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Mapping of the pig/pork cross-border food chain between Zambia and the Democratic Republic of the Congo as a first step to assess its potential impact on the occurrence of Taenia solium in Haut Katanga Province

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Abstract

Background

Taenia solium is a major foodborne zoonotic parasite highly prevalent in sub-Saharan Africa. A comprehensive farm-to-fork analysis of the pig production and supply systems is essential to identify and mitigate associated risk factors. The aim of this study was to map the cross-border pig/pork food chain between Zambia's Copperbelt and Luapula Provinces (Southern Africa) and Haut-Katanga Province in the Democratic Republic of Congo (DRC, Central Africa). A mixed-methods approach was employed, triangulating data from direct observations, stakeholder interviews, border veterinary services records, and counts of pigs crossing the border. This approach was used to map food-chain stages and pig/pork flows, to evaluate stakeholders' roles and pig management practices, to pinpoint critical control points for *T. solium* transmission to humans.

Results

A regular and persistent cross-border pig/pork food chain was identified, comprising six stages (supply sources, handling, health inspection, taxes and regulation, transportation, and first and final points of consumption) and ten stakeholder categories (pig shelter managers; pig buyers; sellers; pig slaughterers; handlers; border veterinarians; transporters; slaughterer–retailer pork sellers; veterinary inspectors; and pork sellers at home and in markets, including grilled-pork sellers). This chain extends from pig supply sources in Zambia and the DRC to multiple pork consumption sites in Haut-Katanga Province. During one week of counting, at least 1,696 live pigs and 32 carcasses were recorded crossing the border from Zambia into the DRC, compared with 4,799 animals officially reported over one year. The chain operates with minimal regulation and lacks effective health oversight from border crossings through slaughter to final consumption. Imported porcine cysticercosis cases were both reported by respondents and directly observed in pork markets. Tongue palpation was not performed systematically at purchase or during transit at the border, veterinary inspection was inconsistent, and infected pork was sold for human consumption at lower prices than non-infected meat. Infected pigs were purchased and their meat subsequently marketed.

Conclusion

These findings reveal notable gaps in cross-border surveillance and veterinary inspections, underscoring the critical need for coordinated control efforts among countries to reduce *T. solium* transmission and safeguard public health.

1. Introduction

Taenia solium taeniasis/cysticercosis is a neglected parasitic zoonosis of significant public health and economic concern, particularly in resource-limited settings (Ndimubanzi et al., 2010; Dixon et al., 2022). Pigs serve as the natural intermediate host (porcine cysticercosis), while humans are definitive hosts (adult tapeworm infection, or taeniasis) and accidental intermediate hosts (cysticercosis, including neurocysticercosis) (Murrell, 2005). Recognized as the leading global foodborne parasitosis and cause of epilepsy, control is urgently needed. The disease is endemic in rural areas of Latin America, sub-Saharan Africa, and Southeast Asia, where smallholder pig production and pork consumption are hindered by suboptimal husbandry, hygiene, and sanitation practices (Laranjo-González et al., 2017; Oyarce et al., 2022). Among sub-Saharan African countries, Zambia and Madagascar report high burdens (Kouadio et al., 2022). In Zambia, serological surveys indicate porcine cysticercosis prevalences of 15–34% based on circulating antigen detection, whereas full carcass dissections reveal substantially higher rates of 46–68% in market-age pigs (Chembensofu et al., 2017). In the DRC, a prevalence of porcine cysticercosis of 5.5% by tongue inspection and 38%-41.2% by Ag-ELISA has been reported in western regions, including Kinshasa and Kongo Central Province (Praet et al., 2010; Kanobana et al., 2011; Madinga et al., 2017). No peer-reviewed studies have assessed the prevalence of taeniasis/cysticercosis in Haut-Katanga Province, although neurocysticercosis is suspected in 4–10% of epilepsy cases based on clinical and neuroimaging data (Mukuku et al., 2020; Tshiasuma & Kasongo, 2022). In this province, pork is highly prized, and smallholder pig farming constitutes a vital livelihood component across Zambia and the DRC (Gulelat et al., 2022).

It is known that the biological transmission of *T. solium* is strongly influenced by livestock production systems and pork marketing networks. Traditional pig production and pork consumption have surged across the region, and associated trade networks remain

predominantly informal and straightforward, with most animals originating from small-scale producers and being sold live at live-animal markets, auctions, and slaughterhouses (Edoukou, 2022; Adesehinwa et al., 2024). Direct trade predominates in several southern African countries, notably Zambia, where smallholder farms rely on live sales to meet diverse economic needs, such as subsistence income, medical expenses, and schooling (Edoukou, 2022). According to the Zambian Ministry of Fisheries and Livestock (2024), approximately 699,200 pigs are marketed annually, with the DRC (particularly Haut-Katanga Province) as the primary export destination (World Bank, 2022; Zambian Ministry of Fisheries and Livestock, 2024). While cross-border trade in agricultural commodities fosters socioeconomic linkages between Zambia and Haut-Katanga, it also facilitates the transboundary dissemination of diseases such as *Taenia solium*. Accordingly, the pig food chain at this interface requires investigation to elucidate *T. solium* transmission dynamics from Zambian pigs to humans in Haut-Katanga Province. This study mapped the pig food chain between Zambia and Haut-Katanga (DRC), identifying key stakeholders, regulatory frameworks, pork marketing processes, and pig/pork management practices to pinpoint transmission risk points.

2. Materials and methods

2.1. Study areas

The study was conducted at border locations between Zambia and the Haut-Katanga Province of the DRC, specifically in the border towns of Kasenga (-10.401322, 28.616202) (bordering Luapula Province in Zambia), Kipushi (-11.756005, 27.251560), Sakania (-12.752570, 28.548453), and Kasumbalesa (-12.270532, 27.795235) (bordering Copperbelt Province in Zambia), as well as in the city of Lubumbashi (Fig. 2). The border sites were intentionally chosen in this study due to their geographical position along the Zambia border. These sites also act as important entry points for pigs and pork products into Haut-Katanga and are places where Zambia-origin pig/pork is consumed.

