



Porcine Cysticercosis Vaccine Market Scoping:

Lessons learnt from the Uganda smallholder pigs value chains



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1. Executive summary

Background

Pig production is an important socio-economic activity in Uganda. Not only does the country have the largest pig population in East Africa, it also has the most rapidly growing pig population in sub-Saharan Africa and the highest per capita pork consumption in Eastern Africa (FAO, 2011). *Taenia solium* cysticercosis is a parasitic zoonosis caused by larval cysts of pig cestode. Porcine cysticercosis is a faecal-borne infection caused by the ingestion of *T. solium* eggs dispersed by a human *T. solium* tapeworm carrier. New tools have become available for the control of porcine cysticercosis that could help to break the disease cycle (Lightowers, 2013), namely a recombinant vaccine antigen, TSOL18, and the benzimidazole drug oxfendazole, which can act as a de-wormer in pigs. These drugs are not currently on the market in Uganda. GALVmed, a product development and adoption partnership focusing on livestock health, has implemented field trials in Uganda aimed at the control of *T. solium* through the combined use of TSOL 18 vaccine and oxfendazole. Results from the trials have confirmed the efficacy of the combined use of the vaccine and oxfendazole in preventing infection in the pigs enhancing immunity against *T. solium* (Nsadha et al., 2021) Although the vaccine has proven effective during the GALVmed field trials in Uganda, its potential for marketing as a private good has not been evaluated. This study addresses this gap by conducting market scoping studies to generate evidence to guide the Porcine Cysticercosis vaccine entry into the market in Uganda.

Objectives and methods

The objective of the market scoping study was to assess the potential demand for the TSOL vaccine -oxfendazole combination and to gain a clear understanding of its potential for 'private good' marketing. It also assesses how the vaccine might influence product availability, supply mechanisms, price structure, competitiveness of products, profit margins, and the potential to sell these products to smallholder pig producers in Uganda.

Eight separate market scoping studies have been conducted in Uganda's Masaka, Bukedea, Kampala and Mukono districts targeted at different nodes of the pig value chain – namely consumers, traders, distributors, and drug stockists – and involved interviews, focus group discussions, a simulated egg experiment, choice experiments, and observation. Choice experiment is a multi-trait/multi-attribute stated preference method that assesses the value of single traits of a bundled good by using individuals' stated preference in a hypothetical scenario. Due to the hypothetical nature of stated preference data in which the respondents are not bound by real life constraints, especially income in the choices made, there are tendencies for Willingness to Pay (WTP) values to be overestimated.

Keys results

The market scoping exercise yielded a broad range of observations from across the pig value chain. Key findings include:

- Farmers had a strong preference for a porcine cysticercosis vaccination that would yield them premium prices when selling their pig and that would only require a single dose to confer immunity. Farmers indicated willingness to pay US\$0.44 more if the vaccine resulted in an additional dollar in price, as well as US\$1.67 more for a vaccine administered once versus three times. This is a key point that unless the pig market system can pay premium price for TSOL18 vaccinated pigs, uptake of the vaccine by farmers through market mechanisms may not be successful.
- The choice experiment results showed a low proportion of farmers (only 19%) that selected the choice option of the vaccine with its current combination of attributes and were willing to pay a total

of US\$2.61 for the vaccine per pig (including administration costs) until immunity is attained. Many farmers (38 – 50%) selected choice options that had combinations of improved attributes of the vaccine especially higher price premium of vaccinated pigs and a vaccine viability detector and were willing to pay US\$12 – 17.

- Pig traders are aware of porcine cysticercosis, and most trader participants indicated that they refuse to purchase pigs suffering from porcine cysticercosis. However, results show that traders' most preferred attribute for pigs was weight gain, although they also reported concerns about consumer health. Weight gain can be achieved through appropriate deworming regimes such as through use of oxfendazole.
- Consumer focus group discussion participants considered hygiene as the most important factor in ensuring pork is safe. They also noted willingness to pay more for pork certified to be porcine cysticercosis-free as long as their safety is guaranteed. However, consumers' preferences as depicted by actual purchases are driven by other factors such as personal preferences versus food safety, and they may have a different perception of what is considered as 'safe food', as compared to food safety experts.
- There appears to be substantial demand for livestock de-wormers in Uganda, and the market for de-wormers is relatively crowded. Animal health service providers preferred ivermectin, while farmers preferred levamisole and albendazole. Most other drugs are cheaper per dose than Paranthic 10% (active ingredient oxfendazole), which is an important consideration for farmers.
- For the TSOL18 vaccine-oxfendazole combination to be competitive (if viewed simply as a de-wormer), it should be priced between US\$1.62 and US\$6.11, per the drug stockist scoping study.
- Even though oxfendazole is comparatively expensive, there is an opportunity for it to capture some market share because it is a broad-spectrum de-wormer on top of being effective against porcine cysticercosis. However, the fact that the vaccine and de-wormers are not packaged together makes the combination unattractive to distributors because of anticipated challenges in acquiring both products at the same time when needed.

Conclusions and Recommendations

Insights from the market scoping study shows that obtaining a premium price for immunized pigs is a strong incentive for farmers to vaccinate pigs for porcine cysticercosis. Additionally, the demonstrated preference for the TSOL18 vaccine with low administration costs (US\$0.90 per pig) underscores a communal approach and preference for a one-dose TSOL18 vaccine. However, quality assurance is a concern for pig farmers, as expressed in their preference for a viability detector; the product manufacturer should take this into account. The TSOL18 vaccine-oxfendazole combination as presented is less likely to succeed as a private good. In addition, there is need for mass sensitisation about the control of *T. solium* cysticercosis amongst stakeholders at all levels (including veterinarians, farmers, traders, butchers, consumers, animal health service providers, and policymakers). Necessary accompanying intervention measures along the value chain would include:

Animal health service providers: They are the major source of information for farmers. So, they represent an important channel for information dissemination to farmers. During awareness campaigns, the animal health service providers should be involved. They should also be trained in disease recognition and management of carcasses that are affected.

Farmers: The product packaging and cost of the TSOL18 vaccine-oxfendazole combination should be addressed so that farmers can easily purchase it. Farmers should be sensitised about the effects of the disease on pigs and its public health importance.

Traders/butchers: this category of actors could be used as an agent of change, because they are highly connected to pig farmers and know all trading networks. They also have high awareness about the disease. They should be trained on the effects of the disease in humans and policy regulations about the disease.

Distributors: They should be supported (ex. subsidised) by the Government to import the product. Government should work together with the distributor to make the product accessible to farmers.

Government: A major role should be played by the Government. This includes:

- Facilitation of product registration and availability is needed.
- Market regulation is needed to enable product entry and market growth.
- There is a need for government engagement and support to promote the TSOL18 vaccine-oxfendazole combination, as well as to lead disease eradication by facilitating product registration and enabling the distribution environment by enforcing regulation on disease control.
- Support mass sensitisation about the control of *T. solium* cysticercosis amongst stakeholders at all levels (including veterinarians, farmers, traders, butchers, consumers, animal health service providers, and policymakers).

Researchers: there is a need to carry out socioeconomic impacts studies of the disease to generate evidence for decision-makers to justify funding support.

A 'One Health' approach to sustain disease control and eradication of porcine cysticercosis is needed. There is a need to identify key stakeholders for capacity building through training, as well as to establish a 'One Health' approach – a public-private partnership forum for stakeholder engagement.

Summary of findings

- **Finding 1:** Farmers want a vaccine which will result in a high premium when they sell the pig. Farmers indicated willingness to pay US\$0.44 more if the vaccine results in an additional dollar premium price. Farmers now get US\$43 for a pig. With the current vaccine attributes, only 19% of farmers are willing to purchase the vaccine and are willing to pay US\$2.61 for it.
- **Implication:** The current pig market structure does not pay premium price for “safe food”. There may be need for consumer sensitisation campaigns to enhance appreciation of safe food.
- **Way forward:** Studies on demand for vaccinated pigs. Investigate public private partnerships which would subsidise the vaccine.
- **Finding 2:** Farmers prefer a vaccine given only once and indicated willingness to pay US\$1.67 more compared to one that is administered three times.
- **Implication:** The current vaccine needs to be given two times which will be a considerable barrier to uptake.
- **Way forward:** Further development of the vaccine as a single dose immunisation is needed to make it more cost-effective.
- **Finding 3:** Farmers prefer the inclusion of a vaccine viability detector. Farmers indicated a willingness to pay US\$4 if the vaccine comes with a viability detector.
- **Implication:** This reflects concern over fraudulent and ineffective products which farmers believe are widespread.
- **Way forward:** Investigate cost of adding viability indicator. Plan how to proactively build farmer trust in drug distribution system.
- **Finding 4:** The farmers preferred a vaccine associated with low administrative costs.
- **Implications:** The high cost for vaccine administration may be a disincentive for vaccine uptake
- **Way forward:** Cheaper models for delivering vaccines to farmers should be investigated (ex. promotion of group vaccination to reduce on the cost)
- **Finding 5:** There are few vaccines for smallholder pig diseases on the market in Uganda
- **Implication:** The TSOL18 vaccine has a high potential for being the first vaccine introduced in the pig sector in Uganda
- **Way forward:** Large sensitization campaign is needed among pig value chain stakeholder to support and promote the uptake of the vaccine
- **Finding 6:** Albendazole and Erafen 5 (active ingredient fenbendazole) are the potential competitors for oxfendazole.
- **Implication:** It will be very hard for oxfendazole to enter and capture market shares for pig deworming
- **Way forward:** Entry of oxfendazole in the market should be accompanied by a lot of advertisement to show the competitive advantage of oxfendazole as compared to the potential competing products
- **Finding 7:** Farmers are the main market segment for dewormers
- **Implication:** The 1 litre package of oxfendazole would not suit farmers
- **Way forward:** A smaller packing size of oxfendazole (ex. 10 ml) would be more suited

2. Smallholder pig value chains in Uganda: An introduction

2.1 Pig production demographics

Uganda has the largest pig population in East Africa and the most rapidly growing pig population in sub-Saharan Africa. Pig production grew from just 16,000 animals in 1961 to more than 3 million in 2011; while pork accounted for only 1 to 2% of the 11 to 12 kilograms per year per capita meat consumption in the 1960s, it now accounts for at least one-third of the current 10 kilograms per year. Uganda has the highest per capita consumption in Eastern Africa, at 3.4 kilograms per year – almost two times higher than all other East African countries – and the highest in sub-Saharan Africa, including South Africa (FAO, 2011). Moreover, whereas the consumption of pork in Uganda sharply increased just before 1990, the consumption of beef has declined; in 2007, they reached the same level (figure 1).

The net result has been that per capita meat consumption in Uganda has remained at a low level of 10 to 11 kilograms per year, yet meat consumption in developing countries has been continuously increasing from a modest average annual per capita consumption of 10 kilograms in the 1960s to 26 kilograms in 2000; it is expected to reach 37 kilograms by about 2030 (FAO, 2011). Cattle and pig populations increased significantly from 1970 to 2010, according to the records of the Food and Agriculture Organization of the United Nations (figure 2). The Uganda Bureau of Statistics found a 4% increase in the country's pig population from 2010 to 2014 (3.4 to 3.5 million) (figure 3). The proportion of female-headed households owning pigs in Uganda has also increased significantly in the last 10 years, from 15% to 32%, whereas the male-headed households with pigs have increased from 21% to 31% (Heinz and Hautzinger, 2007). Most pigs (80%) are kept by smallholder pig farmers owning between one to five pigs managed with limited inputs (UBOS, 2009).

