) of the identified stakeholders, a quantitative study was conducted between September 2023 and January 2025, employing semi-structured interviews and triangulating the results with data from participatory and non-participatory observations. This investigation assessed the KAP of 70 stakeholders in the pig food chain, from the Zambia (Luapula and Copperbelt provinces) –Democratic Republic of the Congo border interface to the various pork meat markets in Haut-Katanga province, with a focus on the zoonotic aspects of the taeniasis/cysticercosis complex caused by *Taenia solium* in pigs and humans. The study utilized a 41-question survey comprising 25 open-ended and 16 closed-ended questions, administered through the EpiCollect5 application (<https://five.epicollect.net/>) (Appendix 1).

The questionnaire was divided into four sections. The first section (5 questions) collected respondents' socio-demographic information: age, gender, role in the pig food chain, years of experience, and workplace. The second section contained 18 questions, 12 of which focused on *Taenia solium*: definition of *Taenia*, porcine cysticercosis, clinical symptoms in pigs, sources of infestation, risk factors, and detection methods. The remaining 6 questions assessed understanding of taeniasis and human cysticercosis. The third section (12 questions) evaluated attitudes and practices regarding healthy pigs and those with cysticerci, especially cysticercosis management in the pig food chain. The fourth section (6 questions) addressed economic aspects of pig and pork trade and the origins of *Taenia solium*-infected pigs.

Participatory and non-participatory observations were carried out alongside interviews. All information regarding pig slaughter sites, inspections, and the handling and destinations of infected carcasses was carefully documented in a field notebook.

1.3. Stakeholder recruitment

The study involved stakeholders engaged in buying and selling live pigs, as well as those involved in pig slaughter and pork sales at selected locations. Participants were purposively selected based on their geographical locations (such as Zambia-DRC border sites (Kasenga, Kasumbalesa, Kipushi, and Sakania), Lubumbashi, and pig markets) and their specific roles in the pig food chain (Tshiasuma et al., 2026). Recruitment was voluntary, and oral consent was obtained after explaining the study's aims, benefits, and potential risks. Most participants were interviewed at their workplaces, including pig sale points, slaughterhouses, and pork markets.

1.4. Data collection

1.4.1. Interview data collection

A structured questionnaire was developed based on existing literature on the taeniasis/cysticercosis complex (Appendix 1). Questions were integrated into the EpiCollect5 application and piloted with ten individuals involved in the pig food chain in Kasumbalesa to identify necessary modifications before full implementation. The questionnaire was administered individually in French to French-speaking respondents and in Swahili to Swahili-fluent participants, with each interview lasting no longer than 30 minutes. The translated responses (by the main author) were provided by Swahili speakers for entry into the application. All responses across questionnaire sections were recorded and securely stored on the application's central online server.

1.4.2. Observation data collection

Observations were carried out at pig purchase points, border crossings, and at pig slaughter and consumption sites in Haut-Katanga province. These focused on the level of sanitary checks during transactions and border crossings, such as tongue palpation, as well as on buyers' and sellers' attitudes and practices regarding pigs that tested positive for cysticercosis. The study also examined regulations and the destination of infected imported pigs. In various markets, slaughterhouses, and sales points, the goal was to identify slaughter sites, evaluate veterinary inspection quality and regulatory compliance, and trace the fate of infected carcasses. Participatory and non-participatory methods in slaughterhouses helped better understand how pigs infected with *Taenia* are managed, including whether they are seized or sold. All collected data were recorded in a field notebook.

1.5. Data management and analysis

All interview responses were extracted from the EpiCollect5 application's central server in Excel format and then cleaned by questionnaire section. Responses about respondents' sociodemographic characteristics were summarized descriptively as percentages.

To assess stakeholders' knowledge of the taeniasis/cysticercosis complex within the pig food chain, 18 questions were selected and divided into two sections: 12 questions addressed porcine cysticercosis (definition of the pork tapeworm, symptoms, localization within the porcine body, detection techniques, and risk factors), and 6 questions covered taeniasis and human cysticercosis. Each response was scored as 0, 0.5, or 1 (Jordan et al., 2021; Nyangi et al., 2022). Zero (0) was assigned to "I don't know" responses or responses inconsistent with the existing literature on the parasite; 0.5 to partially correct responses; and 1 to fully correct responses. Consequently, knowledge of porcine cysticercosis was evaluated on a 12-point scale, and taeniasis and human cysticercosis on a 6-point scale. To evaluate the taeniasis/cysticercosis complex, the scores for human taeniasis and cysticercosis were doubled to match the weight used for porcine assessments. The total taeniasis-cysticercosis score was then calculated on a 24-point scale.

The different scores were categorized into different knowledge levels. For the 12-point assessment of knowledge on porcine cysticercosis, a total score of 1–4 indicated insufficient knowledge, 4.5–8 average knowledge, and 8.5–12 good knowledge. Out of a total of 6 points for knowledge of taeniasis and human cysticercosis, a respondent's score of ≤ 2 indicated insufficient knowledge; 2.5–4, average knowledge; and 4.5–6, good knowledge. Out of a total of 24 points assigned to knowledge of the taeniasis-cysticercosis complex, a total score obtained by a respondent ranging from 1 to 8 indicated insufficient knowledge, a score from 8.5 to 16 indicated average knowledge, and a score between 16.5 and 24 indicated good knowledge of the parasite's life cycle and its zoonotic aspect.