Haut-Katanga Province, located in southeastern DRC, borders Haut-Lomami Province to the northwest, Tanganyika Province to the north, Lualaba Province to the west, and Zambia to the east and south (Luapula and Copperbelt Provinces, respectively). Covering 132,425 km² with an estimated population of 7.341 million, the province serves as a strategic hub for major mining operations (Site Officiel de la Province du Haut-Katanga, 2025). Livestock farming remains a traditional practice, dominated by goats, sheep, pigs, poultry, and fish (Kalenga et al., 2018). Due to limited local agricultural output, Haut-Katanga relies heavily on imported consumer foodstuffs, particularly pigs/pork, which is sustained by extensive cross-border trade with neighboring Zambia (Guéné, 2014).

2.2. Study design

This research constitutes the first component of a larger study designed to assess the role of international pig/pork trade in the circulation of the taeniasis/cysticercosis complex by investigating the cross-border pig food chain between two neighboring countries, Zambia (pig source) and the Democratic Republic of the Congo (pig importer). A mixed-methods study combining qualitative and quantitative approaches was conducted from August 2023 to January 2025 to map and characterize this pig food chain, with an emphasis on its potential role in *T. solium* transmission. The study triangulated data from participant and non-participant observations (from pig supply at border locations to slaughter, retail, and consumption markets in Haut-Katanga province), semi-structured interviews with stakeholders involved in the cross-border pig/pork trade, border veterinary services records, and counts of pigs crossing the border. These activities provided data on pig origins, imported pig breeds, the stages of the pig food chain (including import routes, identified and georeferenced via the Epicollect5 application), stakeholders involved (including their roles), and the flow (including actions and critical points that could facilitate the transmission of *T. solium*) of pigs from Zambia to pork consumption sites in Haut-Katanga Province.

2.3. Stakeholder identification

Stakeholders were identified through field observations and snowball sampling at key sites, including border purchase points, transit areas, veterinary offices, embarkation/loading sites, slaughterhouses, and pork markets. They were then selected based on their specific roles in buying and selling pig/carcasses, animal handling, health inspections, tax collection, slaughtering, marketing, and transport. The roles of all stakeholders, including veterinary services, were documented in field notebooks. A total of 96 stakeholders involved in the purchase, sale, slaughter, and retail of pigs and pork (who voluntarily agreed to participate in the study) were selected and interviewed. They were enrolled and integrated into the study after a brief discussion and an explanation of the study's objectives and expectations.

2.4. Observation

Observations were conducted (for at least a month) at supply sources on border sites (shelters and slaughter structures at the border), on the section between shelters and the border, including the routes used by handlers leading pigs to the border with the DRC, at the DRC veterinary service, up to the slaughter and retail point for pork meat in the city of Lubumbashi. The pigs' entry corridor into the DRC opens onto a free space providing access to the veterinary service warehouse. At this stage, it was necessary to observe the animals' entry into the DRC, their movement direction, and the veterinary service's various activities, such as handling infected pigs and carcasses at border crossings and during transportation.

Information related to the verification of the health status of pigs (lingual palpation), the practices of sellers, buyers, and slaughterers toward infected pigs, as well as the decisions and destination of infected pigs/carcasses, was recorded in a field notebook. Veterinary activities at the border, such as administrative procedures for fees and veterinary acts, were observed. This included activities at border posts related to fee collection and service delivery. At Lubumbashi markets, veterinary interventions at slaughterhouses and retail pork outlets were documented, focusing on inspection standards, carcass condemnations, and practices that could enable the sale of infected pork. These observations were triangulated with interview responses to confirm or challenge participant claims.

2.5. Review of veterinary records and daily count of pigs crossing

Data on the number of pigs crossing the border (from official veterinary records and daily counts) and on the management of live infected pigs and infected carcasses were needed to evaluate the regularity of these trade flows and the risks they can pose to the importing country and pork consumers. Access to animal movement records at border posts was requested and granted by the veterinarians. Pig crossing registers for 2023 at Kasumbalesa, Sakania, and Kasenga (the only available documents) were reviewed. Monthly pig crossing volumes for the year were recorded in field notebooks, and photographs of tables in the registries (taken with a mobile phone) were stored.

At the border, daily direct pig crossings over one week, from 8:00 a.m. to 3:00 p.m., were manually counted (by TKA) using a handheld counter as they crossed into the veterinary service enclosure or elsewhere (informal), with daily records maintained. Geographic coordinates of pig transit routes were recorded using the Epicollect5 application to identify both formal and informal import routes.

2.6. Semi-structured Interviews

Two semi-structured questionnaires (Appendix 1) were developed based on the literature and administered to stakeholders via Epicollect5 (https://five.epicollect.net/). Before data collection, the questionnaire was pretested with 10 stakeholders in Kasumbalesa to identify necessary adjustments. It was written in French and administered (for a maximum of 30 minutes) by TKA to respondents fluent in French or in Swahili.

The first questionnaire consisted of nine items: five to capture respondents' sociodemographic characteristics (age, gender, length of service in the sector, professional role, and workplace) and four to assess pig origin and practices related to the inspection and control of porcine cysticercosis along the chain. It was administered to 96 stakeholders.

The second questionnaire (41 items) was administered to 26 pig-importing traders operating between Zambia and DRC, selected through snowball sampling from among the 96 stakeholders.

This second questionnaire was divided into several sections. Five questions (identical to the first five of the first questionnaire) were designed to collect information on the respondents’ sociodemographic characteristics, including age, gender, length of service in the sector, professional role, and the area from which the pigs were sourced. Thirteen questions were specifically targeted at pig importers to gather economic data on weekly import volumes of pigs or carcasses, purchase price ranges, total import costs, average cost per pig from Zambia to Haut-Katanga province, payment methods, and the administrative qualifications of agents collecting fees. The purchase prices for pigs/carcasses (infected and uninfected), import volumes (pigs per day or week), importation costs (including fees at each stage of the chain), taxes, slaughter volumes for sale or consumption in Haut-Katanga, import permit ownership and costs, and regulatory frameworks governing the pig food chain (all collected through interviews with pig import traders) were included in the study to assess their economic importance and potential links to *T. solium* dissemination.

Sixteen questions explored the (application of the) regulatory framework of the pig trade from the border to the Haut-Katanga destination. They assessed traders' required authorizations (document identification), importation routes, sanitary control procedures (including control officers' perceived competence), and transportation types. Seven additional questions examined traders' purchasing practices in Zambia or at the border, covering preliminary tongue examinations, management of infected animals, veterinary control and inspection regulations, and methods for sorting pigs with cysticercosis.