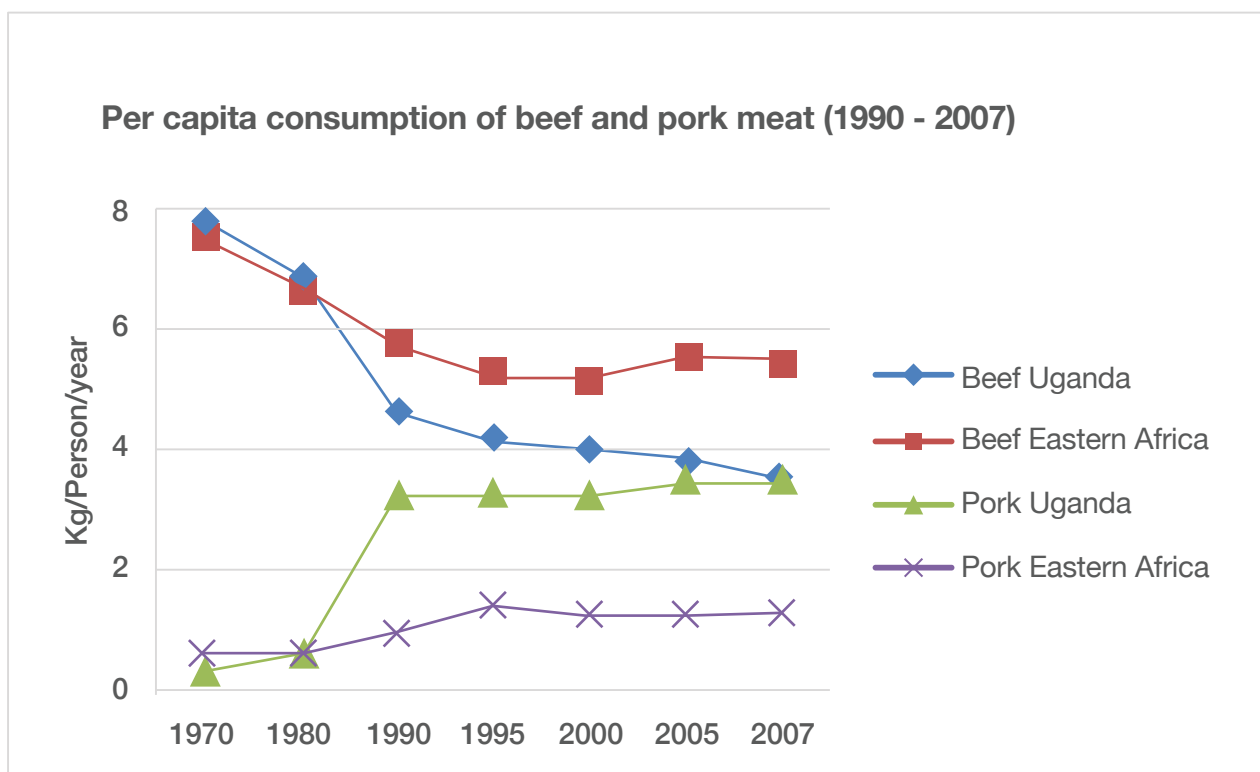


Figure 1: Dynamics of per capita consumption of pork and beef in Uganda and Eastern Africa as a whole between 1970 and 2007 (FAOSTAT, 2010)

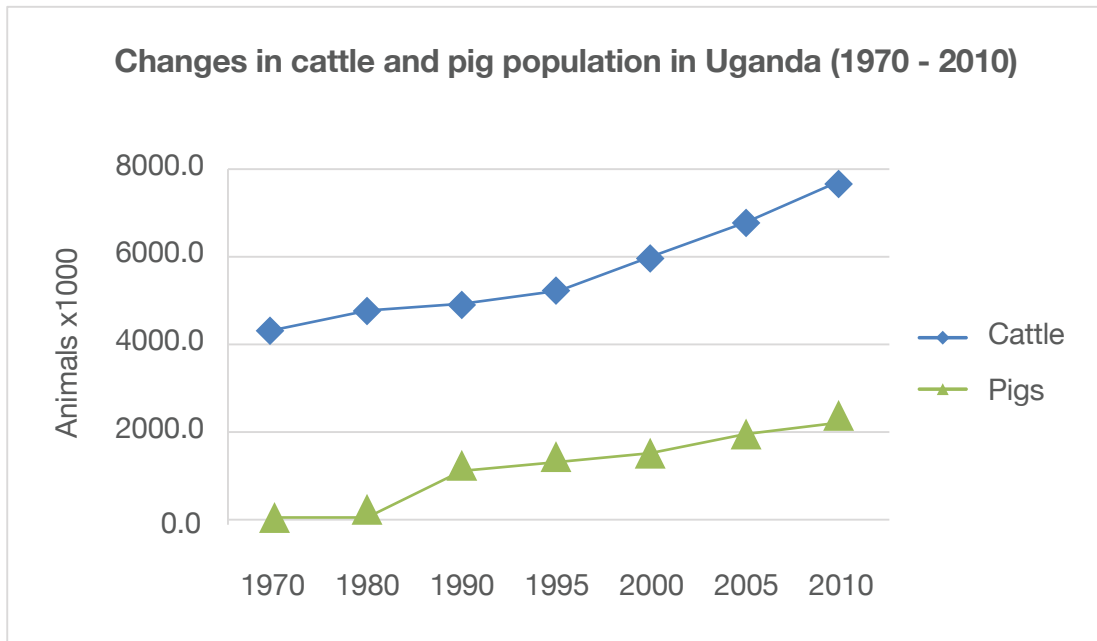


Figure 2: Changes in the cattle and pig populations in Uganda between 1970 and 2010 (FAOSTAT, 2010)

2.2 Importance of pig keeping

In Uganda, pigs are predominantly kept by poor people because pig keeping offers an attractive alternative to ruminants since pigs come with smaller investment costs, do not compete for pasture land, can transform kitchen waste into food, and have a short reproductive cycle allowing for quick financial turnover (FAO, 2011). In addition, marketing pigs and pig products offers a good opportunity for the predominantly rural population to raise money quickly to diversify their income sources and thus mitigate economic risks and improve livelihood-related resilience. Money from pig keeping helps farmers to pay for school fees and household health needs; other benefits include manure production, nutrition and food security, and a source of wealth (Phiri et al., 2003).

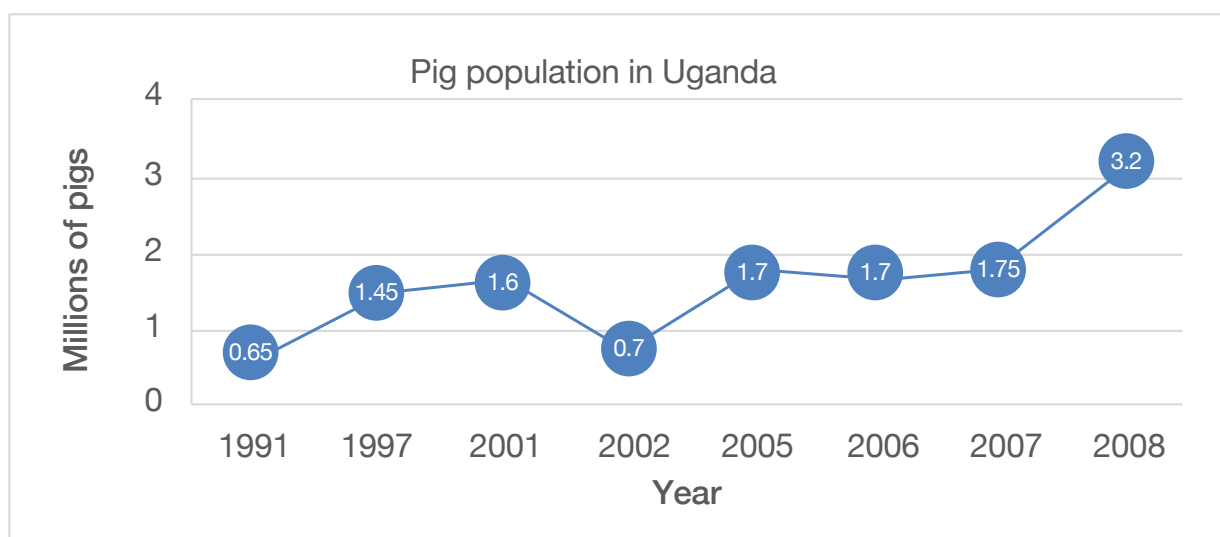


Figure 3: Changes in Uganda's pig population between 1991 and 2008 (UBOS, 2009)

2.3 Pig population density and geographic distribution

The majority of pigs in Uganda are located in the central region, as shown in figures 4 and 5. Masaka, Wakiso, and Mukono districts have the highest pig population density in the country. The northern part of the country has low pig population density, with Nakapipirit and Koboko having the lowest pig population (Annex 1).

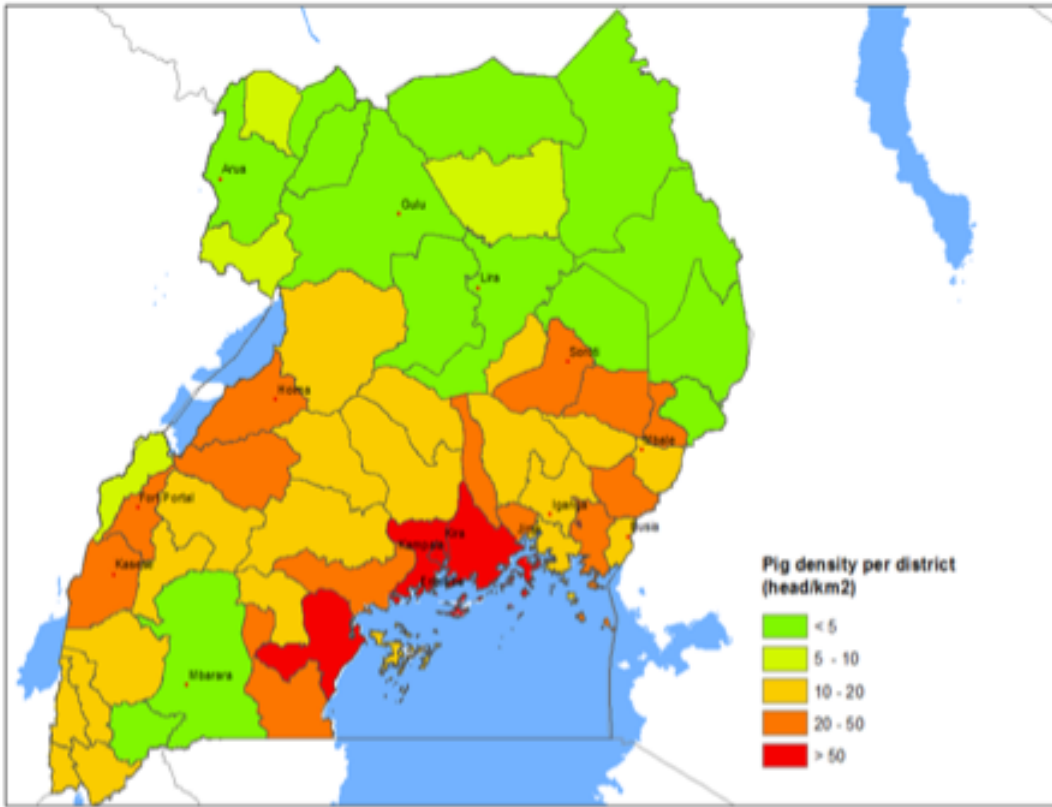


Figure 4: Pig population density in Uganda (Ouma et al., 2015)

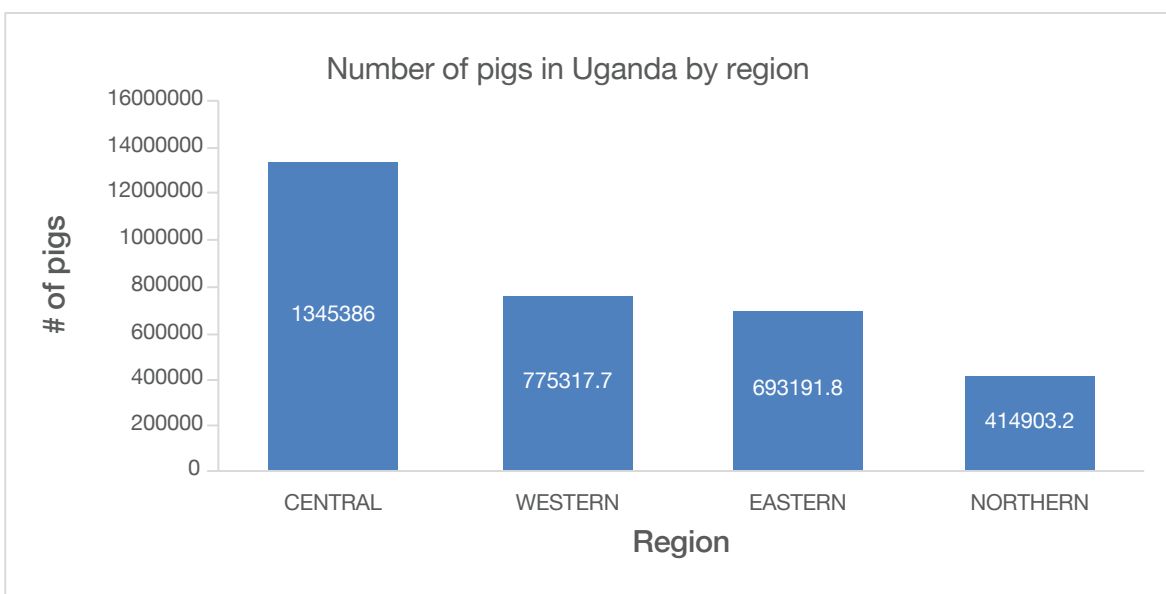


Figure 5: Pig population by region in Uganda (UBOS)

2.4 Pig production systems

2.4.1 Pig production types

Three pig production types exist: exclusive grower producers (wean-finish/farrow-finish), exclusive piglet producers (farrow to wean), and both piglet and grower producers. On average, farmers define small-scale piglet producers as those who own one to three sows. Small-scale growers are defined as those owning one to four grown pigs for slaughter. Typical smallholder farmers, including piglet producers and growers, comprise about 80% of households in the studied regions in Uganda – Masaka, Mukono, Kamuli, Lira, and Hoima (Ouma et al., 2015)

2.4.2 Pig Keeping systems



Three keeping systems are practiced in Uganda: free-range or scavenging (extensive), confinement or housing (intensive), and tethering. Pig keeping types can vary according to the season, with farmers tending to practice extensive systems more during the dry season (compared to the rainy season), when most of the gardens have been harvested and pigs scavenge for plant remains or crop residue. This is in part because the crossed and exotic breeds are feared to contract diseases and succumb to environmental pressure when they roam (unlike the indigenous breeds, which are perceived as resistant). Extensive pig-keeping relieves farmers of the need to collect or purchase feeds, as it is assumed that the pigs find adequate food and sufficient nutrients through scavenging. It also allows sows to access breeding boars within the system when farmers do not have their own boars or enough money to pay for breeding.