Each response to questions on attitudes and practices within the pig food chain was scored as 0, 0.5, or 1. A score of 0 was assigned to no-risk, public health-protective responses (e.g., refusing tongue-positive pigs, conducting meat inspection at slaughterhouses, destroying cysticerci-harboring carcasses, fully cooking pork, or refusing to sell

infected meat); 0.5 indicated partially protective practices (e.g., discarding only infected parts); and 1 denoted public health risks, particularly those perpetuating the parasite lifecycle (e.g., purchasing infected pigs, selling infected carcasses, applying lemon juice to kill cysticerci, inspecting without condemnation, or concealing lesions). Of the 12 attitude/practice questions, three complementary pairs (1–2, 7–8, 11–12) were each scored 0 or 0.5 (0.5 for risk-related responses, 0 for protective ones). Attitudes and practices were thus assessed overall on a 9-point scale.

Out of a total of 9 points assigned to evaluate attitudes and risky practices that could promote parasite spread (with its potential zoonotic effects) and sustain its lifecycle, a score of 0 was categorized as no risk, public health-protective attitudes and practices; 1–2 low risk practice; 2.5–4 moderate risk practices; 4.5–6 high risk practices; and 6.5–9 very high risk practices within the pig food chain.

Explanatory variables, including sex, age, professional activity in the pig food chain, years spent in the pig food chain (as professional experience), and workplace, were used to understand better stakeholders' knowledge, attitudes, and practices regarding the taeniasis-cysticercosis complex. Respondents were grouped into three age categories: (i) the cadet group (14 to 25 years old), (ii) the junior group (ages 26 to 35), and (iii) the senior group (36 years and older).

The number of years of professional experience were divided into four groups: (i) beginner, consisting of individuals with less than one year in the pig food chain; (ii) elementary, made up of those with 1 to 5 years of experience; (iii) intermediate, including people with 6 to 10 years in the industry; and (iv) experienced, composed of participants with 11 to 35 years of experience.

Data were analyzed using R software version 4.4.2 (<https://www.r-project.org/>). Summary statistics, including the minimum, maximum, and median of continuous variables, were calculated. Nonparametric tests, i.e., the Wilcoxon test for two groups and the Kruskal-Wallis test for more than two groups (e.g., workplace, professional activity, age, and number of years spent in the pig trade chain), were employed to evaluate differences in knowledge scores, attitudes, and practices. In addition, Spearman's correlation (ρ) was performed to assess the relationships between participants' knowledge (on porcine cysticercosis, human taeniasis and cysticercosis, and the overall taeniasis/cysticercosis complex) and their attitudes and practices toward pigs infected with *T. solium*.

The questions and their answers from each section were then displayed in tables showing the proportions. Additionally, some verbatim transcripts were included to illustrate some responses.

2. Results

2.1. Socio-demographic characteristics of respondents

A total of 70 respondents operating within the pig food chain at the Zambia–DRC (Haut-Katanga province) border interface were interviewed, specifically linking Zambia's Luapula (to Kasenage/DRC) and Copperbelt provinces (via Sakania, Kipushi, and Kasumbalesa to Lubumbashi). Among them, 53 (76%) worked between border supply sites (mainly between Kasumbalesa – Lubumbashi) and Lubumbashi (slaughter and pork consumption area); 7 (10%) at Kasenga; 5 (7%) at Kasumbalesa; 3 (4%) at Sakania; and 2 (3%) at Kipushi. The sample comprised 41 men (59%) and 29 women (41%), aged 14–60 years. Most had extensive experience in the sector (42/70, 60%), followed by elementary (14/70, 20%), intermediate (11/70, 16%), and beginner levels (3/70, 4%). The majority were pig buyer-sellers at markets (33/70, 47%), followed by slaughterer-pork sellers (18/70, 26%), grilled pork sellers (11/70, 16%), and market pork sellers (8/70, 11%), as shown in Table 1.

Table 1
Socio-demographic characteristics of the respondents

Socio-demographic characteristics	Number	Percentage (%)
Gender		
F	29	41,4
M	41	58.6
Age		
Cadet (14 to 25 years old)	13	18.5
Junior (26 to 35 years)	23	32.8
Senior (36 and over)	34	48.5
Location and focus		
Kasenga	7	10
Kasumbalesa	5	7.1
Lubumbashi	53	75.7
Kipushi	2	2.8
Sakania	3	4.3
Professional experience		
Beginners (< 1 year)	3	4.3
Elementary (1 to 5 years)	14	20
Intermediate (6 to 10 years)	11	15.7
Experienced (11 to 35 years)	42	60
Tasks performed in the industry		
Pig buyer-pork seller at the market	33	47.1
Pork seller at the market	8	11,4
Slaughterer-pork seller	18	25.7
Sellers of grilled pork	11	15,7

2.2. Knowledge of the taeniasis/cysticercosis complex

2.2.1. *Taenia solium*, porcine cysticercosis, its clinical symptoms, and sources of infestation in pigs and humans

Most respondents (60 out of 70, or 86%) described porcine cysticercosis as a pig disease marked by white nodules in pork or grains that look like rice, fish eyes, or insects. Most respondents (89%) accurately described the manifestations of *Taenia* in porcine carcasses, and 90% identified the anatomical sites harboring cysticerci.

Of the 70 respondents, 61 stated that they were unaware that humans could develop cysticercosis. Among the remaining 9 who reported being informed about human cysticercosis, only two mentioned headaches and loss of

consciousness as signs of the condition.

Nearly all respondents (97%) were unaware of how pigs become infected, and 84% did not know how humans are infected by *T. solium*. More than half (73%) of respondents were unaware of the factors contributing to pig infection. Most respondents indicated that pigs become infected through contaminated food, free-range farming, eating kitchen waste, lack of vaccination, epidemics, poor hygiene, lack of treatment during feeding, eating hot food, being too agitated, mating, or pig breed. In contrast, 25/70 responded, "I do not know." Only 11/70 respondents indicated that humans become infected with the intestinal worm by consuming undercooked infected pork.