2.7. Data analysis

Monthly pig border crossings data (from veterinary services) were compiled in Microsoft Excel to calculate average monthly volumes. Daily observed crossing records (logged from 8:00 a.m. to 3:00 p.m.) were also maintained in Excel for deriving daily averages and minimum weekly volumes. Transit route geographic data were mapped in ArcGIS 10.7 to distinguish formal routes (with sanitary controls) from informal ones used by pigs from Zambia.

Interview data were extracted from the Epicollect5 server in Excel format, cleaned, and thematically categorized. All data were presented descriptively. Sociodemographic characteristics of respondents were reported as proportions. Pig-sourcing areas, as well as slaughter, sales, and pork-consumption sites in Haut-Katanga province, were tallied and presented by tally frequency. Reported weekly import volumes of pigs/carcasses, along with slaughter and sales figures, were grouped into categories (< 10, 10–20, 50+) and presented by citation frequency. Purchase prices were reported as minimum and maximum values in Congolese francs, converted to US dollars at a rate of 2,850 FC per USD (the 2023 USD exchange rate).

3. Results

3.1. Sociodemographic characteristics of the identified and interviewed stakeholders

Ten stakeholder categories involved in the pig food chain were identified (Fig. 1), and interviews were conducted with 96 stakeholders in total. Table 1 provides an overview of their sociodemographic characteristics. The male-to-female ratio was 51:45 among individuals aged 16 and above. Most participants (64.5%) in the pig and pork markets were retail buyers and sellers, mainly active along the Zambia–Kasumbalesa–Lubumbashi corridor.

Table 1
Sociodemographic characteristics of stakeholders operating within the pig food chain at the Zambia– DRC (Haut-Katanga province) interface.

Socio-demographic characteristics	Number	%
Gender		
M	51	53.1
F	45	46.9
Age range (years)		
< to 30	30	31.2
30 to 40	25	26
41 to 50	33	34.4
51 and over	8	8.3
Years of experience in the profession		
< 10	38	39.6
10–20	38	39.6
21–35	20	20.8
Sector activities		
Slaughterers	9	9.4
Buyer-slaughterer-retailers	9	9.4
Retailers of pork	12	12.5
Buyer-sellers of retail pork	62	64.5
Buyer-sellers of live pigs	4	4.2
Workplace and operational axis.		
Lubumbashi	32	33.3
Kasenga	7	7.3
Kasenga-Lubumbashi	1	1
Kasumbalesa	8	8.3
Kasumbalesa-Lubumbashi	34	35.4
Kipushi	5	5.2
Sakania	3	3.1
Lusaka-Kolwezi	1	1
Zambia-Lubumbashi-Likasi-Fungurume-Kolwezi	5	5.2

Shelter managers (1) protected housed pigs and collected per-pig housing fees. Pig sellers (breeders and intermediaries) from Zambia and the DRC (2), along with buyers (3), formed the key stages of exchange. Handlers (5) performed diverse tasks: restraining and delivering pigs to buyers; herding pigs toward DRC exit corridors or Zambian-side slaughterhouses; transporting bagged carcasses into the DRC; or loading animals onto trucks. At the border, the pig slaughterers (4) slaughtered and packed the carcasses into bags for transport to the DRC. Zambian veterinary service agents stationed on the Zambian side of the border periodically collected fees from DRC-origin pig slaughterers operating there (6).

Congolese veterinarians and veterinary assistants, police, National Intelligence Agency (ANR), and Migration Department (DGM) personnel stationed at the border corridor (6) collected fees for crossing pigs, import health taxes, and registered transboundary pigs. Transporters (drivers) (7) moved pigs to consumption sites in Haut-Katanga province. Pig slaughterer-pork retailers at slaughter and consumption sites in Haut-Katanga Province (8) purchased live pigs from traders, slaughtered them on-site, and sold the meat retail in markets or at home, most often as grilled meat. Veterinarians at animal slaughter sites in various markets across Haut-Katanga Province were assigned and collected veterinary service fees (9). The chain ended with abattoir slaughterers (4) and meat-inspector veterinarians (9), home and market pork sellers (10), and grilled pork vendors (10).

3.2. Import routes

3.2.1. Supply sources, pig breed, and consumption sites in Haut-Katanga Province

More than half (67 out of 96) of the respondents reported sourcing pigs from 25 locations in Zambia, including 8 cities (Lusaka, Ndola, Kitwe, Chililabombwe, Kapiri, Kabwe, Livingstone, and Solwezi) where pigs are aggregated, 2 border sites (Kasumbalesa and Kipushi), and 15 villages or rural localities (Kalomo, Choma, Kisubwa, Katandano, Kijiba, Kaburibo, Kasempa, Dolwe, Kiwele, Kanga, Matanda, Kibodia, Batonga Kamuala, and Serenje). Thirty-four respondents reported local pig sources in Haut-Katanga Province, including Kasenga Territory, Kipushi, Lubumbashi city, and surrounding villages. Nineteen respondents reported that pigs were sourced from various locations, including Zambia. Among the 26 respondents specifically involved in importing Zambian pigs, 18 (by frequency of citation) reported Lubumbashi as the main consumption site for these pigs; 4 cited Kolwezi city in Lualaba Province; 4 mentioned Kipushi; 3 reported Kasumbalesa; and 2 referred to Likasi city and Fungurume (Lualaba Province). Observations revealed that most pigs consumed in Sakania were local breeds originating from small-scale farms. Similarly, pigs observed in Kasenga and Kipushi were primarily local breeds sourced from small-scale farms, with a smaller contribution from neighboring villages in Zambia. In contrast, pigs imported in Zambia via Kasumbalesa into Lubumbashi, while predominantly local breeds, included a substantial proportion of improved breeds.

3.2.2. Routes used to import pigs.

A total of eighteen (18) pig entry routes into Haut-Katanga Province from Zambia (Luapula Province and Copperbelt Province) were identified as likely to be used by pig importers at the four border sites (Fig. 2). Of these, seven (7) routes were formal, and eleven (11) were informal. At Kasumbalesa, pig traders used eight (8) routes, including one formal route and seven informal routes. Sakania had three (3) formal routes; Kasenga had six routes (two formal and five informal); and Kipushi had one formal route. The main import routes run through Ndola and Kitwe in the Copperbelt Province, ultimately reaching Kasumbalesa toward Lubumbashi, and through Luapula Province via Kasenga toward Lubumbashi.