Tethering usually involves pigs grazing in the field in the morning and later in the day being tethered inside compounds or very close to homestead, where they have easy access to crop/plant residues, sufficient water, and assured shade. Tethering is the most practiced system in rural areas, with approximately 62% of rural farmers

participating in the study practicing it. Farmers using this technique indicated that small land does not allow animals to scavenge and that lack of funds to construct pig corrals or purchase feeds was the main reason they tethered their pigs.

Confinement in pens is usually associated with investment because housing structures require farmers to have the necessary financial sources. In Masaka, Mukono, and Kamuli, 17 to 18% of participating farmers, mainly in rural areas practiced the free-range scavenging system. Confinement in pens is more common in urban areas, with 86% of farmers participating in the study reporting their households practiced it. Free-range was reported to be more common in rural areas, and mainly seasonal, being more common during dry season (Nantima et al., 2015).

2.4.3 Pig husbandry practices

The pig husbandry practices typically used by Ugandan farmers include castration, deworming, iron injection, parasite control, vitamin administration, sow serving, and ear tagging. Farmers are generally responsible for all husbandry practices; they engage with para-veterinarians for specific services, mostly those that require high-level skills such as drug injection and castration. The most common disease prevention measure adopted by farmers is deworming and parasite control, including spraying pigs with acaricides to control mange; multiple studies report the average proportion of farmers who annually deworm their animals is 80%, with farmers deworming an average of two times before the pigs are sold or slaughtered (Dione et al., 2014; Ouma et al., 2015). The most common dewormers reported by stockists participating in the study to be used by farmers are albendazole and ivermectin. Para-veterinarians and drug stockists are the main sources of the drugs, and the cost of the service varies with the age of pigs. Piglets cost UGX300 to UGX500 (US\$0.08 to US\$0.10), while adult pigs cost UGX800 to UGX1,000 (US\$0.20 to US\$0.30) per treatment. A few farmers prefer to pay veterinarians for a year's worth of service, which can cost up to UGX50,000 or US\$14. Additionally, farmers sometimes deworm by themselves or assist each other to lower the cost. This leads to high levels of self-medication, which was reported by farmers to be a major problem. (Dione et al., 2014; Opio et al., 2015).

2.4.4 Pig disease burden

African swine fever is the most feared pig disease among Ugandan farmers (Dione et al., 2014; Opio et al., 2015; Ouma et al., 2015). African swine fever outbreaks have been linked to a strong negative impact on pig farmers' socioeconomic status, involving losing revenue and experiencing more severe poverty (Muhanguzi et al., 2012; Dione et al., 2014; Nantima et al., 2016). The disease is recognised as one of the biggest hurdle for the development of Uganda's pig sector (Chenais et al., 2015; Chenais et al., 2017). Lack of sufficient knowledge on how to control African swine fever, coupled with high-risk practices and the absence of effective prevention and management strategies, has resulted in continuous outbreaks of the disease (Ssewaya, 2003). Empowering value chain actors to better prevent and respond to African swine fever in a sustainable and realistic manner is key to reducing the disease burden in domestic pigs and protecting unaffected areas (Dione et al., 2016d; Nantima et al., 2016).

Infection with gastrointestinal parasites is also common for smallholder pig farms in Uganda. Almost two-thirds of the pigs examined in the district of Masaka, Mukono and Kamuli were infected with at least one of the parasites studied, predominantly strongyles followed by coccidia (Roesel et al., 2017). The most significant risk factors identified are relatively easy to control at the farm level, such as litter and manure removal and routine disinfection. These biosecurity-related practices may not only be effective against productivity-inhibiting parasites, but also against pathogens such as African swine fever and respiratory pathogens (Dietze et al., 2012). In Uganda generally, there is a high prevalence of *Streptococcus suis* and *Leptospira* spp., as well as a range of respiratory pathogens such as porcine circovirus type 2, *Actinobacillus pleuropneumoniae*, *Mycoplasma hyopneumoniae*, Influenza A and porcine parvovirus (Dione et al., 2018). Several zoonotic pathogens have been detected in the pig value chain: cysticercosis (Waiswa et al., 2009; Nsadhha et al., 2014; Kungu et al., 2017c; Kungu et al., 2017b), trypanosomosis, trichinellosis, salmonellosis, toxoplasmosis, and erysipelosis (Roesel et al., 2016). Observed patterns of multiple infections, related risk factors, biosecurity perceptions, and farmers' practices provide important entry points to improve production systems and reduce the economic impact of common pig pathogens. The few existing disease surveillance activities are usually limited to body temperature checks and parasite control carried out by farmers themselves and village veterinarians. Additionally, information-sharing

platforms in the villages are almost non-existent (Dione et al., 2016c). There is need to reinforce pig disease surveillance and control mechanisms in Uganda to reduce the impacts of diseases.

2.4.5 Animal health service suppliers

According to Ouma et al. (2015) most veterinary drug sellers in 3 major pig producing districts namely Masaka, Mukono, and Kamuli are male (72%), and the majority (54%) hold a diploma in animal production. Almost all (99%) provide services in addition to selling drugs including treatment, consultation services, and the sale of farm equipment. Dewormers are the most sold drugs by stockists (93%), followed by antibiotics (4%) and multivitamins (3%). The most used dewormers by farmers are albendazole (46%) and ivermectin (40%). Levamisole, praziquantel, and piperazine are also used. Drug stockists claimed that the main causes of drug ineffectiveness are related to the large proportion of farmers medicating on their own, leading to wrong dosage due to poor dilution of drugs, poor administration, and poor handling and storage.

The majority of animal health service suppliers are para-veterinarians. They usually hold a diploma in animal husbandry or a certificate in agriculture or livestock. Only 5% hold at least a bachelor's degree in animal health, e.g., a bachelor's degree in veterinary medicine. The main services provided by the veterinarians and para-veterinarians are treatments and advisory services, and almost all (97%) carry out secondary activities such as the sale of animal feed, crop production, or breeding services. Advisory services include training farmers in pig business management (Dione et al., 2014a).

2.5 Marketing and value chain governance



The major pig related products traded in Uganda are live pigs and pork. Traders play the dominant marketing role in the value chain, and they take on multiple roles – essentially, a ‘pig trader’ in this context searches for the pigs, bargains with the producer or another trader, buys live pigs, and transports them to where they will be slaughtered. Traders will generally either use a motorcycle or bicycle or a truck. If traders are from within the village, they mostly use a bicycle or trek with the pig; if they are from outside the village or district, they often use a motorcycle to gather the pigs in one central place in the village and transport them using a truck. After slaughter, the traders sell the pork either roasted/fried or raw to the final consumer or another trader. Smallholder pig farmers have three major channels through which they sell their pigs: pork butchers within the village, pork butchers near urban centres, and traders coming from Kampala. The channel most available to the farmers is through pork butchers within the village (Lule, 2014).

In terms of value chain governance, there are no contractual arrangements between actors in smallholder pig value chains. Farmers and traders do not have contracts with buyers or suppliers in all three districts. However, most live pig traders are vertically integrated, performing several functions in the value chain under single ownership.

Compared to pig farmers who are largely concentrated at the production node, live pig traders are also involved in the retail nodes of the value chain, operating pork butcherries and pork joints while also carrying out pig slaughter functions (Ouma et al., 2017).

2.6 Animal health service delivery and extension services

In Masaka, Lira and Mukono districts, pig farmers identified various sources of animal health services, including veterinarians employed by the government such as former National Advisory Agricultural Services staff members, private veterinarians and animal health workers (para-veterinarians), and experienced farmers who help fellow farmers with basic animal health services. Private animal health service providers are the most accessed source of services; access to radio programmes (talks show on issues related to crops and livestock) are one source of extension services (Ouma et al., 2017). Most agro-vet business operators among the interviewed population in Masaka, Lira and Mukono (21/36) hold diplomas in animal husbandry and do not have specific training in animal health (Opio et al., 2015; Ouma et al., 2015). Therefore, substantial efforts to enhance their capacities in animal health would improve livestock health care in Uganda. Additionally, from this study, a higher proportion of men received animal health services compared to women except in urban settings.

2.7 Gender and pig production

In Uganda, most pig producer households are male headed (81%). The female spouse often plays a major role in initiating pig production through purchasing first stock in male-headed households. In terms of production, men and women divide up tasks. Men often build the pigsties and to some extent work on the animals' health and husbandry, while women take care of the pigs (e.g., clean the sties, mix feed, and bring water for the animals). Sometimes, women also take on non-traditional roles that require knowledge of animal health and husbandry (Dione et al., 2014a); this happens, for example, during outbreaks of diseases like African swine fever. However, men largely dominate other components of the pig value chain, including working as drug stockists, livestock feed stockists, live pig traders, and in agro-veterinary services and village boar-keeping businesses.

According to recent study examining gender roles in the pig value chain in Uganda, (Ouma et al., 2016) decision-making in the pig enterprise in general, women claimed that they exclusively did most of the activities and decisions. Men claimed that most activities and decision-making were of shared responsibility or done jointly by men and women. Activities clearly in the women's domain included pig feeding, watering, and cleaning pens; marketing was mainly in the men's domain. In urban areas, most women indicated the enterprise was theirs and consequently it was their role to carry out activities and make most decisions (Dione et al., 2016). The study found that men were more knowledgeable and skilled in pig husbandry. This is because they have more ties to outside organisations, interact more often with veterinary services (whose staff are mostly men), are offered more training, and have greater access to the media and thus to messages about the disease. Men usually can easily interact outside the household and access health inputs more easily than women (Ouma et al., 2015). Given the critical roles that women play in pig management, there is a need to engage them while implementing interventions aiming to upgrade the pig value chain.

2.8 Pig slaughter and pork consumption

There is a lack of designated slaughter facilities for pigs in Uganda in both rural and urban areas, except for Kampala. This gap is filled by traders who invest in backyard slaughter facilities that are not regulated and lack ante-mortem inspection of pigs. The resulting pork is largely not inspected and mainly sold through local retail outlets such as butcherries and pork joints (Ouma et al. 2015). Furthermore, the hygiene of the backyard slaughter premises and pork joints, in addition to pork handling, are often poor (Tatwangire, 2014). The veterinary and public health departments in local governments are responsible for regulating such premises and enforcing standards to ensure that only safe, high-quality pork and other meat products are offered in the market. However, there is poor enforcement of these regulations. A study carried out in 158 pork-eating places in Kampala reported that 68% of the pork consumed was from places where slaughter was not authorised and meat inspection not carried out, with



*Carcass of pig hanging at the slaughter slab, Masaka, Uganda
(Picture credit/Michel Dione, ILRI)*



Ready to eat roasted pork, Masaka, Uganda (Picture credit/Michel Dione, ILRI)

only 42% of the outlet owners having a public health certificate to operate; holding a public health certificate is an important predictor of good practices (Kungu et al., 2017a).