Most respondents reported where the infected pigs came from. Out of 70 respondents, 22 reported Zambia as the source; 16 mentioned both Zambia and DRC; another 16 cited Haut-Katanga Province alone; 10 believed the infected pigs came from various places; 3 were unsure of the origin; and 2 had never seen cases of porcine cysticercosis in their practice (appendix, Table A1). One stakeholder was unclear about the specific location inside the pig.

Respondent No. 9, aged 60 and experienced, stated: "*Taenia is in the intestines; many see white balls in the meat and say it is taenia, but that is not true: Taenia is in the pig's intestines.*"

2.2.2. Knowledge Scores

The different knowledge scores for the disease in pigs and humans were as follows (Fig. 2): for the 12 questions on porcine cysticercosis, scores ranged from 2 (insufficient knowledge) to 11 (good knowledge), with a median of 8, indicating generally average knowledge, although individual scores ranged from insufficient to good. For human taeniasis and cysticercosis (6 questions), scores ranged from 0 (no knowledge) to 5 (good knowledge), with a median of 0. Most respondents (59/70) scored 0–2, including 40 who scored 0, indicating insufficient knowledge, while only one respondent demonstrated a good understanding of the human disease form. The total score for the taeniasis/cysticercosis complex (18 questions scored out of a 24-point scale) ranged from 2.5 (insufficient knowledge) to 19.5 (Good knowledge), with a median of 9, reflecting an average understanding of the zoonosis but with considerable variation, from insufficient knowledge to good knowledge, in understanding infections in pigs and humans.

Statistically, none of the explanatory parameters (gender, age, professional activities, workplace, and professional experience) were significantly associated with respondents' knowledge levels regarding human taeniasis and cysticercosis. However, professional experience (years in the profession) was significantly associated with porcine cysticercosis knowledge scores ($p = 0.027$) and with the zoonotic dimension of the disease (Taeniasis-cysticercosis complex). Beginners' knowledge levels regarding porcine cysticercosis were statistically lower than those of elementary ($p = 0.043$), intermediate ($p = 0.035$), and experienced workers ($p = 0.035$), suggesting that fieldwork experience enhances knowledge and that newcomers tend to learn about the parasite and its zoonotic aspect on-site. Figure 3 illustrates knowledge score levels across professional experience levels.

Regarding understanding porcine cysticercosis and its zoonotic potential, beginners' knowledge ranged from insufficient to average. Conversely, elementary, intermediate, and experienced respondents showed mostly average and good knowledge. Nonetheless, most respondents across all categories had insufficient knowledge of human taeniasis and cysticercosis. These scores primarily reflected knowledge of porcine cysticercosis rather than awareness of its zoonotic aspect.

These scores did not differ significantly across gender categories, regardless of professional experience.

2.3. Attitudes and practices of stakeholders in the pig value chain toward infected pigs/carcasses

2.3.1. Attitudes and practices of stakeholders in the pig food chain

Three-quarters of respondents reported checking for cysticerci under pigs' tongues during purchases. Among these, 23 identified live infected pigs by detecting nodules under the tongue, plucking hair (which often pulls out easily with some blood at the tip in infected animals), and inspecting the eyes. Others used a combination of methods or looked at the animals' overall condition.

Respondent No. 13, an experienced individual, stated: *"We examine the pig's oral cavity; we take soil in hand, hold the tongue, turn it to see the nodules, and also check the eyes for any nodules inside."*

Respondent No. 16, also experienced, noted: *"We also examine the cry, or pluck the hairs and look at the tips; if there is a little blood, such a pig is infected. But above all, the tongue examination."*

Most (61%) reported veterinarians did not inspect pork, and some respondents (23 out of 70) admitted to selling contaminated carcasses, while others (8 out of 70) discarded them or returned them to pig owners (19 out of 70). Additionally, 35% of respondents acknowledged engaging in practices such as decontaminating pork, disguising signs, or selling it regardless of the signs. These methods included applying red blood to the pork, using lemon juice before cooking, soaking in salt water, boiling and selling the meat, mixing infected and healthy pork, feeding pigs salt, and manually removing cysticerci with knives (appendix Table A2).

Observations indicated that neither tongue palpation nor carcass inspections were conducted at the border. Pigs imported from Zambia crossed into Congolese territory without restrictions, only paying a transit tax to veterinary authorities. In Haut-Katanga Province, most pigs were slaughtered at home without veterinary oversight or at informal sites near pork markets. Veterinary officials visited meat selling locations irregularly and often with delays. All carcasses with viable cysticerci, even if infected, were delivered for human consumption, either as retail pork cuts or as grilled pork, which was reportedly treated with lemon juice to kill the cysticerci (Fig. 4). For instance, respondents No. 10, 13, 16, and 20, who are senior and experienced stakeholders, provided comments about veterinary meat inspection:

"It really hurts us; we sell to people who resell grilled meat to avoid losses. If the veterinarian sees it, we pay him money, and He lets us sell; it is really visible on the meat."

"The pork is sold to people who grill it and make sausages. The veterinarians here do nothing, unlike those in our city who check all the organs. Here, whether the pig is sick or healthy, it is only about money".

"There is a lot of disorder; in Kasumbalesa, He only asks 2,500 CDF per animal head, and that is it. They do not check the animals' health. Locally, they demand money, and we negotiate so that they do not burn the meat. "I myself have already eaten it, but I did not experience any symptoms".

"He will not know how to eat; while you eat that, it is like chewing lice in your mouth, the meat has no taste".