Route locations utilized by pig/pork traders traveling from Zambia to DRC (Haut-Katanga Province) are indicated by red dots. The names of the different routes varied by site and were coded as follows:

- *for Sakania: Lonshi road (Sa_Lo), Lukangaba road leading to the dry port (Sa_Lu), and Lukangaba Majimu road leading to Kipusha (Sa_Lu_Ma);*
- *for Kipushi: Kipushi road (Ki_bord);*
- *for Kasumbalesa: the Kasumbalesa corridor (Kasu_corr) and several informal paths crossing the wall separating the DRC from Zambia (w1, w2, w3, w4, w5, w6, w7).*
- *for Kasenga: river ports along the Luapula, namely Kaluba port (Kas_Ka), Kazembe port (Kas_Kaz), Kapumba port (Kas_Kap), Makungu port (Kas_Ma), and two main ports (Kas_P1 and Kas_P2)*.

Most pig traders (25 out of 26) reported that they do not import pigs via informal routes. They mainly use the Kasumbalesa corridor as the official crossing point for exporting pigs, which are then transported along the main Kasumbalesa–Lubumbashi Road to the city of Lubumbashi. Several informal routes identified in this study were employed by other traders for transactions involving non-porcine commodities.

3.2.3. Number of pigs crossing the border

3.2.4.a. Number of pigs recorded by the veterinary services

Data on official pig movements between Zambia and Haut-Katanga Province were obtained from three veterinary services, as shown in Table 2. For Kasumbalesa border post data, the database excludes the two weekend days (Saturday and Sunday). The pigs recorded in this table, therefore, correspond to five working days per week.

Table 2
Monthly summary of recorded pigs crossing the border at the sites visited in 2023.

Month in 2023	Kasumbalesa	Kasenga	Sakania
January	346	23	15
February	256	0	8
March	431	6	3
April	329	6	19
May	352	3	8
June	455	0	5
July	535	17	2
August	259	12	5
September	460	3	3
October	346	2	6
November	409	23	21
December	441	-	-
Total	**4619**	**88**	**95**
Average	**385 ± 84.5**	**8 ± 7.8**	**9 ± 6.6**

Monthly records indicate that a total of 4,799 pigs were imported from Zambia in 2023 through the Kasumbalesa corridor (4,619), Kasenga port 1 (88), and the Lukangaba Majimu road in Sakania (95).

3.2.4.b. The observed number of pigs crossing borders.

No pigs from Zambia were observed crossing the border at Kasenga or Sakania during the observation period. The daily count of pigs recorded at the Kasumbalesa corridor (formal route) over one week, from 8 a.m. to 3 p.m., is presented in Table 3.

Table 3
Counted number of pigs and carcasses crossing the border

Days	**Number of pigs passing through formal routes and the veterinary service**	**Number of pigs passing through formal routes and not through the veterinary service**	**Number of carcasses observed crossing through the formal route and not through the veterinary service**
Monday	332	34	7
Tuesday	201	38	2
Wednesday	173	21	10
Thursday	164	68	6
Friday	249	52	6
Saturday	156	34	1
Sunday	161	13	0
Total	**1436**	**260**	**32**

Table 3 shows that 1,696 pigs were observed crossing the border over the course of one week along the Kasumbalesa corridor. Of these, 1,436 passed through veterinary services for purchase tax purposes, while 260 did not. Additionally, 32 pig carcasses were identified as having bypassed veterinary inspection despite transiting the formal route.

3.2.4.c. Reported number of pigs by traders.

Twenty-six (26) respondents provided details on the weekly importation of live pigs and carcasses into Zambia, indicating that these imports are continuous and regular. They also reported the number of pigs sold in markets in Haut-Katanga Province (Table 4).

Table 4
Number of pigs and carcasses reported by traders, imported from Zambia, and sold in the DRC per week

Weekly number of pigs imported per trip (n = 26)	**Number**
< 10	14
10 to 20	7
22, 30, and 35	3
50 and 200	2
Number of carcasses imported per week (n = 26)	
0	22
3 and 4	2
Over ten	2
Number of pigs sold per week on the market in Haut-Katanga province	
< 10	12
10 to 20	11
35, 60, and 200	3

Table 4 indicates that pigs are more often imported live rather than as carcasses.

3.3. Mapping the pig trade chain between Zambia and the Democratic Republic of the Congo

Pigs and carcasses pass through 4 to 6 stages of the food chain to reach their destination (e.g., Kasumbalesa, Lubumbashi) in Haut-Katanga province (Fig. 4).

Stage 1: supply source

Congolese traders buy pigs either directly from Zambian farmers, from intermediaries in villages and cities, or from border shelters where they store them for resale. Some buyers, those purchasing 1–9 pigs and living in Kasumbalesa or Lubumbashi, prefer to slaughter on the Zambian side of the border and transport the bagged carcasses into the DRC. Pigs that die on the way from Zambian towns and villages are bought cheaply by Congolese-origin slaughterers, who work with female pork sellers for informal slaughter on the Zambian side, processing and shipping the bags to the DRC. Pig traders were classified into two categories. The first consisted of small-scale importers who purchased 1–3 pigs daily, primarily from border posts or nearby Zambian villages. The second category included live pig buyers and resellers (wholesale buyers). The various reported purchase prices of pigs and pork carcasses, both non-infected and cysticercosis-infected, are shown in Table 5.

Table 5
Variation in purchase prices of healthy and cysticercosis-infected pigs and pork carcasses

Pig/carcass prices in Congolese francs (FC) and dollars ($)	FC	USD (1USD = 2850 FC)
Pig variation in maximum prices	200000–2500000 FC	70.2–877.2
Pig variation in the minimum price	47000–1500000 FC	16,5–526,3
Carcass variation in maximum price	50000–1000000 FC	17.5–350.9
Carcass variation in the minimum price	50000–250000 FC	17.5–87.7
Infected pig variation in the maximum price	200000–1300000 FC	70.2–456.1
Infected pig variation in the minimum price	40000–500000 FC	14 – 175.4

Table 5 indicates that large (heavy) pigs infected with cysticercosis were sold at lower prices than healthy pigs, whereas the prices of small and medium-sized pigs remained similar regardless of infection status.