2.9 Pig value chain's constraints

2.9.1 Production level

The production and management of pigs is affected by a lack of organisational strategies to achieve economies of scale at the farm level (Ouma et al., 2017). Productivity is very low and is largely attributed to the dominance of low-input/low-output systems practiced by small-scale producers. The following constraints have been reported by several studies: feed shortages during the dry season; poor pig health management resulting from diseases such as African swine fever, helminthiasis (such as porcine cysticercosis), and external parasite infestation; poor feeding practices and poor quality of feeds; poor husbandry practices; and an absence of appropriate breeding strategies (Nabiky and Kugonza, 2016). Low productivity coupled with poor access to services such as veterinary assistance, extension (Muhanguzi et al., 2012; Dione et al., 2014; Roesel et al., 2017), financial and market information services, and the absence of sustainable farmer organizations have all greatly affected the development of the pig value chain in Uganda. These weak linkages have had significant negative impacts on farm gate prices. (Dione et al., 2014a; Nabiky and Kugonza, 2016). In addition, regulations on biosecurity measures and waste management are poorly implemented, and the adherence of farmers and other actors to these regulations is equally limited (Ouma et al., 2017). Poor implementation of regulations results in negative environmental impacts and the spread of diseases.

2.9.2 Health input supply level

Unavailability of inputs and veterinary services are among the most notable constraints to the pig value chain, and the poor quality of services and price fluctuations of these inputs are priority concerns. Farmers claimed that inputs and veterinary services are costly. Veterinary services are scarce, leading to low access to extension services for farmers. Additionally, farmers reported a lack of financial resources to purchase more pigs and low prices of outputs (live pigs) relative to the high prices of inputs; this lowers pig farmers' profit margins and thereby discourages them from acquiring inputs (Dione et al., 2014a; Dione et al., 2016d). Lack of acceptance of new

versions of the same brand of drug by some farmers and drug stockists is a major challenge. The major constraint faced in terms of veterinary services is the poor infrastructure, including roads, and poor access to vet service. Other studies such as Ilukor et al (2013) find farmer inability to pay for quality veterinary products and services. Drug misuse by farmers and service providers was also cited as an important constraint; this practice is associated with lack of knowledge of farmers together with low education levels of drug stockists and animal health workers – especially the use of poorly trained animal health workers (Ouma et al., 2015).

2.9.3 Trading/Marketing

There are limited pig sales outlet options for farmers, especially in rural areas due to poor linkages with pig buyers and poor information flow (Ouma et al., 2017). As a result, farmers are exposed to low price offers for their animals as they sell their pigs individually to traders and lack bargaining power. Pig farmers within the same locality tend to sell their pigs to the same (local) buyers, leading to a glut in the pig market (especially just before schools reopen), and further depressing market prices. In addition, farmers have limited capacity in estimation of live weight of pigs and are therefore unable to assess whether price offers are fair (Ouma et al., 2017). Marketing is mostly done by itinerant traders through brokers located in the villages. There are no fixed-point pig collection centres due to lack of marketing infrastructure and poor value chain coordination. Such capacity gaps and market disincentives, limits farmer investment into the enterprise.

2.9.4 Quality control

Quality assurance standards in the pig production process have yet to be embraced since few traders grade pork products and quality standards do not exist in Uganda. There is a challenge in enforcing existing rules and regulations in the feed, live pig, pork, and veterinary drug businesses because traders and service providers still operate without following government regulations. For example, rules that some businesses do not adhere to include having inspection certificates, business licenses, health examination certificates, slaughtering permits, or animal movement permits (Ouma et al., 2015).

2.9.5 Policy

Although the pig sector has significant potential in Uganda both commercially and as a pathway towards poverty reduction, the sector has been marginalised due to its low priority in the national agricultural sector policy framework (the Development Strategy and Investment Plan). Pig-raising was not chosen to be among the 12 priority strategic commodities, although it was recognised as very important for the population's food and nutrition security. According to a stakeholder meeting held in Kampala in 2013, the main underlying cause for the government to not prioritise the pig sector is lack of evidence of the industry's full scope and potential and misconceptions about pigs being dirty animals (Worsley, 2013). However, some districts such Hoima and Masaka have prioritised the pig sector in their district development plans and are leveraging different partners' work to support the sector. Although the pig sector is not a priority per se, the government of Uganda recognised the role played by pigs especially in poorer settings. To confirm this, the Ministry of Agriculture, Animal Industries, and Fisheries has allocated strategic funds for controlling African swine fever – a disease with significant socio-economic impact – in the Agriculture Sector Strategic Plan 2015/16 to 2019/20. There is no specific policy or strategies to harmonise the way actors in smallholder pig value chains are governed. The lack of organisation of farmers, traders, processors, and other actors in the value chain creates inefficiencies that open the door for exploitation and poor-quality products. There is a need for a good policy if actors, particularly pig farmers, are to move up the value chain (CGIAR, 2013).

3. Porcine cysticercosis in Uganda: Background and status

T. solium cysticercosis is a parasitic zoonosis caused by larval cysts of pig cestode. The primary intermediate host is the pig (which harbours the cysticercal stage), with the only definitive natural host being humans (who become infected via the adult intestinal tapeworm). Humans can also harbour the cystic stage in their tissue, causing cysticercosis or – if located in the central nervous system – neurocysticercosis. Neurocysticercosis is the most serious form of cysticercosis in humans and causes epilepsy. Porcine cysticercosis is a faecal-borne infection caused by the ingestion of *T. solium* eggs dispersed by a human *T. solium* tapeworm carrier. *T. solium* has received little attention for decades despite its traumatising health and socioeconomic impacts (Tatwangire, 2014).

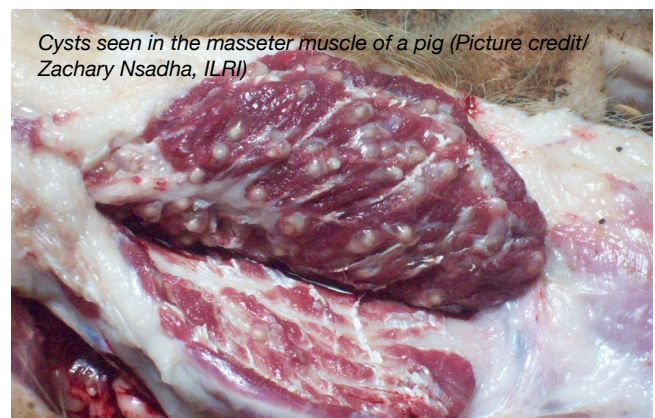
In many areas in which it is endemic, *T. solium* cysticercosis is inadequately controlled by the existing sanitary systems, resulting in considerable public health impact. It remains a major public health problem in developing and some developed countries (Boa et al., 2006; Pondja et al., 2012). However, despite the numerous, often obvious, and seemingly simple options for preventing *T. solium* transmission, few intervention programmes have led to sustained reduction in the incidence of the disease. Considering the life cycle of *T. solium*, there are many opportunities for controlling the parasite's transmission.

T. solium cysticercosis is largely under-recognised in many developing countries (Lightowers, 2013). In Uganda, few studies have explored the epidemiology of the disease. Most studies have been limited to reporting prevalence and are factor-associated data. Very few studies have addressed the disease from the human health perspective.

3.1 Prevalence and risk factors of porcine cysticercosis in Uganda

Porcine cysticercosis has been reported in Uganda in several studies:

- High seroprevalence was reported in slaughter slabs in Moyo district (37.7%) (Tsang and Wilson, 1995).
- Post-mortem surveys at Wambizi slaughterhouse found a prevalence of 9.4% (Anyanzo, 1999).
- A field survey reported the highest prevalence of porcine cysticercosis in the Lac Kyoga bassin, with an average of 24% in five districts (Kisakye and Masaba, 2002).
- The disease was reported in area of high pig density such as Masaka (11.7%), Kamuli (13.5%), and Mukono (11.2%) (Nsadha et al., 2010).
- Other regions with lower prevalence include Lira (6.5%) and Moyo (13.2%) (Kungu et al., 2018) .



Major risk factors are free-range piggery systems, the absence of latrines, and a lack of knowledge amongst pig farmers about the disease's impact in Uganda (Kungu et al., 2019). Open-air defecation is common in many parts of Uganda, and some studies have shown that many households do not have latrines. In Soroti District, 54% of households were reported to not have latrines (Kungu et al., 2017b), while 36% of households had no latrines in the Lake Kyoga basin. Proper disposal of human faeces is needed in most of these areas. In addition, wrong or poor perceptions about the disease in pigs prevent communities from self-evaluating pork for cysticercosis before consumption. Ignorance about the transmission of *T. solium* cysticercosis prevents the adoption of proper control measures (Nsadha et al., 2010).

Veterinary inspection of live pig and pork to identify cysts is lacking at both markets and slaughter slabs in most districts. The few times it is done for live pigs, it is limited to lingual screening, which is known to have low sensitivity. Regular pork inspection in Uganda is only carried out at the country's only regulated pig slaughterhouse at Wambizi, which mainly supplies the urban and peri-urban areas of Kampala (Nsadha, 2013; Kungu et al., 2017a). Most of the pork consumed in rural areas is not inspected – for example, a field study in the Lake Kyoga basin found 90% of the pork consumed undergoes no inspection (Nsadha, 2013). This is mainly because slaughter is carried out in unregistered places, making it difficult for inspection personnel to access the sites.

Practices such as open-air defecation and lack of inspection are key contributors to the persistence of porcine cysticercosis in Uganda. However, prevalence studies need to be extended to other districts in order to have a clearer picture of the distribution of the disease.

3.2 Human health perspectives on porcine cysticercosis

Approximately 2.5 million people worldwide carry the *T. solium* tapeworm, and at least 20 million people are infected with *T. solium* cysticerci (Nsadha et al., 2010). Neurocysticercosis represents the most common helminthic infection of the central nervous system and is one of the most important causes of secondary epilepsy worldwide. Conservative estimates attribute 50,000 deaths every year to neurocysticercosis (Bern et al., 1999). The World Health Organization estimates that eight people per 1,000 worldwide have neurocysticercosis (Mafojane et al., 2003), and the disease can lead to epilepsy, severe mental illness, blindness, and death. The disease is reported to cause 20 to 50% of all late-onset epilepsy cases globally and is also assumed to be a common cause of juvenile epilepsy in certain parts of the world, in particular southern Africa (Phiri et al., 2003). In Uganda, *T. solium* cysticercosis in humans has been confirmed (Winkler, 2012); however, there is a lack of evidence of *T. solium* as cause of neurocysticercosis.

In some sub-Saharan African countries (such as Nigeria), the prevalence of human taeniosis is quite high (8.6%). Surprisingly, however, no cases of human cysticercosis have been reported, although epilepsy is very common. Large epidemiological surveys have only been carried out in Togo and Benin, where the prevalence of human cysticercosis was 2.4% and 1.3%, respectively. In Central Africa, human cysticercosis is endemic in Rwanda, Burundi, the Democratic Republic of the Congo, and Cameroon. Cysticercosis has been shown to be one of the major causes of epilepsy in Cameroon, with figures as high as 44.6% (Willingham and Angels, 2006).

Based on the available information, a conservative rough economic estimate indicates that the annual monetary losses due to porcine cysticercosis in ten western and central African countries amount to about EUR25 million (Zoli et al., 2003). In countries where this condition occurs, every case of cysticercosis in pigs has been estimated to result in an average loss of EUR194 and nine disability adjusted life years (DALYs) per 1,000 persons per year (Zoli et al., 2003). Financial losses due to human cysticercosis are very difficult to estimate, but they are certainly exceeded by the social impact of the disease, especially because of the negative perception of epilepsy in many African communities. In addition, it is important to note that the true prevalence of *T. solium* cysticercosis in pigs and humans in central and west Africa remains underestimated because of unreliable slaughterhouse data and the lack of awareness and diagnostic facilities in the public health sector (Ngowi et al., 2003).

3.3 Control measures for porcine cysticercosis

The eradication of *T. solium* from most European countries was due to progress in environmental sanitation, adequate husbandry of pigs, and adequate inspection of pig carcasses. Unfortunately, these measures have not yet been completely implemented in many developing countries (Zoli et al., 2003). Porcine cysticercosis is potentially eradicable for several reasons:

- The adult *T. solium* lives exclusively in human beings.
- Taeniosis is the only source of infection for the intermediate host.
- Porcine cysticercosis can be controlled.
- There are no wild reservoirs.
- There are safe and efficient cestocidal products against the tapeworm and the cysticercus (Flisser et al., 2003).