If the veterinarians discover it, we give them something, and we sell the meat cheaper to children who grill it, to avoid losses.

Based on the workplaces of the stakeholders, 53/70 respondents were from Lubumbashi (an urban city). Among them, 30/53 engaged in moderate-risk practices, and 19/53 engaged in high-risk practices, such as those at border sites in rural areas.

2.3.2. Stakeholders' attitudes and practices scores

Stakeholders' attitudes and practices in the pig food chain regarding pigs and carcasses infected with *Taenia*, responses focused on risky behaviors that could promote parasite transmission and sustain its life cycle, given its potential zoonotic impact. Attitude and risk practice scores ranged from 1 (low risk) to 6.5 (high risk), with a median of 3.5 (moderate risk) (Fig. 5A).

Over half of the respondents (38, or 54%) engaged in moderate-risk practices, 28 (40%) in high-risk practices, 1 in very high-risk practices, and 3 (4%) in low-risk practices.

No statistically significant differences were observed in these scores by gender ($p = 0.776$), age ($p = 0.689$), professional activities ($p = 0.522$), workplace ($p = 0.298$), or professional experience ($p = 0.212$). However, all beginner respondents were engaged in high-risk practices (Fig. 4B).

2.2.3. Statistical trends in knowledge of the taeniasis/cysticercosis complex and the attitudes and practices of stakeholders in the pig trade chain

Spearman's correlation was used to assess relationships between participants' knowledge (of porcine cysticercosis, human taeniasis and cysticercosis, and the overall taeniasis/cysticercosis complex) and their attitudes and practices toward pigs infected with *T. solium*. Stakeholders' knowledge level does not appear to positively influence their behavior toward good management and public health protection. However, a weak negative correlation ($r = -0.20$, $p = 0.091$) was observed between knowledge of human taeniasis and cysticercosis and stakeholders' attitudes and practices, but the association was not statistically significant. Figure A1 (appendix) illustrates these trends across different scores.

2.4. Economic impact of cysticercosis in Haut-Katanga province

Five questions assessed the economic impact of porcine cysticercosis on stakeholders throughout the pig food chain (Table 2). These questions aimed to determine if infected pigs caused financial losses. Most respondents (60 out of 70, or 86%) reported that the pig sector remains generally profitable, while 8 out of 70 (or 11%) gave mixed answers (Yes and No). Among the 68 respondents who reported profitability, 57 (84%) linked it to variable factors, including live pig purchase prices, pork selling prices, and retail sales costs. Additionally, 68 out of 70 (97%) experienced losses during pork sales, caused by factors like the gap between live pig purchase prices and retail pork selling prices (34/70, 50%), porcine cysticercosis and unsold meat (9/70, 13%), poor meat conservation (7/70, 10%), and animal deaths before sale (5/70, 7%). While 23 of 70 respondents (33%) reported no consequences from buying infected pigs, others reported carcass seizures by veterinarians (23/70, 33%) or customers refusing to buy the meat (21/70, 30%).

Table 2

Economic aspects of the pork food chain and the impact of cysticercosis on pork sales

Questions and responses	Number	Percentage (%)
Is the pig and pork business profitable for you? (n = 70)		
Yes	60	86
No	1	1
Yes-No	8	11
No answer	1	1
If so, how? (n = 68)		
Regarding purchase and sale prices	57	84
After the sale, we made a profit	1	1
Hard to say	1	1
Discipline in trade	1	1
People appreciate pork meat and buy a lot of it	1	1
No answer	7	10
Have you ever suffered losses in the pig/pork industry and trade?		
Yes	68	97
No	1	1
No answer	1	1
If so, what is the reason? (n = 68)		
Meat contamination by <i>Taenia</i>	9	13
Sale prices versus purchase prices	34	50
Poor meat preservation practices	7	10
Pre-sale animal mortality	5	7
Unpurchased pork	9	13
Meat theft	1	1
Excessively fatty pork	3	4
Can you tell me what the consequences are of buying a contaminated pig for marketing?		
Losses due to carcass condemnations by veterinarians	23	33
No Consequences	23	33
Customers refuse to purchase meat	21	30
I do not know about it	2	3
No answer	1	1

Table 2 shows that the pig and pork trade is profitable, mainly because of differences between source purchase prices and market selling prices for animals and carcasses. Additionally, porcine cysticercosis contributes as a secondary factor causing losses for stakeholders involved in the pork trade.

Out of 70 stakeholders, 23 reported no consequences from selling infected pork. Among these, 13 practiced moderate-risk behaviors, 9 practiced high-risk behaviors, and 1 practiced very high-risk behaviors. Among the 32 respondents who indicated carcass seizure and destruction by veterinary services as consequences, 14 practiced moderate-risk behaviors, 8 engaged in high-risk behaviors, and 1 had low-risk practices. Among the 21 respondents who noted customer refusal to purchase pork as a consequence, 10 exhibited moderate-risk practices, 10 exhibited high-risk practices, and 1 had a low-risk practice.

3. Discussion

This study evaluated knowledge, attitudes, and practices (KAP) of stakeholders across the Zambia-DRC border and how this can influence *Taenia solium* transmission. To our knowledge, it is the first regional investigation to examine this among cross-border pig trade stakeholders, with a focus on how livestock movement and related practices drive the transboundary transmission of porcine cysticercosis. While prior research has documented travel- and tourism-related importation of human cysticercosis from endemic low-income regions into Europe and North America (Zammarchi et al., 2013; Trevisan et al., 2018; Kusnoto et al., 2025), this work uniquely highlights the role of international pig trade in parasite dissemination. By linking stakeholder knowledge, attitude, and practices directly to trade-driven cross-border parasite spread, this study offers a novel contribution to understanding transboundary disease dynamics.