These price ranges consider the supply source, whether from Zambian villages, border sites, or sources in the DRC. Observations showed that the selling price of pigs produced in Lubumbashi ranged between 4 and 5 USD per kilogram of live weight.

Stage 2: handling

Stage 2 is a point of transaction facilitation. Handlers (typically young men aged 15–23) play multiple roles. During purchases, some capture pigs, mark them with paint, and transport them from shelters to the DRC veterinary service (large herds) and loading points, or to Kasumbalesa buyers' homes or Lubumbashi bus stops (1–3 pigs, bypassing veterinary checks). Handlers also unloaded pigs arriving from Zambia on vehicles and loaded animals onto trucks at loading points.

Stage 3: health inspection, taxes, and regulation

Stage 3 is the point at which either the veterinary tax or/and transaction fees are paid. At the DRC entry corridor, several state services are stationed, including the veterinary service. Upon arrival, pigs are directed along two routes depending on herd size. The main corridor path is typically used by handlers transporting 1–3 live pigs or carrying bagged pork carcasses and is staffed by non-governmental agents operating under the veterinary service, as well as DGM and ANR personnel, who charge 1,000 Congolese francs (FC) (USD 0.35) per person crossing, although payment was not mandatory for everyone, as some avoided fees through personal connections. The second route leads to the veterinary office, where importers pay an import health tax to enter Congolese territory without prior pig inspection or veterinary examination. The veterinary service office is headed by a veterinarian and includes other non-veterinarian state agents. Most pigs were imported live, while pig carcasses were typically packaged in bags and transported across the border by handlers via the corridor, bypassing the veterinary service office. During fieldwork, pig traders were observed using official import routes and paying an import health tax to Congolese veterinary services. In some cases, veterinary services facilitated small-scale cross-border trade for importers carrying 1–3 pigs by allowing them to cross without paying the tax or by charging a reduced amount of 1,000 FC (USD 0.35), which was lower than the official rate of 3,500 FC (USD 1.22) per head. No instances of pigs or carcasses crossing via informal routes were observed during our fieldwork. However, some traders at border market sites reported occasional use of informal routes to import pigs or carcasses, though this could not be confirmed by our daytime observations. At the entry points into the DRC (informal routes) created by the separation walls between Zambia and the DRC, police officers (military personnel) collected transit fees for products crossing the border. The various reported costs of taxes and administrative documents related to importation are presented in Table 6.

Table 6
Cost of taxes and duties for crossing the border with healthy and infected pigs

Questions and responses (n = 26)	**Number**
Are you authorized to import pigs?	
Yes	14
No	12
Do you have a pig import document? (n = 14)	
Yes	13
No	1
How much does an import document cost (Congolese Francs) and USD (n = 26)	
0 Fc	3
1000–2500 FC (USD 0.35–0.877)	8
3000–5000 FC (USD 1.05–1.75)	13
120000 and 140000 FC (USD 42.10–49.12)	2
Do you pay for each pig crossing the border? (n = 26)	
Yes	23
No	3
What type of tax? (n = 26)	
Animal health certificate for import and export	15
Transfer authorization	5
Passage fee	2
Service	1
How much do you pay per animal crossing?	
2500–3000 (USD 0,877–1.05)	9
3500 (USD 1,22)	12
5000 (USD 1,75)	1
6000 (USD 2;1)	1
Total prices paid for pigs reaching the destination (per pig or load) in FC and $.	
Per pig	1000–50000 FC USD 3.7–17,5
100 and more	70000–135000 FC USD 24.9–47.4

In Table 6, 14 of the 26 traders interviewed about cross-border pig trade stated they were authorized to import pigs; 13 of these 14 confirmed they had import documents. The import documents cited included the Health Certificate for the Import and Export of Animals (mentioned by 12 interviewees), which indicated that a tax had been paid at the border to the Veterinary Services, and the pig transfer authorization (noted by one interviewee). The cost of these import documents varied from 2,500 to 3,500 FC, mainly for the health certificate, while a pig transfer authorization cost 120,000 FC. They reported paying for each pig crossing the border. The “health certificate for import and export” was the most used document. For each pig that crossed the border, they paid between 2,500 and 6,000 FC per head, with 3,500 FC being the most frequently referenced price. The total cost of importation ranged from 10,000 to

50,000 FC (USD 3.7 to USD 17.5) per pig (depending on the distance) and 70,000 to 135,000 FC (USD 24.9 to USD 47.4) per batch of pigs, again depending on the distance between the purchase location in Zambia and the pig's destination in Haut-Katanga province.

Stage 4: First point of consumption

Stage 4 is the first point at which imported pigs/carcasses are slaughtered and consumed (i.e., border sites). Pigs delivered to homes in Kasumbalesa, Kasenga, and Sakania are slaughtered domestically without veterinary oversight, and the pork is sold at home, in public markets, and at roadside stalls. Carcasses are transported and sold in public markets in the same way. One Kasumbalesa resident buyer had pigs slaughtered at her home by Zambian-side border slaughterers; these carcasses, including those from pigs dying during transport, were smoked and transported to Kolwezi (Lualaba Province) for sale and consumption.

Stage 5: transportation

Stage 5 is where the pigs are loaded onto vehicles and transported to the final point of sale. Traders imported pigs directly via the Kasumbalesa corridor, and most stakeholders traveled by vehicle, primarily along National Road No. 1 (Kasumbalesa–Lubumbashi Road), to supply Haut-Katanga and Lualaba Provinces. Traders operating at the border sites with Zambia, however, crossed on foot with the pigs and then used motorcycles to transport them to their homes or to local markets.