Recently, much progress has been made in terms of research on diagnosis, treatment, and prevention of human taeniosis and porcine cysticercosis, although more operational research is still needed. Major obstacles to practical implementation of control measures include low levels of sanitation and health education amongst endemic populations, ineffective health services infrastructure, and inadequate socioeconomic development in these areas (Schantz et al., 1993).

Pawlowski et al. (2005) showed the mass drug administration in humans and pigs interrupted transmission of taeniosis and cysticercosis in a region in which these diseases were endemic. However, the magnitude of the effect was small and did not attain the goal of eliminating transmission. According to Garcia et al. (2016), mass drug administration is a temporary solution since unhealthy conditions and poverty prevail in countries where these diseases are endemic, making this approach unsustainable; this means that the eradication of taeniosis and cysticercosis requires a socioeconomic and political approach, not an entirely pharmacological one. Most previous studies that aimed at controlling porcine cysticercosis did not target regional elimination but rather assessed control interventions in a few villages (Carpio et al., 2016). There is a need to validate these studies in wider geographical locations.

Eventual elimination of *T. solium* taeniosis-cysticercosis will benefit from the use of a 'One Health' approach recognising the connections between human and animal health, with implementation of multiple interventions in human, animal, and ecosystem health simultaneously occurring across sectors and supported by appropriate health education tools (Garcia et al., 2006; O'Neal et al., 2014). Based on a *T. solium* cysticercosis transmission model (Johansen et al., 2014) and on the available evidence in the literature, the World Health Organization recommends a combined approach as the current 'best-bet' option for rapid reduction of infection pressure – utilising the treatment of human taeniosis cases through mass drug administration or selective chemotherapy combined with the TSOL18 vaccination and treatment of the porcine host (oxfendazole, 30mg/kg). This core approach should be supplemented by supporting measures such as health education and followed with measures requiring fundamental social changes such as improved meat inspection, husbandry, and sanitation (Kyvsgaard et al., 2007). Full community commitment of policymakers and communities will be essential to achieve successful, sustainable disease control.

4. Characteristics of the porcine cysticercosis vaccine product (TSOL18 vaccine and oxfendazole)

New tools have become available for controlling porcine cysticercosis that could help break the disease cycle (World Health Organization, 2015). *T. solium* parasites encysted in the muscle tissues of pigs are killed following a single oral treatment of 30 mg/kg of the benzimidazole drug oxfendazole (Gonzales et al., 1996). In 2013, oxfendazole manufactured under Good Manufacturing Practice standards was licensed for the first time for use in pigs to treat cysticercosis by MCI Santé Animale, Morocco. Vaccines have also been developed for porcine cysticercosis (Flisser et al., 2004). A recombinant vaccine antigen, TSOL18, produced in *Escherichia coli* has been shown to be highly effective at reducing *T. solium* pig infections under field conditions in Africa and Peru (Garcia et al., 2016); A commercial vaccine based on TSOL18, and produced under Good Manufacturing Practice standards, was licensed in 2016 by Indian Immunologicals Limited, India. These tools provide opportunities for new interventions against *T. solium*.

TSOL18 and oxfendazole
TSOL18 vaccine (Cysvax™): Containing the <i>T. solium</i> oncosphere antigen (TSOL18), 150 ug/ml adjuvanted with mineral oil. Dose of 1 ml per pig was administered by intramuscular injection at three-month intervals.
Oxfendazole (Paranthic™ 10%): Containing 10% w/v oxfendazole, oral suspension. Dosage of 3 ml/10kg body weight (30 mg/kg) was administered orally.
<ul style="list-style-type: none"> • The TSOL18 vaccine is effective when both primary and booster vaccines are applied. • Primary vaccination is given to pigs at least 2 months old. • Booster vaccine can be given from three weeks to four months after the primary vaccine. Immunity in pigs develops within two weeks of the booster dose. • Re-vaccination occurs six months later if the pig is still on the farm and not yet sold. • The vaccine is thermal labile and needs to be stored and transported at temperatures between 2°C and 8°C (thus requiring a cold chain). • Oxfendazole is administered concurrently with the vaccine during primary and booster vaccinations, as well as re-vaccination to treat infected pigs. • The mode of administering the TSOL18 vaccine is deep intramuscular injection behind ear for vaccine and drenching for dewormer. • The withdrawal period for the vaccine is zero days, but use of oxfendazole requires a withholding period of 21 days (three weeks).

Lightowlers (2013) indicated that the most effective control of *T. solium* cysticercosis was usage of chemotherapy and vaccination every six months. The vaccination regime was based on current knowledge at the time, which indicated that immunity was induced by two vaccinations given approximately one month apart. More recently, it has been shown that the immune response is maintained even after longer vaccination intervals and more flexible intervention strategies are possible and by the same logic based modelling vaccination and deworming of pigs at three monthly intervals has the potential to prevent transmission of *T. solium* in slaughter weight pigs (Lightowlers et al., 2016; Lightowlers and Donadeu, 2017)

The trials carried out in Uganda by GALVmed aimed to evaluate concurrent treatment of porcine cysticercosis, with the TSOL18 vaccine and oxfendazole administered to pigs exposed to natural *T. solium* infections under field conditions in Uganda. Results showed that three monthly interventions with the TSOL18 vaccine (Cysvax™) and the dewormer Paranthic™ eliminated cysts in pigs (Nsadha et al., 2021). The intervention regimen was safe (no adverse reactions), and there were high levels of compliance and acceptance. In addition, anecdotal evidence from pig farmers indicated there were economic benefits. Similar trials have been carried out in Nepal, Tanzania and Zambia and also demonstrated the same high level of efficacy of this control strategy (Poudel et al., 2019; Gabriël et al., 2020; Kabululu et al., 2020).

5. Background to the study

As part of the programme Protecting Livestock, Saving Human Life, funded in part by the UK Government (formerly Department for International Development, DFID, currently the Foreign, Commonwealth and Development Office, FCDO) and the Bill & Melinda Gates Foundation, GALVmed was implementing activities aimed at controlling porcine cysticercosis in pigs in Uganda. Initial field tests have confirmed the efficacy of the combined use of the TSOL18 vaccine and oxfendazole. In addition, farmers in the pilot study reported improved weight gain in vaccinated pigs compared to non-vaccinated ones (probably due to reduction of helminths), and pigs attracted a higher market price. Farmers also claimed that it was easier to sell pigs. Due to these benefits, there could be potential for marketing the porcine cysticercosis vaccine as a private good. At the same time, experience and a review of the literature show that poor smallholder farmers are unlikely to invest in preventive animal health treatments, even highly effective ones; this can undermine a purely market-driven approach. In addition, the technical features of the package can both incentivise and de-incentivise farmer adoption (e.g., benefits from controlling other parasites versus the need for a booster).

The purpose of this porcine cysticercosis market scoping exercise was to gain a clear understanding of the opportunity for 'private good' marketing of the TSOL18 vaccine and oxfendazole. It also aimed to quantify the market size more accurately and determine market segments and the registration status of these products, as well as how these might influence product availability, supply mechanisms, price structure, competitiveness of products, profit margins, and the potential to sell these products to smallholder pig producers in Uganda.

Findings and recommendations from the scoping study will guide GALVmed and its partners subsequent entry into the market related to porcine cysticercosis in Uganda by thoroughly describing the possible market routes for the TSOL18 vaccine and oxfendazole, highlighting any potential marketing challenges, providing insight into strategies for engaging other pig value chain partners with capacity to undertake large-scale sustainable porcine cysticercosis vaccination delivery, and identifying key interventions that have potential to benefit producers and other value chain stakeholders.

6. Study objectives

The study's main objective was to understand market opportunities for the TSOL18 vaccine and oxfendazole in order to:

- i. Determine whether pig producers are willing to pay (and if so, how much) for vaccination and treatment against porcine cysticercosis as a routine practice;
- ii. Evaluate animal health delivery and the ability to market both products; and
- iii. Discuss with key stakeholders – and report recommendations on – the potential for large-scale, sustainable private-sector distribution mechanisms for the TSOL18 vaccine in Uganda.

7. Methodology for the market scoping studies

7.1 Study site selection

The market scoping studies took place in Uganda's Masaka and Bukedea districts (figure 6). Masaka was selected because it has the highest pig population density in Uganda and because the International Livestock Research Institute's smallholder pig value chain projects have been active there in terms of undertaking research. ILRI have established strong partnerships with local government and pig value chain actors. Bukedea was selected because porcine cysticercosis vaccine trials are being carried out with GALVmed in the district. This was to leverage existing information on vaccine trials and porcine cysticercosis awareness. For the consumer studies, Kampala and Mukono districts were selected because they have the highest number of pork consumers in the country.



Figure 6: Map of Uganda showing the study sites

7.2 Field studies

Several scoping studies targeting different nodes of the pig value chain were conducted. The focus and approach of each are summarised below:

7.2.1 *Farmers' willingness to pay for TSOL18 vaccine and oxfendazole*

Objective: Assess farmers' willingness to pay for the TSOL18 vaccine-oxfendazole product combination

Participants: Individual interviews with 294 randomly selected pig farmers (140 in Masaka district and 154 in Bukedea district)

Approach: Choice experiments using different attributes and levels

Location: Masaka and Bukedea districts

Theoretical framework of choice experiment:

A choice experiment is a multi-trait/multi-attribute stated preference method that assesses the value of single traits of a bundled good by using individuals' stated preference in a hypothetical scenario.¹ The traits to be valued – as well as value levels – are identified and combined according to an experimental design to create sets of discrete choice alternatives. Respondents are then presented with a series of choice alternatives and asked to choose their most preferred option. Each alternative is characterised by a number of traits, one of which is a monetary trait offered at different levels across alternatives. Analysts can then assess how respondents' choices change as the traits and monetary amounts are varied. Appropriate models are then applied to the choice data to reveal a measure of utility for the traits of the choices.² The choice experiment method is particularly useful for valuing traits without market values since the trade-offs that people make within traits demonstrate a willingness to pay.³

The theoretical framework for choice experiments derives from Lancasterian consumer theory and discrete choice random utility theory.⁴ The Lancasterian framework postulates that utility (U) is derived from traits or attributes of goods (z_i) rather than the good per se, assuming a random utility function, depicted as:

$$U_{njt} = \beta_0 \gamma_n + \gamma_n P_{njt} + \beta_n X_{njt} + \varepsilon_{njt}$$

Here, P_{njt} denotes the cost parameter or price of alternative j , which is often included as one of the attributes of the choice alternative. X_{njt} denotes the other observed attributes of choice alternative j . The constant, $\beta_0 \gamma_n$ denotes individual n 's choice-specific intercept for alternative j ; γ_n is the coefficient for the cost parameter, and β_n represents the coefficient vectors for the other traits for individual n . The implicit prices (willingness to pay) for the traits can be estimated as the rate of change in the trait divided by the rate of change of the cost parameter (marginal rate of substitution) represented as:

$$\frac{\partial U / \partial X_{nj}}{\partial U / \partial P_{nj}} = - \frac{\beta_n}{\gamma_n}$$

1 Louvière, J.J., Hensher, D.A., Swait, J.D., 2000. Stated choice methods, analysis and application. Cambridge University Press.

2 Train, K., 2003. Discrete choice methods with simulation (1st ed.). Cambridge University Press.

3 Loomis, J., 2005. Economic values without prices: The importance of nonmarket values and valuation for informing public policy debate. *Choices*, 20(3), 179-181.

4 Lancaster, K., 1966. A new approach to consumer theory. *Journal of Political Economy*, 74(2), 132-157.

Identification of the attributes/traits and levels used in this study were based on past studies and expert opinion (table 1).