The study found that most respondents had a moderate to good understanding of porcine cysticercosis, consistent with prior research in Sub-Saharan Africa (Nyangi et al., 2022; Zulu et al., 2023; Minani et al., 2025). However, having sufficient porcine cysticercosis knowledge alone did not prevent the importation of infected pigs. Three distinct control levels for traded pigs were identified along this food chain, from initial sourcing in Zambia and border points to slaughterhouses and pork consumption areas in Haut-Katanga province. The first control level occurs at the source, where pig buyers could perform tongue palpation. The second occurs at the border and nearby facilities, where veterinary services can conduct tongue inspections. The third occurs at slaughter sites and pork consumption points, where official veterinary authorities inspect carcasses (Tshiasuma et al., 2026, submitted). Dorny et al. (2004) and Phiri et al. (2006) note that tongue palpation is a quick field test but has limited sensitivity, while routine slaughter inspections are more sensitive. Despite these limitations, they remain vital in endemic regions like Haut-Katanga Province, where laboratory testing is unavailable. Nonetheless, even with these three checkpoints and stakeholder knowledge, tongue palpation was not systematically implemented, and infected pig carcasses were still imported and delivered for human consumption in Haut-Katanga. The lack of veterinary oversight during pig importation and slaughter can increase epidemiological risks associated with the taeniasis/cysticercosis complex in Haut-Katanga province.

This study highlighted a significant awareness gap: knowledge of porcine cysticercosis was fairly well established, while understanding of human cysticercosis and taeniasis was notably limited. This gap could reflect unequal stakeholder access to information, shaped by differences in educational background or personal experience with the disease. However, Zulu et al. (2023) found that education level did not significantly impact participants' knowledge of porcine cysticercosis in Zambia. Instead, this local, animal-level knowledge likely comes from stakeholders who directly observe lesions during pig slaughter. In contrast, healthcare facilities generally diagnose human infections, where medical ethics and patient confidentiality prevent public disclosure (Lucas, 2009). Furthermore, most cases of human neurocysticercosis are difficult to diagnose in Lubumbashi due to a lack of diagnostic tools, limited laboratory

infrastructure, and the high cost of CT scans (Mukuku et al., 2020; Tshiasuma & Kasongo, 2022). The widespread lack of understanding of human cysticercosis and taeniasis among respondents underscores an urgent need to improve community awareness, as knowledge gaps could seriously hinder parasite control efforts (Sharma et al., 2025).

While stakeholders' knowledge of porcine cysticercosis increases with their professional experience in the sector, their attitudes and practices paradoxically become higher-risk over time, exposing pork consumers to significant health threats. This gap between awareness and practice is largely driven by financial motives: a vast majority of respondents (67 out of 70) prioritized the economic aspects of the trade, mirroring findings by Thys et al. (2016) in Zambia. Many stakeholders believed selling infected pork had no real consequences, while others saw consumer distrust at the point of purchase as the sole drawback. Consequently, lingual palpation was used not primarily to exclude infected animals from the market, but to negotiate lower purchase prices for diseased pigs, with 16% acknowledging the sale of infected carcasses. This profit-driven mindset also explains why some stakeholders deliberately use methods to mask or eliminate visible cysticerci before commercialization. Economic data from the region further illustrate this incentive structure. In eastern Zambia (Katete and Sinda districts), Hobbs et al. (2018) reported that an infected pig sold for a median price of 10 USD, a 45% drop compared to a healthy animal. Similarly, in Burundi, Minani et al. (2025) observed that an adult pig's price dropped from 300,000 Burundian francs (BIF) to just 100,000 BIF when infected, making discounted diseased meat a lucrative trade alternative. This could suggest that cysticercosis is perceived in this international pig food chain as a veterinary issue or an economic problem unrelated to public health. The lack of systematic carcass condemnations and destructions by veterinary services further contributes to the importation, commercialization, purchase, and consumption of infected pork among the population. Minani et al. (2025) observed similar patterns in Burundi, noting risky practices such as free-range pig farming, the absence of systematic meat inspections, and the direct consumption of potentially infected pork. This suggests that stakeholders prioritize economic considerations in the pig food chain, selling infected pork without knowing the health consequences for human consumers.

The study found that gender, age, professional activity, and workplace do not affect stakeholders' knowledge, and risky practices are evenly spread across locations, including Lubumbashi, an urban town. However, Zulu et al. (2023) in Zambia observed that gender impacted knowledge levels, with males having more knowledge than females.

A "One Health" approach, emphasizing links among animal, human, and environmental health, is crucial for fostering sustainable and effective behavioral change (Gabriël et al., 2017; FAO, 2019) in this cross-border food chain.

This study uses data from individual interviews, which may be influenced by response biases stemming from participants' emotions and concerns about a topic that directly affects their livelihoods. These biases might have led to underreporting respondents' knowledge of the taeniasis-cysticercosis complex and risky behaviors, or overreporting socially accepted practices related to managing infected pigs and carcasses. Moreover, the limited number of interviews may have restricted the overall representativeness of the results, and may have limited the diversity of viewpoints. This research used a voluntary convenience sample limited by the targeted study population; those directly involved in the live pig trade between Zambia and the DRC, as well as slaughterers and pork sellers in local markets. While this narrowed the respondent pool, it ensured data collection from the key stakeholders responsible for transmission risks along this trade route, achieving thematic saturation in their knowledge, attitudes, and practices concerning porcine cysticercosis.