Stage 6: end of the chain, point of consumption

Stage 6 is the end of the chain and represents a pork retail outlet. In Lubumbashi and the various pig slaughter and sales points, pigs are slaughtered without veterinary oversight, and pork is sold without prior inspection, except at the Kampemba abattoir and the Kabasele slaughterhouse in Mzée Market. Locally produced pigs in Lubumbashi and Kasumbalesa are commonly sold in butcher shops and supermarkets, but rarely in slaughterhouses or public markets. Pigs raised in Kasenga, Kipushi, and Sakania are mostly slaughtered and consumed on-site, although some are transported to Lubumbashi for slaughter and sale in public markets, restaurants, neighborhoods, or households. The city of Lubumbashi is the primary destination for these pigs, according to 77.1% of respondents, followed by Kasumbalesa and Kasenga. Among the 26 traders involved in pig imports, the frequency of imports ranged from fewer than 10 pigs or carcasses per week to several dozen or even hundreds per week. This variation reflects the sales rates in Haut-Katanga province, where pigs are sold alive or processed into pork, with sales ranging from fewer than 10 to several hundred. Pigs are mainly sold to households for retail pork, followed by restaurants and businesses. Figure 4 illustrates the pig food chain between Zambia and the DRC, with the various stakeholders highlighted in blue.

3.4. Management of infected pig carcasses

Among respondents involved in pig imports, 15 of 26 reported selling cysticercosis-infected pigs or carcasses for human consumption, and 19 reported reduced pig prices, offering pigs at substantial discounts compared with healthy animals. Observations revealed that infected pork was sold by retail meat sellers to grilled-meat vendors for further preparation and consumption. Most respondents (70 out of 96) reported that veterinarians did not inspect pig carcasses at slaughter. Participant observations revealed that veterinary inspections were not conducted systematically. Infected carcasses were frozen by slaughterers at the Kabasele slaughterhouse, then processed and marketed for human consumption. At the household level, infected carcasses treated with lemon juice were observed and subsequently delivered for human consumption as grilled pork. When asked whether veterinarians condemned infected carcasses, 79 participants reported that carcasses were not condemned, and one participant reported that, in cases of condemnation, the veterinarian collected hidden fees and still authorized the sale of the carcass. The various responses to questions on the management of infected pigs and carcasses are reported in Table 7.

Table 7
Management of infected pigs and pork carcasses in the pig food chain

Questions and answers	Number
Do you examine the tongue for cysticerci? (n = 26)	
Yes	11
No	15
Do you check carcasses for cysticerci? (n = 26)	
Yes	19
No	7
Do you reduce the price of pigs carrying cysticerci? (n = 26)	
Yes	19
No	7
Is the pig/carcass checked at the border? (n = 26)	
Yes	7
No	19
From Zambia to Haut-Katanga Province, who controls the pork/carcass? (n = 26)	
Veterinarians	20
Other agents	6
Where are pigs slaughtered? (n = 26)	
At home in Lubumbashi	12
Killing and/or slaughterhouse in Lubumbashi	13
In Zambia and Kasumbalesa	1
Do veterinarians inspect meat at slaughter? (n = 96)	
Yes	24
No	70
Yes and no	2
Do veterinarians condemn infected carcasses? (n = 96)	
Yes	17
No	79
What do you do with an infected carcass? (n = 96)	
Sell the carcass	23
We return the carcass to its owner.	19
Burn the carcass	8
Discard the carcass	8
Refuse to buy	4
Seizure of the carcass by veterinarians	6
Destroy the carcass or pay money to the vet	4
No answers	24

Table 7 indicates that practices like tongue palpation, health checks for animals crossing the border, antemortem health checks, and inspections of pork at slaughter are not consistently applied throughout the pig/pork food chain between Zambia and the DRC.

4. Discussion

Pig value chain mapping has been conducted across several East African settings, including studies by Ouma et al. (2017) and Ngwili et al. (2023) in Uganda; Shyaka et al. (2022) in Rwanda; Murungi et al. (2021) in Kenya; and Minani et al. (2025) in Burundi. To our knowledge, this is the first study to focus on pig food-chain mapping at the interface between Southern Africa (Zambia) and Central Africa (DRC), specifically addressing cross-border movement and the potential spread of *T. solium* via pig trade. This offers the first detailed overview of a cross-border pig and pork supply chain, highlighting three key findings: (i) a very active cross-border trade network; (ii) minimal veterinary supervision throughout the chain; and (iii) common commercialization of pigs and pork infected with cysticercosis. It also offers the first empirical mapping of a cross-border pig food chain, detailing routes, practices, and the management of infected pigs and carcasses, as well as each stakeholder's contribution to the potential spread of *T. solium* from pig farms in Southern Zambia to Central Africa (DRC). The study by Shyaka et al. (2022) reports that 65% of pig carcasses produced in Rwanda (East Africa) are exported to the DRC (Central Africa). However, this cross-border pig food chain and its public health implications for *T. solium* remain undocumented.

Our study identified an active and regular pig food chain linking these two countries, involving ten stakeholder categories. The list of stakeholders and stages within this chain (supply sources, handling, health inspection, taxes and regulations, transportation, and consumption points) mirrors the pig value chain structure reported by Ngwili et al. (2023) in Uganda (a neighboring country to the east of DRC). Potential critical risk points include supply sources (in both Zambia and the DRC), border-crossing locations, traders' households, informal slaughterhouses, and retail meat markets, as well as practices for managing pigs and infected carcasses at different stages of the food chain. These observations corroborate the findings of Minani et al. (2025) in the Burundi pig value chain (another neighboring country to the east of the DRC). In Rwanda, only two transmission risk points for *T. solium* were documented: bar slaughtering and on-farm practices.

High-risk practices that may introduce *T. solium* from supply sources in Zambia to consumption points in Haut-Katanga include purchasing live pigs without tongue palpation, conducting border transactions without systematic veterinary inspection, loading pigs directly onto trucks at the Congolese border, home slaughter, and final household distribution, all of which occur without veterinary oversight.

The cross-border dimension highlighted by this study does not appear to affect practices for controlling and managing pigs and carcasses infected with *T. solium*. This observation suggests that countries in sub-Saharan Africa not only share linguistic, anthropological, and economic ties (Fazili et al., 2020) but also exhibit similar practices in pig husbandry, marketing, and pork consumption, as well as comparable approaches to managing health issues, particularly the taeniasis/cysticercosis complex.

The results showed that the stakeholders based in the DRC regularly import locally bred pigs through this food chain from Zambian towns and villages (a total of 1,696 live pigs and 32 carcasses per week were recorded), without prior clinical or veterinary inspection at the border. These pigs, which have been reported to be infected with *T. solium* in Zambia (Chembensofu et al., 2017), are transported from border sites to consumption points in the Haut-Katanga and Lualaba provinces (DRC), where they are slaughtered and consumed without systematic veterinary inspection of the meat. Such practices may promote the parasite's regional spread and facilitate the maintenance of its life cycle. These practices may also lead to infections among pork consumers in Haut-Katanga province if the meat is consumed undercooked.