Table 1: Attributes used to study pig farmers' willingness to pay for the porcine cysticercosis vaccine

Attribute/Trait	Levels
A. Cost of vaccination (includes the cost of two doses of oxfendazole and TSOL18 vaccine)	0. UGX10,500 (US\$2.92)
	1. UGX13,500 (US\$3.75)
	2. UGX18,000 (US\$5.00)
B. Administration of vaccine (service fee for the veterinarian/ animal health worker without including transport)	0. UGX2,500 (US\$0.69) per pig – service fee for veterinarian/animal health worker who administers vaccine and deworming service to a group of 10 farmers
	1. UGX4,000 (US\$1.11) per pig – service fee for veterinarian/animal health worker who administers vaccine and deworming service to one farmer
	2. UGX6,000 (US\$1.67) per pig – service fee for veterinarian/animal health worker who administers vaccine and dewormer to one farmer
C. Improved pig weight gain	0. Pig gains an extra 10% weight because other worms are killed
	1. Pig gains an extra 5% weight because other worms are killed
D. Price premium for vaccinated pigs	0. 50% of market price
	1. 30% of market price
	2. 15% of market price
E. Frequency of vaccination to attain immunity	0. Once at 2 months old
	1. Twice (one dose at 2 months old and another dose three months after)
	2. Three times (one dose at 2 months of age, second dose three months later, and a third dose after another three months)
F. Vaccine viability detector	0. Non-inclusion of an indicator to test for vaccine viability
	1. Inclusion of indicator that shows vaccine viability

US\$1 is equivalent to UGX 3600

The identified traits and the associated levels were combined based on a fractional factorial orthogonal main effects-only experimental design using SAS software. The design resulted in 12 generic choice sets, each with three alternatives and a 'no-buy' option. The overall efficiencies of the choice experiment were high – D efficiency: 98.6%; an efficiency: 97.1%; and G efficiency: 93.4%. The high efficiencies shows that the designs are statistically efficient. The key consideration is that maximizing statistical efficiency minimizes the variability of the parameter estimates (Rose and Bliemer, 2004)

These choice sets were used to construct cards with pictorial profiles describing the differences in traits and levels to demonstrate each choice set to pig farmer survey respondents (see annex 3). The 12 choice sets were blocked into two groups of six choice sets each. Each pig farmer was presented with six choice sets. The choice experiment was administered as part of a short farm-level survey questionnaire using in-person interviews. The rest of the questionnaire covered socioeconomic aspects such as location of the farm and other household- and farm-level characteristics (see annex 4).

The administration of the choice experiment was conducted in the following manner: The farmers were first asked if they were aware of porcine cysticercosis and its effects. They were then provided with background on porcine cysticercosis and its transmission cycle and health effects. They were also provided with information about the porcine cysticercosis vaccine that will soon be introduced into the market in Uganda and the importance

of feedback from pig farmers to the vaccine manufacturer. They were then presented with the choice cards developed from the information in table 1 in the form of pictorial profiles. They were shown three vaccine choice options at a time for each of the six choice sets and asked to choose the most preferred vaccine to purchase. In each case, a 'no-buy' option was also presented for farmers who preferred none of the three options. A total of 294 farmers from Masaka and Bukedea districts (140 and 154, respectively) participated in the choice experiment interviews. Each farmer responded to six choice sets, yielding a total of 1,764 observed choices.

A conditional logit model using *NLOGIT 6* (Econometric Software Inc.) was applied to assess factors influencing choice and to estimate the implicit prices (i.e., willingness to pay) for the traits. Table 2 presents the choice experiment variables used in the model and the coding of their corresponding levels.

Table 2: Choice experiment variable coding

Variables	Units/coding of the variable levels
Cost of vaccine	Cost in US\$
Premium price	Premium price in US\$ (top-up premium price due to vaccination)
Low vaccination frequency	1=Once at 2 months
	0=Twice
	-1=Three times
Medium vaccination frequency	1=Twice
	0=Once at 2 months
	-1=Three times
Weight gain	Weight gain in kilograms
Vaccine viability detector	1=Inclusion of a vaccine viability detector
	-1=Non-inclusion of a viability detector
Vaccine administration cost	Cost in USD

7.2.2 Traders' willingness to pay for porcine cysticercosis-vaccinated pigs

Objective: Determine whether pig traders are willing to pay premium prices to pig farmers for *T. solium*-free pigs (i.e., vaccinated)

Participants: 33 pig traders

Approach: Choice experiment, similar to that described for farmers in the previous section, using different attributes and levels presented in table 3 based on field experience and previous studies

Location: Bukedea district

The administration of the choice experiment was conducted in the following manner: The traders were first asked if they were aware of porcine cysticercosis and its effects. They were then provided with background on porcine cysticercosis and its transmission cycle and health effects, as well as information about the porcine cysticercosis vaccine that will soon be introduced into the market in Uganda and the importance of feedback from pig farmers to the vaccine manufacturer. The traders were then presented with the choice cards developed from the information in table 3 in the form of pictorial profiles. They were shown three vaccine choice options at a time for each of the eight choice sets and asked to choose the most preferred vaccine to purchase. In each case, a 'no-buy' option was also presented for farmers who preferred none of the three options. A total of 33 traders from Bukedea district participated in the choice experiment interviews. Each trader responded to eight choice sets, yielding a total of 264 observed choices.

Table 3: Attributes used to study traders' willingness to pay for the porcine cysticercosis vaccine

Variables	Units/coding of the variable levels
A. Top-up premium price due to porcine cysticercosis-vaccinated pig	1. 5% top-up
	2. 10% top-up
	3. 15% top-up
	4. 20% top-up
B. Market price of pig (average of a 40-kilogram pig)	1. UGX155,000 (US\$43.06)
	2. UGX200,000 (US\$55.56)
	3. UGX225,000 (US\$62.50)
	4. UGX250,000 (US\$69.44)
C. ++Proof of vaccination	1. Producer's word
	2. Certificate provided by a government veterinarian
	3. Certificate provided by a private veterinarian
	4. Vaccinated pigs are ear-tagged
D. Improved carcass weight gain	1. Pig gains an extra 15% carcass weight because other worms are killed
	2. Pig gains an extra 10% carcass weight because other worms are killed
	3. Pig gains an extra 5% carcass weight because other worms are killed

US\$1 is equivalent to UGX 3600

7.2.3 Consumer perceptions on porcine cysticercosis-free pork

Objective: Analyse practices around the consumption of safe pork in general and consumer awareness of porcine cysticercosis and cystic pork at retail outlets

Participants: Four groups of consumers (2 groups of men and 2 groups of women)

Approach: Focus group discussions

Location: Two divisions in Kampala – Makindye and Nakawa divisions

Four focus group discussions with pork consumers were held in Makindye and Nakawa divisions in Kampala district using a checklist for guiding discussions (annex 4). The two divisions have the highest number of pork joints in Kampala district, a proxy for high number of pork consumers. Two focus group discussions per division (four total) were held, covering a total of 50 consumers (25 men and 25 women). Posters and pictures were used to illustrate the life cycle of the tapeworm. Pictures showing cystic pork and non-cystic pork of different qualities were presented to participants to assess knowledge and preferences.

7.2.4 Consumers' preference for safe food from animal sources

Objective: Assess consumers' preference for safe food from animal sources

Participants: 47 (24 women and 23 men)

Approach: A simulated egg experiment with consumers (due to ease of handling eggs compared to other animal-source foods such as pork)

Location: Goma and Kyaggwe sub-counties in Mukono municipality

Four different egg types and qualities were purchased and used for the experiment. Equal amounts of each type were presented to the consumers during the experiment. The per-unit prices of the different egg types varied, with costs based on actual market prices:

- Regular eggs (eggs from local hens kept under backyard systems): UGX600 (US\$0.17)/egg
- Antimicrobial-free eggs – organic eggs: UGX700 (US\$0.19)/egg
- Eggs from hens vaccinated against Newcastle disease: UGX400 (US\$0.11)/egg
- Eggs from hens that have been vaccinated against Newcastle disease and are antimicrobial-free – UGX1,200 (US\$0.33)/egg

At the start of each experiment, per site, a workshop-like format was adopted to provide participants with detailed information on the effects of antimicrobial residues and Newcastle disease on human health. Posters and pictures were used for illustration, and the different eggs in the market were explained in detail. After this, each of the participants was given UGX5,000 (US\$1.39) to individually purchase at least four eggs from any of the egg categories in the market. They were allowed to keep leftover money from the purchase. This was to avoid the known hypothetical bias that occurs with stated preference methods such as choice experiments when participants make purchases with imaginary or endowed money and to create a real world situation where participants would buy as frugally or extravagantly as they would with their own money. A short questionnaire was then administered to each participant to collect information on the number and type of eggs purchased, as well as other socio-demographic characteristics.

7.2.5 Therapeutic product profiling

Objective: Determine potential market entry points and barriers for the TSOL18 vaccine-oxfendazole package

Participants: 21 drug stockists

Approach: Individual interviews and observations

Location: Masaka and Bukedea districts

In both districts, a list of all drug stockists registered at the District Drug Inspector's Office was generated. In Masaka, 11 of 16 drug stockists (79%) were interviewed, while in Bukedea all 10 drug stockists were interviewed (100%). In Masaka, interviews took place between 20 and 27 October 2017, while in Bukedea they took place between 31 October and 4 November 2017. An interview was conducted with each stockist, which took about two to three hours each and involved visual inspection of products. Data were entered into Microsoft Excel and Stata for analysis.

7.2.6 Service providers' willingness to sell the TSOL18 vaccine and oxfendazole

Objective: Assess the perspective of the veterinarians and para-veterinarians on their willingness to sell the TSOL18-oxfendazole package and farmers' willingness to buy it

Participants: 22 veterinarians

Approach: Focus group discussion Location: Masaka and Bukedea districts

The heads of both districts' veterinary departments were asked to invite all the veterinarians and para-veterinarians that operate in the municipality (for Masaka) and town council (for Bukedea). Twelve veterinarians in Masaka and 10 veterinarians in Bukedea were interviewed. The focus group discussion for Masaka took place in Katwe Butego sub-county on 20 October 2017, while in Bukedea it took place in Bukedea Town Council on 31 October 2017. Each session lasted about two hours, and a checklist was used to guide the process. For the focus group discussion, there was a session facilitator and a note-taker that recoded all of the responses to the checklist.

7.2.7 Potential for large drug distributors to market TSOL18 and oxfendazole

Objective: Assess the distribution channel for pig dewormers and livestock vaccines and large stockists' willingness to distribute the product (TSOL18-oxfendazole package)

Participants: Two veterinary drug distributors

Approach: Face to-face interviews

Location: Kampala

Two major veterinary drug distributors participated in the study. The research team conducted a two-hour face-to-face interview with the executives of these companies at their head offices in Kampala. The discussions were centred around brands of dewormers distributed (with emphasis on oxfendazole), channels of distribution, and the regulatory framework for drugs and vaccine distribution.

7.2.8 Stakeholder meeting in Uganda

Objective: Discuss with key stakeholders – and report recommendations on – the potential for large-scale, sustainable private sector distribution mechanisms for the TSOL18 vaccine in Uganda

Participants: Key stakeholders in the pharmaceutical industry and management and animal health sector (described below)

Approach: Brainstorming

Location: Kampala

The ILRI team proposed a list of stakeholders that would answer the set objectives: one district veterinary officer, one drug stockist, one experienced veterinarian, one individual from the National Drug Authority veterinary section, one drug stockist, and one focal person for 'One Health' at the Ministry of Agriculture, Animal Industries, and Fisheries. Invitation letters were sent out, and four of the six attended the meeting on 4 December 2017 at the ILRI offices on Naguru Katalima Road in Kampala. The meeting started at 10 a.m. and ended at midday. A checklist was administered to participants in the form of a discussion and their responses were noted.

8. Results

8.1 Farmers' willingness to pay for TSOL18 and oxfendazole

8.1.1 Surveyed farmers' socio-demographic characteristics

Of the interviewed farmers, 63% were female and 37% were male. The average age of the farmers was 39.2 (± 13.7). About half of the farmers interviewed reported having primary-level education (figure 7), and 48% of households had a monthly income of less than UGX100,000 (US\$28) per month (table 4). The farmers had an average total herd size of 3.8 pigs (± 4.4), with at least one sow and one weaner. Various categories of pigs were sold by farmers in the previous six months (table 5). The buyers for the finishers, sows, and boars are mainly butchers (78%), while weaners are mainly bought by individual households.

Summary of findings

- Farmers prefer vaccines that would reward them in terms of yielding a high premium price for vaccinated pigs, as well as vaccines administered only once at 2 months old to attain immunity.
- Key attributes highly valued by farmers included a high premium price due to porcine cysticercosis vaccination and the inclusion of a vaccine viability detector. Farmers indicated willingness to pay US\$0.44 more if the vaccine results in an additional dollar premium price, as well as US\$4 if the vaccine comes with a viability detector.
- The farmers had a high preference for a vaccine that is only administered once to achieve porcine cysticercosis immunity and indicated willingness to pay US\$1.67 more compared to one that is administered three (is this missing from table 6 and 7) times.
- The farmers preferred a vaccine associated with low administrative costs.