4. Conclusion

This study examined the knowledge, attitudes, and practices of stakeholders in the pig food chain operating between Zambia and Haut-Katanga Province (DRC), with a focus on the zoonotic risks associated with *Taenia solium* and

practices related to infected pigs. The results show a significant mismatch in stakeholders' understanding of the taeniasis/cysticercosis complex. While many respondents had a good grasp of porcine cysticercosis, important gaps remained, especially regarding its zoonotic nature, which led to underestimating the risk to human health. As a result, stakeholders often purchased infected pigs imported from Zambia and consumed them in Haut-Katanga, putting economic interests before public health. These findings highlight the urgent need for interventions based on a One Health approach, including targeted education and active stakeholder involvement across the regional pig sector. An integrated, multisectoral strategy is crucial to reducing transmission risks and improving food safety in this cross-border context.

Abbreviations

- DRC: Democratic Republic of Congo
- FC: Congolese franc.
- KAP: Knowledge, attitudes, and practices
- UNILU/CEM: Medical Ethics Committee of the University of Lubumbashi
- USD: The **United States Dollar**
- BIF: Burundian francs
- VLIR-UOS: Vlaamse Interuniversitaire Raad - Universitaire Ontwikkelingssamenwerking

Declarations

Ethical approval and consent to participate

The study protocol was approved by the Faculty of Veterinary Medicine of the University of Lubumbashi and the Medical Ethics Committee of the University of Lubumbashi (Approval No: UNILU/CEM/017/2023/Comité d'éthique médicale de l'Université de Lubumbashi). Research authorizations were obtained from the administrative authorities of the Kasenga, Sakania, and Kipushi territories, as well as from the Lubumbashi city council. Informed consent was obtained from each participant verbally, in accordance with national and international guidelines for research involving human subjects. The study, its potential benefits, and risks were fully explained to participants. Individuals who declined participation were excluded. In the field, we clearly informed participants that involvement was voluntary and that they could withdraw at any time without prejudice. The consent form was read aloud to each participant, and their verbal consent was obtained. Two minor participants, aged 14 and 16, were interviewed after obtaining verbal informed consent from their mothers, who ran separate meat stalls at the same market. The study followed applicable guidelines and regulations, including the Declaration of Helsinki. Data confidentiality was maintained throughout collection and analysis: unique identifiers were assigned, no names were used in review, and results were disseminated while strictly preventing access to direct or indirect personal identifiers.

Consent to Publish declaration

Not applicable.

Data Availability

The data supporting the findings of this study are included within the article. Raw datasets are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare no competing interests.

Funding

VLIR-UOS (Belgium) funded this research in collaboration with the University of Lubumbashi (DR Congo) through a local PhD scholarship program.

Authors' Contributions

Tshiasuma Kedi Alain, Kasongo Aseke Grégoire, Sarah Gabriël and Tshikung Kambol Moses designed the study protocol, developed the survey questionnaire, and contributed to writing the manuscript. Tshiasuma Kedi Alain conducted data collection. Inge Van Damme performed the statistical analyses in collaboration with the lead author. All authors edited and revised the manuscript.

Acknowledgments

The authors sincerely thank all stakeholders in the pig food chain between Zambia and Haut-Katanga province for their active participation in this research. They also acknowledge the use of AI to translate French into English and to improve the quality of academic English sentences.

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Figures



Figure 1

Map of Haut-Katanga province showing border areas and sampling sites visited.

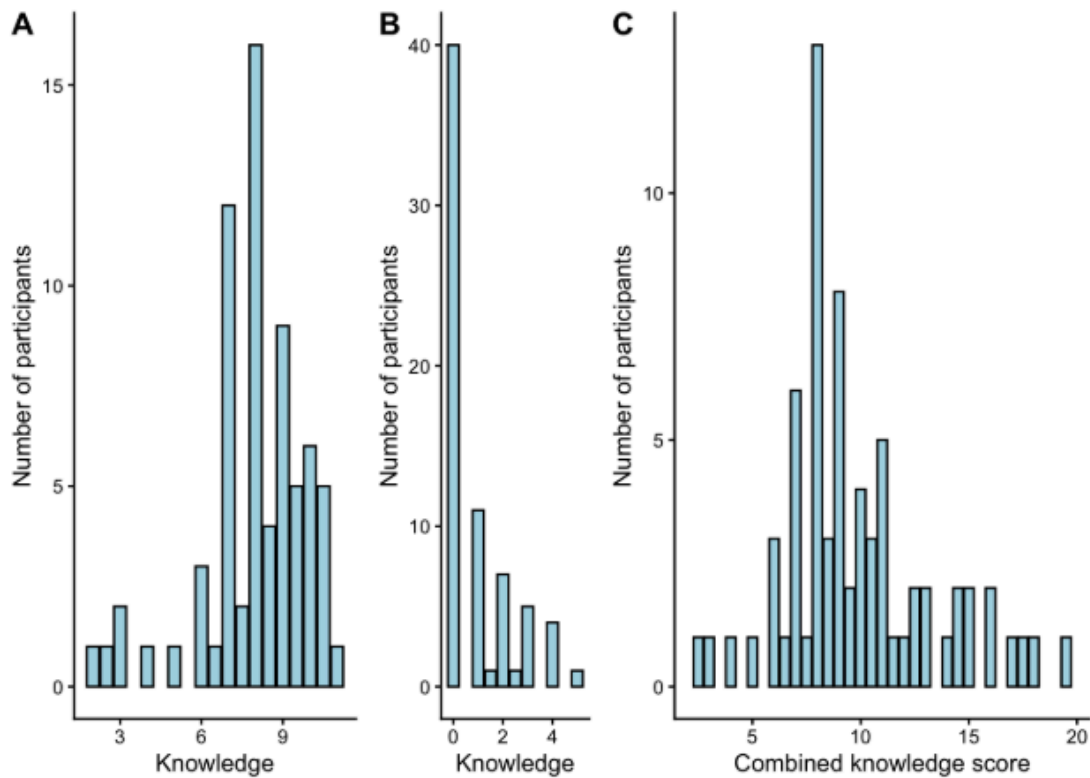


Figure 2

Distribution of stakeholders' knowledge scores in the pig/pork food chain across Zambia and DRC. A: Knowledge of porcine cysticercosis (12-point scale); B: Knowledge of human taeniasis and cysticercosis (6-point scale); C: Overall knowledge of the taeniasis/cysticercosis complex (24-point scale).