Several sources indicate that local breeds constitute most of the Zambia's pig population and are the primary pigs exported to the DRC, the main destination for Zambian agricultural products (Abigaba et al., 2022; World Bank, 2022; Zambian Ministry of Fisheries and Livestock, 2024). In 2023, Zambia's pig population was estimated at approximately 1,579,287 pigs, of which 97.9% were kept by households under free-range systems (Zambian Ministry of Fisheries and Livestock, 2024). Free-range husbandry markedly increases pigs' exposure to *T. solium*, thereby raising their risk of cysticercosis (Sikasunge et al., 2007). These facts suggest the persistence and presence of *T. solium*-related risk within the cross-border pig food chain between these two countries.

This study indicates that porcine cysticercosis is chiefly perceived as an economic rather than a public health problem within the Zambia–DRC pig food chain. Nineteen of twenty-six traders reported lowering the price of infected pigs and selling affected

carcasses to limit financial losses. Consequently, the primary impacts are economic, wasted time and effort within a long and highly competitive pig food chain, and reduced sale prices, rather than recognized sanitary or health concerns. These behaviors are likely to perpetuate the parasite's transmission cycle, with negative implications for public health. Our findings are consistent with previous regional reports. Minami et al. (2022) documented that porcine cysticercosis was widely recognized in Burundi and estimated economic losses of approximately USD 2.4 million in the pork sector. Similarly, Ngwili et al. (2023) described practices in Uganda in which cyst-infected pork was openly sold in butcher shops; in that study, many consumers recognized cysts, some declined to buy infected pork, others citing no perceived health risk, while others believed that thorough cooking rendered the meat safe. In our study, stakeholders demonstrated awareness of cysticercosis. They detected infected animals at the time of purchase, slaughter, and sale. Yet, infected carcasses continued to enter the human food chain, a behavior that mirrors the regional pattern and helps explain ongoing transmission despite apparent recognition of the condition.

Purchase prices for small and medium-sized pigs did not differ between infected and uninfected animals. However, respondents reported decreases in pork retail prices. These reports on lower market prices do not appear to reflect the practices of all pork retailers. Stakeholders such as buyers-slaughterers, and sellers of grilled meat were implicated. Minami et al. (2022) observed that in the absence of veterinary oversight, pigs with cystic infections were concealed and later sold alongside healthy carcasses. This finding suggests that infected carcasses may be sold at prices like those of uninfected carcasses, especially among grilled-meat sellers, which may explain the claims made by 15 of the 26 stakeholders who reported, in a single response, that they sell infected carcasses. The observation shows that certain retail and grilled-pork sellers deliberately treated infected pork with lemon juice before offering it for human consumption. These practices confirm the absence of veterinary services, as reported by traders, in monitoring the pig food chain. However, in Rwanda (Shyaka et al., 2022), populations pretended to bury carcasses in the presence of veterinarians and retrieved them once the veterinarians were absent. This behavior was observed in our study at the Kabasele slaughterhouse, where a heavily infested pig carcass, detected in the veterinarian's presence, was set aside, processed, and subsequently supplied for human consumption.

This pig food chain appears vital to regional food security, yet it requires effective organization and active involvement from competent state services to safeguard public health.

This pig food chain mapping between Zambia and the DRC is based on data collected at specific, targeted times and locations; it might not fully account for seasonal fluctuations, changes in pig trade volumes over time, or shifts in regulatory frameworks along the border between these two countries. Moreover, the study primarily relies on data from individual interviews, which are susceptible to response biases stemming from respondents' emotions and concerns about a topic that affects their livelihoods; such biases could lead to underreporting of risky practices or overreporting of socially desirable behaviors. The small number of questionnaire items focused on knowledge and practices further limits the study's representativeness. Additional significant limitations include potential selection bias among participants, which may have restricted the diversity of viewpoints and prevented the discovery of alternative practices or knowledge. These considerations are essential when evaluating the results and designing future, more detailed studies.

5. Conclusion

This study mapped the cross-border pork supply chain linking Zambia's Copperbelt and Luapula provinces and Haut-Katanga province in the Democratic Republic of Congo, while studying its role in the circulation of *T. solium*. The findings revealed an unregulated pork sector lacking essential veterinary control, posing a significant public health risk by facilitating unrestricted pig movement and the circulation of *T. solium* in pork destined for human consumption in Lubumbashi and Haut-Katanga provinces. Sustained monitoring (which currently does not exist) of the Zambia-DRC pork trade is essential to mitigate the risk of human infection and to disrupt the parasite's life cycle. Strengthened veterinary inspections, stricter controls, improved sanitation practices, and heightened awareness among local authorities and public health officials are critical to curbing *Taenia* transmission and ensuring food safety.

Abbreviations

ANR
National Intelligence Agency
DGM

Migration Department
DRC
Democratic Republic of Congo
ELISA
Enzyme-linked immunosorbent assay
FC
Congolese franc
FEPACO
Pentecostal Evangelization Fraternity in Africa and the Congo
TKA
Tshiasuma Kedi Alain
UNILU/CEM
Medical Ethics Committee of the University of Lubumbashi
USD
The United States Dollar
VLIR-UOS
Vlaamse Interuniversitaire Raad - Universitaire Ontwikkelingssamenwerking

Declarations

Ethics

The research protocol was approved by the Faculty of Veterinary Medicine at the University of Lubumbashi. Ethical clearance was obtained from the university's medical ethics committee (N° Approbation: UNILU/CEM/017/2023/Comité d'éthique médicale de l'Université de Lubumbashi). Additionally, authorization was granted by the city authorities of Lubumbashi and the administrators of Kasenga, Sakania, and Kipushi territories. Informed consent was obtained from all participants. In the field, the study, including its potential benefits and risks, was fully explained to participants, who could decline participation at any time. They were explicitly informed that involvement was voluntary and that withdrawal was possible without consequence. Consent forms were read aloud to all participants, and verbal consent was obtained. 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. The study was conducted in accordance with applicable guidelines and regulations, including the Declaration of Helsinki.

Consent to Publish declaration

All four authors have consented to the article's publication.