Figure 7: Respondents' education level

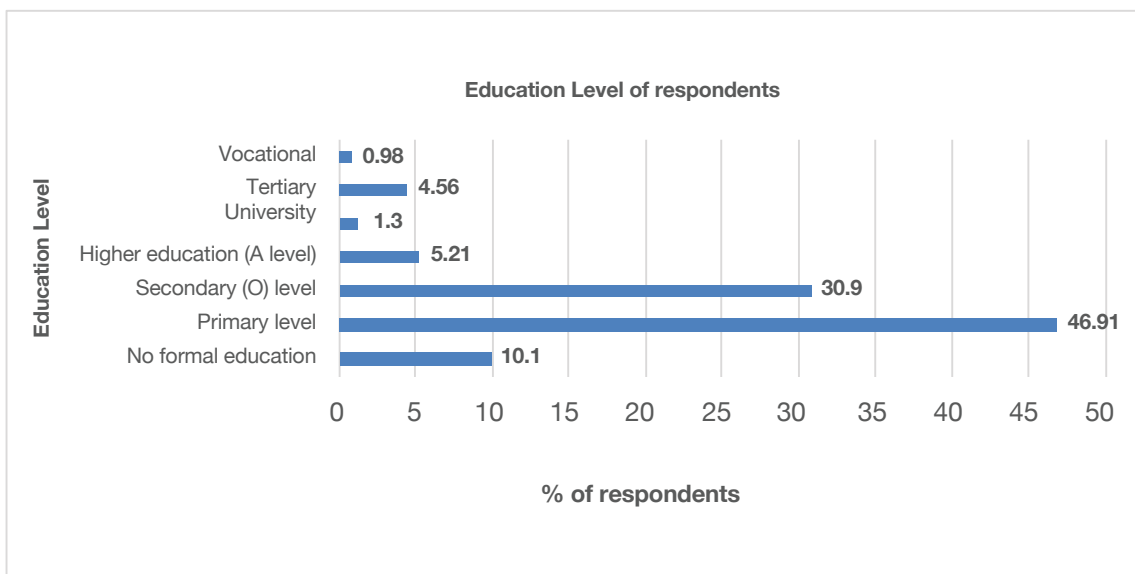


Table 4: Respondents' household income category

Income category (in UGX)	% of households
Less than 100,000	47.9
100,001–200,000	21.1
200,001–300,000	10.8
300,001–400,000	6.8
400,001–500,000	5.5
More than 500,000	7.8

Table 5: Respondents' number of pigs sold in the previous six months

Pig category	Average numbers sold (standard deviation in parenthesis)	Min.	Max.
Boars	0.6 (1.3)	0	14
Sows	0.6 (1.3)	0	13
Gilts	0.3 (1.2)	0	12
Weaners	1.1 (4.5)	0	50
Finishers	0.5 (1.2)	0	9
Piglets	0.9 (2.8)	0	25

8.1.2 Awareness of porcine cysticercosis

Fifty-five per cent of the farmers interviewed had heard of porcine cysticercosis, and 87% of farmers who reported being aware were from Bukedea district. The main source of information regarding porcine cysticercosis was the veterinary officer/animal health assistants (figure 8). Twenty-two per cent of the farmers interviewed indicated their pigs had suffered from porcine cysticercosis in the last 24 months; most of these were from Bukedea district. For the affected farmers, the main effect of porcine cysticercosis in pigs was loss of money (figure 9).

Figure 8: Respondents' reported main source of information on porcine cysticercosis

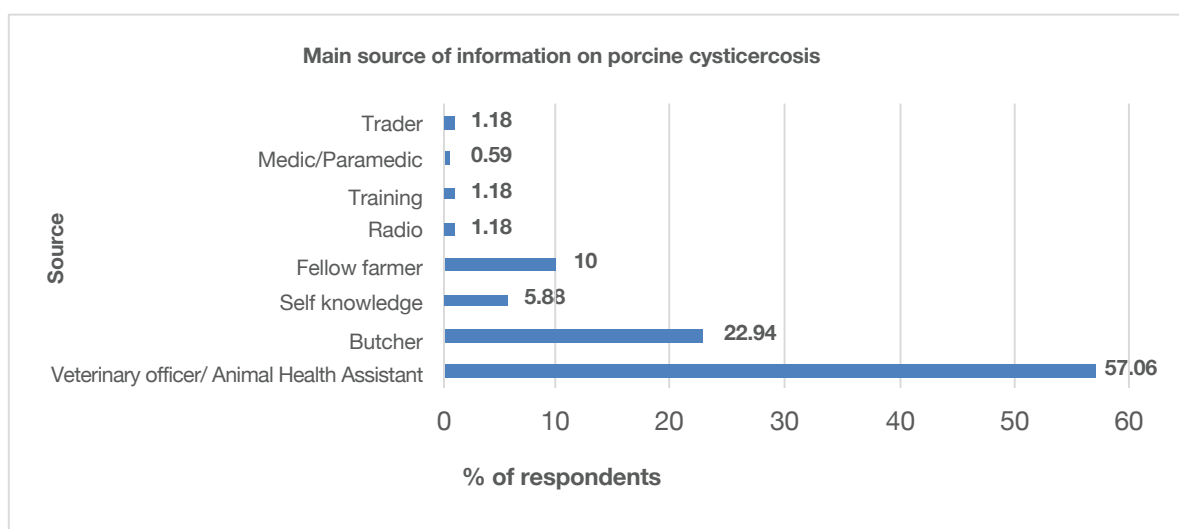
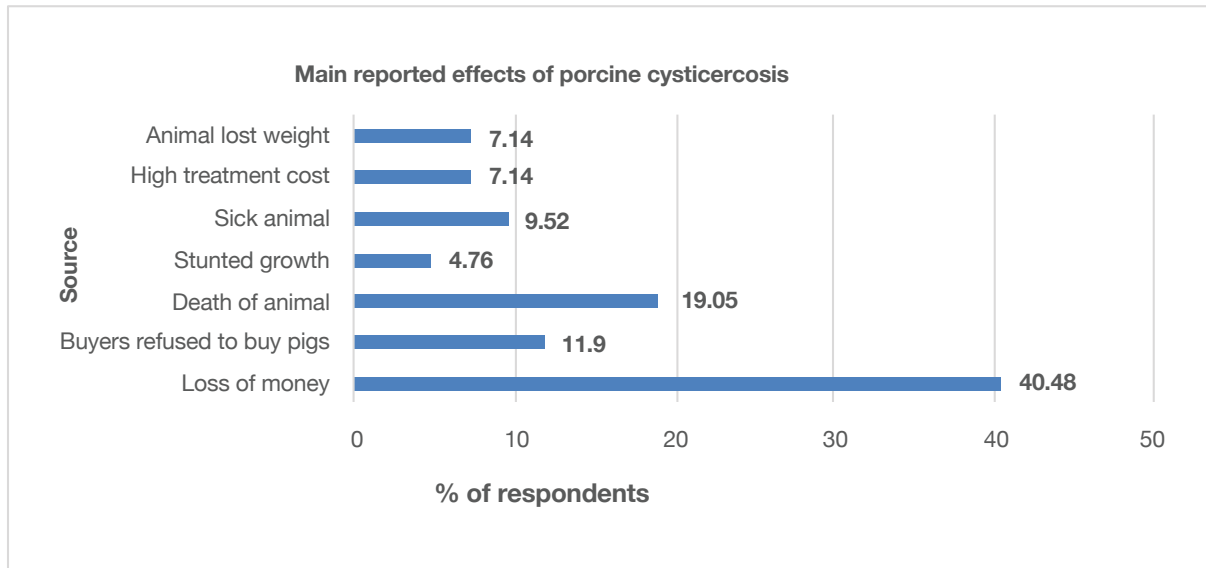


Figure 9: Farmers' main reported effect of porcine cysticercosis

Figure 9: Farmers' main reported effect of porcine cysticercosis



8.1.3 Willingness to pay for porcine cysticercosis vaccine

The maximum likelihood estimates of the conditional logit model are presented in table 6. The results show that farmers prefer vaccines that would reward them in terms of a high premium price for vaccinated pigs and one that is administered only once at 2 months to attain pig immunity. The results also show a strong preference for a vaccine with a vaccine viability detector. The negative and strongly significant coefficient on cost of vaccine and vaccine administration cost shows low preference for high vaccine and administrative costs.

Table 6: Conditional logit maximum likelihood estimates from choice experiment for porcine cysticercosis vaccine

Variable	Coefficient	Standard error	Z
Constant	0.3621*	0.1966	1.84
Cost of vaccine administration	-0.2514***	0.0674	-3.23
Premium price (top-up)	0.0295***	0.0033	9.04
Low vaccination frequency (once at 2 months)	0.1109***	0.0363	3.06
Medium vaccination frequency (twice)	-0.0648*	0.0381	-1.70
Weight gain	-0.0081	0.0284	-0.29
Vaccine viability detector	0.2671***	0.0296	9.03
Cost of vaccine	-0.0666**	0.0307	-2.17
Log likelihood function=-2254.4897			
Number of observations=1,764			
***, ** and * denote significant variables at 1%, 5% and 10%, respectively			

Estimates of the implicit prices of the traits are presented in table 7. The results show two key attributes are highly valued by farmers: a high premium price due to porcine cysticercosis vaccination and inclusion of a vaccine viability detector. Farmers are reportedly willing to pay US\$0.44 more if the vaccine will result in an additional dollar premium price. They are also willing to pay US\$4 if the vaccine comes with a viability detector. This indicates a

“lemons market” for veterinary drugs in Uganda: a lemons market occurs when consumers who cannot observe the quality of a specific item but believe that a fraction of products in the market are low quality (or counterfeit) will have lower willingness to pay for the product, thereby depressing prices. A similar issue has been well described for pesticides in Uganda. A World Bank study found that one third of pesticides were sub-standard and that farmers believed 40% of pesticides were sub-standard and this substantially reduced their WTP for pesticides (Ashour et al., 2017)

The farmers have a high preference for a vaccine that is only administered once to achieve porcine cysticercosis immunity, being willing to pay US\$1.67 more. Additionally, they prefer a vaccine that is associated with low administration costs, which has implications for communal vaccination initiatives and other efforts aimed to reduce transaction costs.

Table 7: Trait implicit prices (willingness to pay values) in US\$ and UGX

Trait	US\$	UGX	Standard error	Z
Vaccine administration cost	3.7754*	13,591.4	1.9869	-1.90
Price premium	0.4431**	1,595.2	0.2085	2.12
Low vaccination frequency (once at 2 months)	1.6651*	5,994.4	0.9287	1.79
Medium vaccination frequency (twice)	0.9723	3,500.3	0.7198	-1.35
Weight gain	0.1217	438.1	0.4323	0.28
Vaccine viability detector	4.0111**	14,439.9	1.8571	2.16
Wald Statistic=4.78289 Prob. from Chi-squared [6]=0.5576 Functions are computed at means of variables. ***, **, and * denote significant variables at 1%, 5%, and 10%, respectively				

The farmers’ willingness to pay (WTP) for combined features of the PC vaccine traits has been estimated using the compensating surplus model. The compensating surplus shows the change in income that would make a respondent indifferent between the base-case (current attributes of the PC vaccine) and subsequent alternative scenarios with specified combination of the vaccine traits. The compensating surplus (CS) model, is calculated as:

$$CS = -\frac{1}{\beta_{cost}}(V_0 - V_n)$$

Where β_{cost} is the coefficient associated with the cost of the vaccine, V_0 is the expected utility from the base case attributes of the vaccine, and V_n is the utility of an alternative vaccine scenario. Table 8 presents the farmers WTP for two PC vaccine scenarios containing an improved combination of the vaccine attributes. The WTP estimate of the base scenario of the vaccine (current existing attributes), until the pig attains immunity is US\$2.61, though only 19% of the surveyed farmers selected that vaccine combination. The improved traits of the vaccine results in higher farmer WTP. For instance, scenario 1 of the attributes (lower administration cost and a 50% price premium) was selected by 37% of the farmers and result in a WTP of US\$12.84. The WTP for scenario 2 (50% price premium, vaccine viability detector and a 10% increase in pig live-weight) is US\$16.94 selected by 49% of the farmers. The results show that under baseline scenario – which mimics current vaccine attributes, only few farmers would be WTP for the vaccine. Farmers are interested to pay for the vaccine if they are assured of a price premium and have confidence in the quality of the vaccine (through a viability detector).