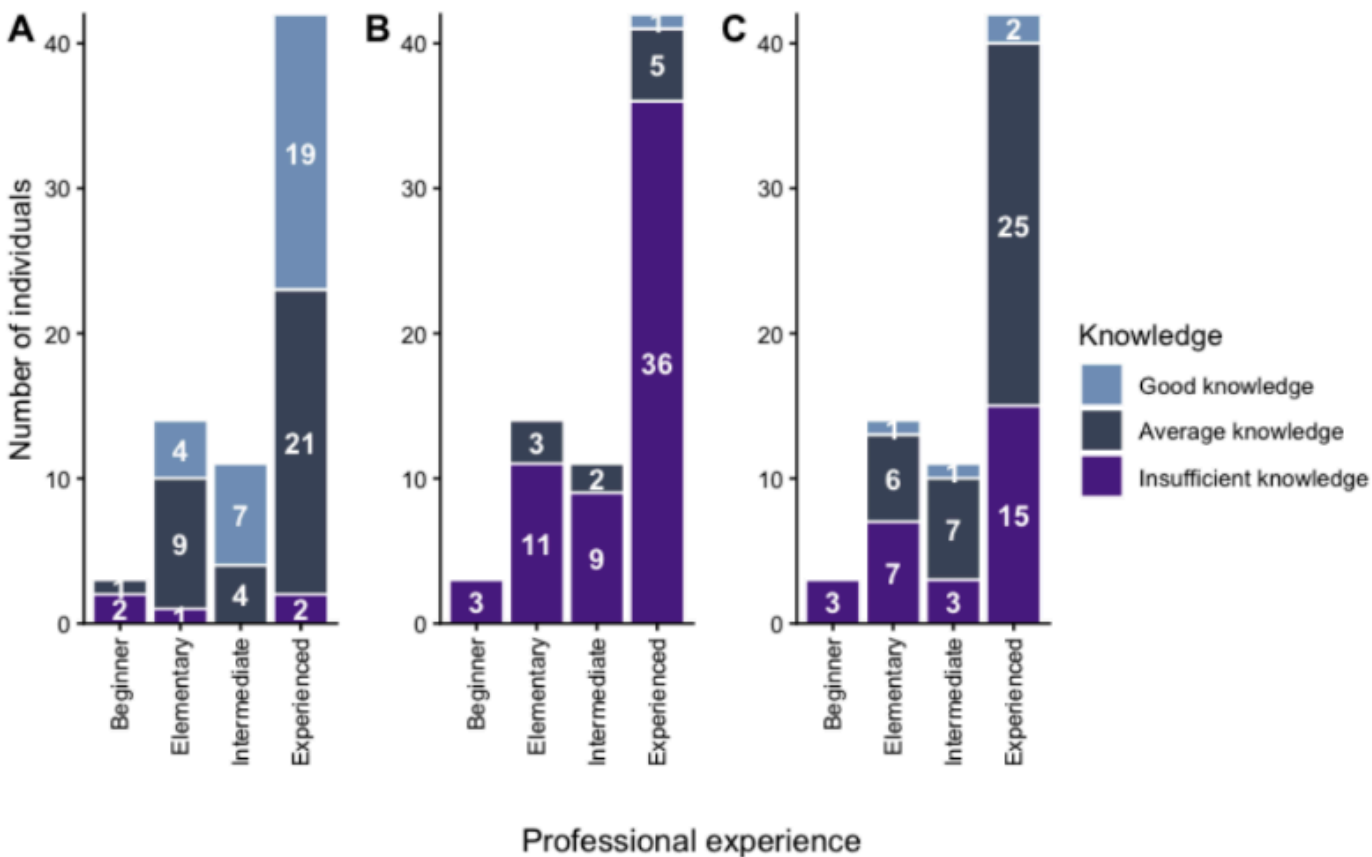


Figure 3

Knowledge of *T. solium* stakeholders based on their professional experience. A: score of porcine cysticercosis; B: score of human taeniasis and cysticercosis; C: score of the taeniasis/cysticercosis complex.

These scores did not differ significantly across gender categories, regardless of professional experience.