Data availability

The findings of this article are supported by the data included within it. Interested parties can obtain the raw data sets from the corresponding author upon making a reasonable request.

Interest

No conflicts of interest are to be declared in this study.

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Authors' contributions

Tshiasuma Kedi Alain, Kasongo Aseke Grégoire, Tshikung Kambol Moses, and Sarah Gabriël developed the protocol, the survey questionnaire, and the manuscript. Tshiasuma Kedi Alain gathered the data, and all authors contributed to editing and revising the manuscript.

Consent for Publication

Not Applicable

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Figures

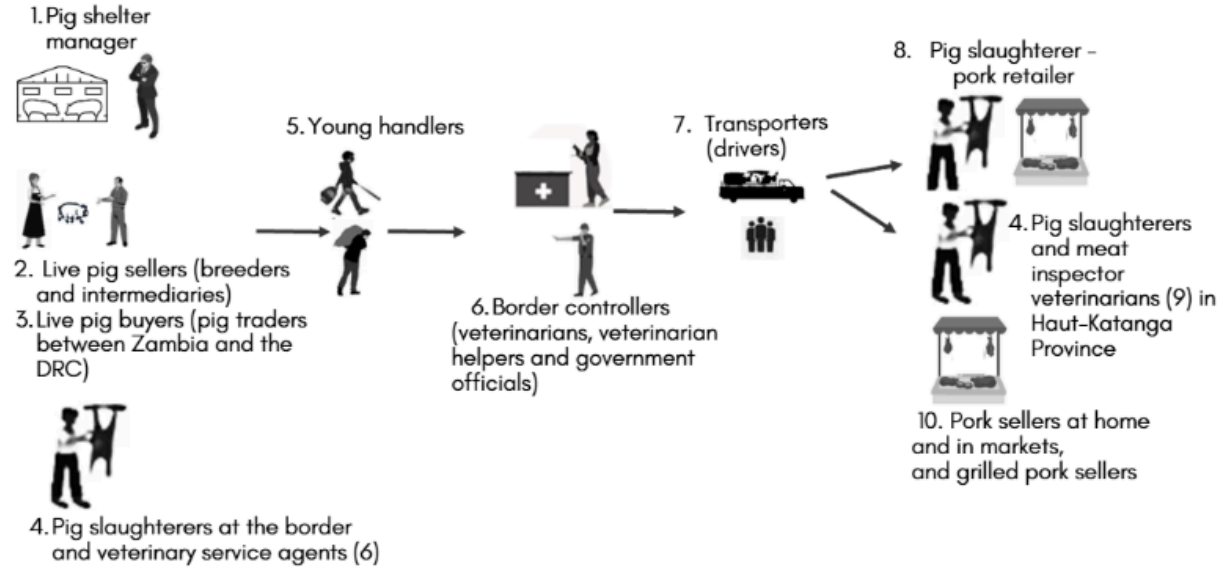


Figure 1

Stakeholders in the cross-border pig/pork food chain between Zambia and the DRC.



Figure 2

Map of Haut-Katanga Province illustrating principal study sites and the principal pig trade routes from Zambia to Haut-Katanga. Kasenga, Kipushi, and Sakania are key territories within Haut-Katanga Province; Kasumbalesa (marked by a purple dot) lies within the Sakania territory.

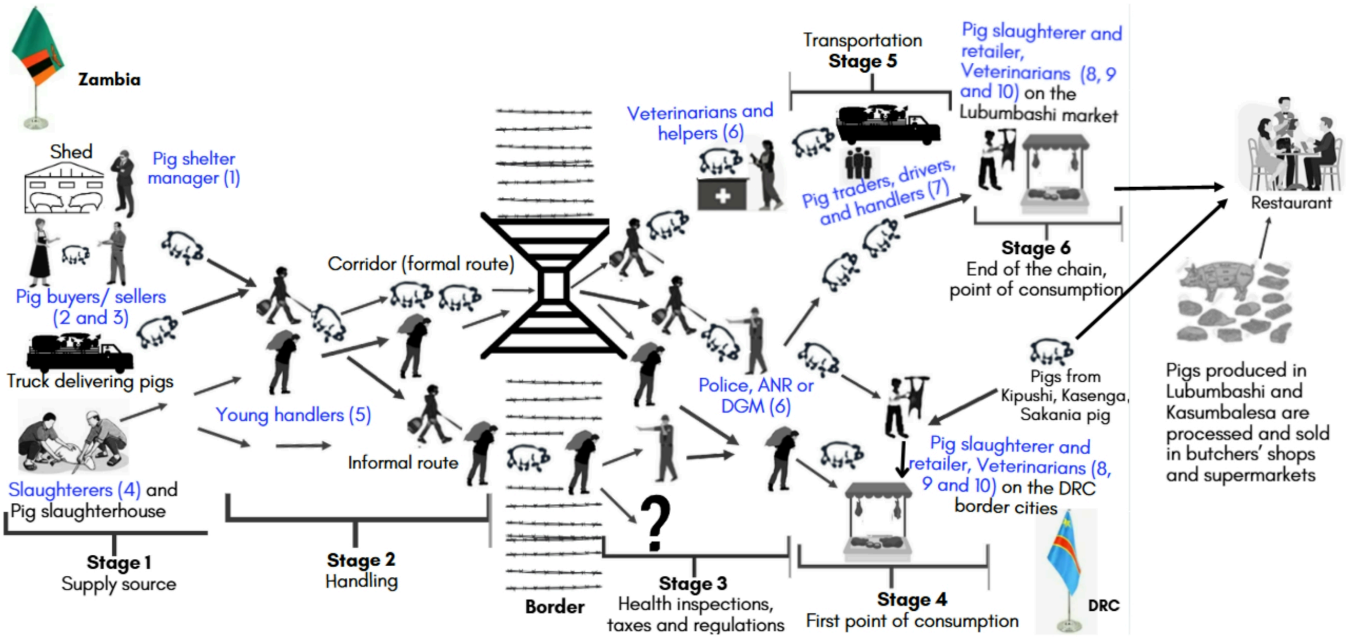


Figure 3

Figure. 4: Pig food chain at the interface between Zambia (Copperbelt province) and DRC (Haut-Katanga province) (ANR = National Intelligence Agency and DGM = Migration Department).

Supplementary Files

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- APPendix1.docx