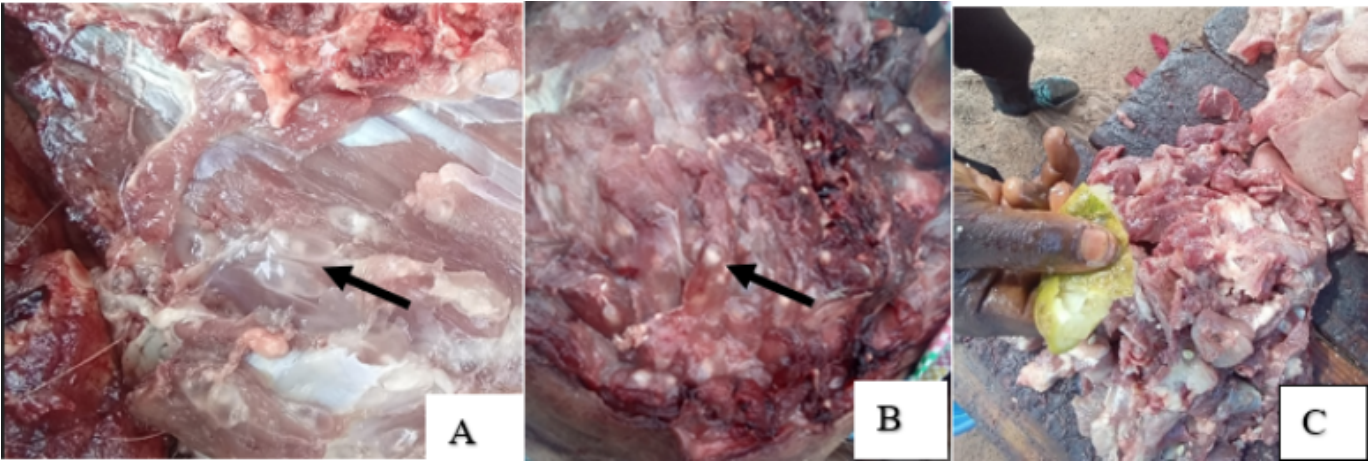


Figure 4

shows, in panels A and B, parts of pig carcasses slaughtered at home in Lubumbashi containing viable cysticerci, and in panel C, the lemon-juice treatment of pork infected with cysticercosis before consumption in Lubumbashi by a grilled-pork vendor.

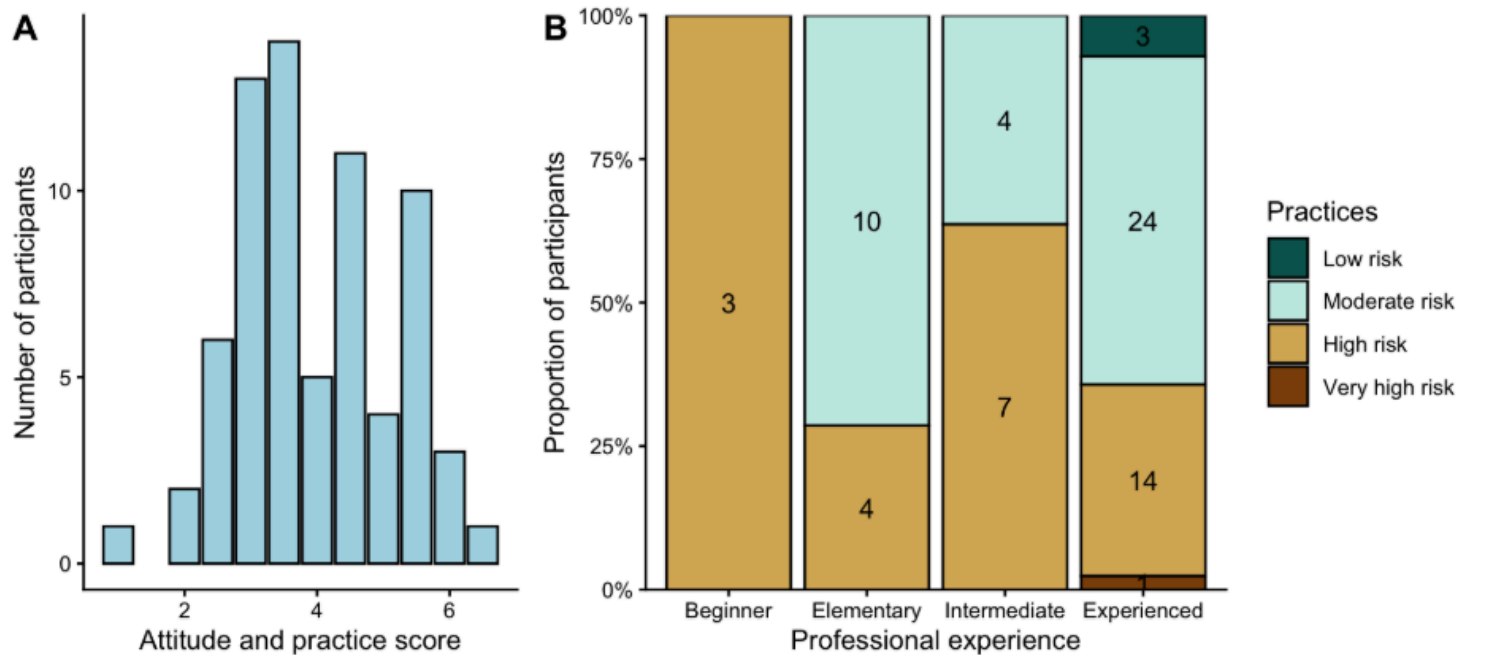


Figure 5

Stakeholders' attitude and practice scores reflect the management of pigs and porcine carcasses infected with *T. solium*. A: Distribution of attitude and practice scores among respondents (ranging from 1 to 6,5). B: Risk practices categorized by professional experience, primarily moderate and high-risk behaviors.

Over half of the respondents (38, or 54%) engaged in moderate-risk practices, 28 (40%) in high-risk practices, 1 in very high-risk practices, and 3 (4%) in low-risk practices.

No statistically significant differences were observed in these scores by gender ($p = 0.776$), age ($p = 0.689$), professional activities ($p = 0.522$), workplace ($p = 0.298$), or professional experience ($p = 0.212$). However, all beginner respondents were engaged in high-risk practices (Figure 4B).

Supplementary Files

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