Table 8: Estimates of respondents' willingness to pay (WTP) for combined attributes associated with TSOL18 - oxfendazole porcine cysticercosis vaccine (three scenarios)

Attribute	WTP in Uganda Shillings (UGX)	WTP in US Dollars (US\$)	% of farmers choosing the vaccine option (n=294 farmers)
<u>Base scenario</u> ADMIN COST PER PIG – UGX6000 PRICE PREMIUM – 15% of market price VACCINATION FREQUENCY – twice WEIGHT GAIN – 5% VIABILITY DETECTOR - none	9,396	2.61	19.73
<u>Scenario 1</u> ADMIN COST PER PIG – UGX2500 PRICE PREMIUM – 50% of market price VACCINATION FREQUENCY – once WEIGHT GAIN – 5% VIABILITY DETECTOR - none	46,224	12.84	37.41
<u>Scenario 2</u> ADMIN COST PER PIG – UGX6000 PRICE PREMIUM – 50% of market price VACCINATION FREQUENCY –once WEIGHT GAIN – 10% VIABILITY DETECTOR - yes	60,984	16.94	48.98

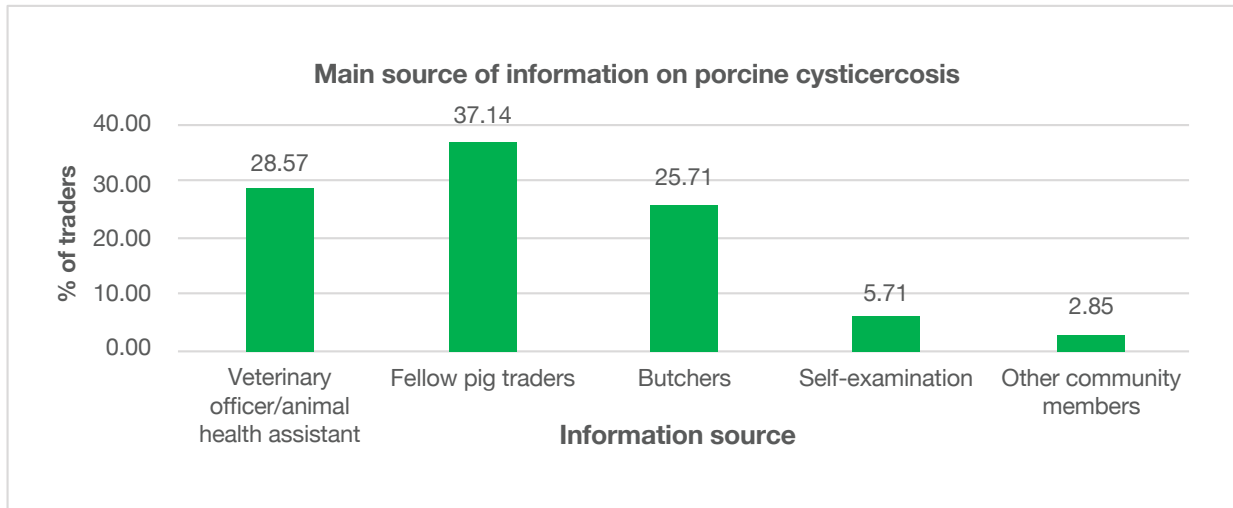
8.2 Traders' willingness to pay for porcine cysticercosis-vaccinated pigs

8.2.1 Socio-demographic characteristics of the traders and porcine cysticercosis awareness

The average age of the traders interviewed was 36, and 85% reported having primary-level education. The traders sold an average of six to 10 pigs per month between May and October 2017. Most of the interviewed traders (94%) said they had heard of porcine cysticercosis. Their main source of information on porcine cysticercosis was fellow traders and veterinary officers and animal health assistants (figure 10).

Summary of findings
Traders are aware of porcine cysticercosis; 94% of traders interviewed had heard of it.
Most of the traders (94%) said they reject (i.e., do not purchase) pigs suffering from porcine cysticercosis. In some cases, they offer lower prices for these pigs.
The traders are concerned about consumers' health, and 96% condemned infected pigs/pork.
Pigs' weight gain was traders' most preferred attribute.

Figure 10: Traders' main source of information on porcine cysticercosis



Eighty per cent of the surveyed pig traders said they had come across porcine cysticercosis-infected pigs. They recognised the disease by lingual palpation (below the tongue) and observing poor quality pork from slaughtered pigs (table 9). Most of the traders (94%) said they reject (i.e., do not purchase) pigs suffering from porcine cysticercosis; in some case, traders offer lower prices for these pigs.

Table 9: How traders recognised porcine cysticercosis

Identification method	Traders
Performed lingual palpation (below tongue)	15 (40%)
Poor quality pork from slaughtered pigs	10 (27%)
Worms below the ears	1 (3%)
Hair on back of animals falling off	1 (3%)

8.2.2 Traders' perceptions and preferences related to porcine cysticercosis

The traders reported being concerned about consumers' health, with 96% condemning infected pigs/pork (table 10). They reported believing that the vaccine and dewormer are the most effective means of controlling the disease. Eighty-one per cent, however, believe that controlling porcine cysticercosis is the government's role and it should therefore subsidise the cost of the vaccine.

Table 10: Traders' perceptions about porcine cysticercosis and the TSOL18 vaccine/oxfendazole combination

Statement	Level of agreement				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
A. I believe it is important to protect my consumers' health by ensuring that I sell porcine cysticercosis-free pigs/pork.	3 (9.1%)	0 (0%)	0 (0%)	10 (30.0%)	20 (60.6%)
B. I condemn pork/pigs infected with porcine cysticercosis.	1 (3.0%)	0 (0%)	0 (0%)	8 (24.2%)	24 (72.7%)
C. The market system should encourage farmers to vaccinate their pigs against porcine cysticercosis by giving premium prices.	1 (3.0%)	0 (0%)	2 (6.1%)	23 (69.7%)	7 (21.2%)
D. From the information and discussions we had today, I believe the porcine cysticercosis vaccine + dewormer is the most effective option for controlling porcine cysticercosis.	0 (0%)	0 (0%)	2 (6.1%)	17 (51.5%)	14 (42.4%)
E. I feel that control of porcine cysticercosis is the role of the government and it should therefore subsidise the cost of the vaccine.	1 (3.0%)	4 (12.1%)	1 (3.0%)	13 (39.4%)	14 (42.4%)
F. Public health is the role of the government, not the pig traders.	9 (27.3%)	1 (3.0%)	0 (0%)	11 (33.3%)	12 (36.4%)
G. I don't care about porcine cysticercosis-infected pigs because I don't consume them. The consumer is the one to care.	22 (66.7%)	11 (33.3%)	0 (0%)	0 (0%)	0 (0%)

Table 11 presents the maximum likelihood estimates of the conditional logit model. The constant parameter representing the 'no-buy' option is positive and statistically significant at 10%. The 'no buy' choice alternative is the base for the choice model and is associated with 'zero utility'. Traders selected at least 4.9% of the 'no-buy' choice options. The coefficient on weight gain was positive and significant at 5%, indicating preference for the increased pig live-weight gain attribute. Most of the variables are not statistically significant and should be interpreted with caution due to the low sample size.

Table 11: Conditional logit maximum likelihood estimates from choice experiment for the porcine cysticercosis vaccine

Variable	Coefficient	Standard error	Z
Constant	0.9727*	0.5265	1.8475
Pig purchase price in US\$	0.0062	0.0075	0.8332
Top-up price premium in US\$	0.0190	0.0214	0.8909
Weight gain	0.0948**	0.0392	2.4186
Private sector vaccine certification	0.0214	0.1162	0.1844
Pig tagging as vaccination proof	0.0609	0.1154	0.5276
Vaccination proof based on farmers' word	-0.0978	0.1217	-0.8038
Log likelihood function=-322.842 Number of observations=264 ** and *denotes significant variables at 1% and 5% levels, respectively			

8.3 Consumer perceptions on porcine cysticercosis-free pork

8.3.1 Demographic characteristics of respondents

Across the two divisions in Kampala where the study took place, the participants were from diverse ethnic groups with different cultural values, norms, and experiences relating to pork consumption.

8.3.2 Safe pork consumption

Consumers across the two divisions reported that the most important factors to consider for ensuring that consumed pork is safe relate to environmental factors associated with the pork joint, as well as pork-quality attributes. These included the hygiene of the pork joint, the person handling the pork, the plates, and the kitchen where pork is prepared. Hygiene was considered by the participants to be the most important attribute because poor hygiene could lead to illnesses like diarrhoea, cholera, and tapeworm. Participants in the focus group discussions noted (parentheses indicate discussion location and date):

“My life is my priority, thus I have to eat from a clean environment in order not to contract diseases” (Nakawa, 7 November 2017).

“Hygiene is important because I can avoid health-related problems associated with contaminated pork” (Makindye, 5 November 2017).

“Cleanliness of the place is vital because eating from a dirty environment can be very expensive because after eating, you have to go for treatment. Hence, it is better to eat from a place which cannot cause harm to one’s health” (Nakawa, 6 November 2017).

Additionally, participants mentioned the quality of pork as an important attribute influencing their decision to purchase and/or consume pork from specific retail outlets. According to the respondents, important aspects of pork quality they look for are leanness and fat content, freshness demonstrated through colour, and cooking method. Participants in the focus group discussions noted (parentheses indicate discussion location and date):

“Well-cooked pork doesn’t contain diseases because all the liquid is dried out” (Nakawa, 6 November 2017).

“Pork takes a very short period to go bad. That is why I want the fresh pork, which is free from contamination” (Nakawa, 7 November 2017).

“I like lean pork because the fats may cause illnesses in my body that I don’t know” (Makindye, 5 November 2017).

8.3.3 Gendered knowledge related to *T. solium* cysticercosis

Generally, both male and female focus group discussion participants had some knowledge of *T. solium* cysticercosis and were able to describe the signs of infection and how it is transmitted; two men and one woman (of 48 total participants) had never heard of it. Although almost all respondents knew about tapeworms in humans, none knew about cysts in pork. Additionally, some of the information participants provided about tapeworms was inaccurate. Focus group discussion participants noted (parentheses indicate discussion location and date):

“Tapeworm is got through eating leftovers/food that have stayed overnight, and sign I know is swollen stomach, especially in children” (Nakawa, 6 November 2017).

“When one eats raw/half-cooked food like potatoes, cabbages, and cassava, one can get tapeworms, and one of the signs is severe headache, diarrhoea and loss of appetite” (Makindye, 5 November 2017).

“One can get tapeworm through eating meat from animals which have not been dewormed. This can cause body weight loss, vomiting, and anaemia” (Makindye, 10 November 2017).

“Tapeworm is transmitted through eating raw food which the enzymes cannot digest. The signs include very high appetite, itchy behind, constipation, and crumps (stomach makes noise like ‘kukukuku...’)” (Nakawa, 7 November 2017).

Most of the women (in contrast to the men) reported that had actually seen tapeworms, especially in children’s faeces, and two women actually noted that they were once victims of tapeworm.

Summary of findings

- Consumer focus group discussion participants considered hygiene to be the most important factor in ensuring pork is safe because poor hygiene could lead to illness like diarrhoea, cholera, and tapeworm.
- Participants noted pork’s leanness and fat content, freshness demonstrated through colour, and cooking method as pork quality attributes they look for.
- Although almost all participants had knowledge on tapeworms in humans, none knew about cysts in pork. Some information they provided on tapeworms was inaccurate.
- The most significant source of information on tapeworms amongst participants was the home/parents and particularly mothers.
- Female participants reported being more observant in terms of taking relevant safety measures in terms of food.
- Although participants were trained about the dangers of eating pork with cysts, most said they cannot throw away what they have already bought and would rather cook the pork thoroughly to kill the cysts. Both male and female participants in both divisions noted willingness to pay more for pork certified to be porcine cysticercosis-free as long as their safety is guaranteed.

8.3.4 Participants’ information sources on tapeworm

Participants noted a variety of channels as their information sources on tapeworm, with the most significant source given being the home/parents and particularly mothers; other sources included schools, hospitals, seminars, and village health teams. There was no significant difference between male and female respondents. Focus group discussion participants noted (parentheses indicate discussion location and date):

“My mother was a traditional herbalist, so I learnt from her because she used to treat children in our village who had tapeworm” (Nakawa, 6 November 2017).

“My siblings suffered from tapeworms, and when my mother took them to the hospital, the nurses told her it was tapeworms. Then she came back, she informed us about tapeworms and its effects” (Nakawa, 7 November 2017).

8.3.5 Pork cysts

The consumer focus group participants were asked if they had ever seen cystic pork. Six of the 25 men (24%) had seen pork with cysts either in Kampala or in their home districts; ten of the 25 women (40%) had seen cysts in various pork retail outlets. Participants attributed the gender difference to men being less vigilant: Most men order pork by calling the pork joint owners, and by the time they get to the joint, the pork is ready for consumption; female consumers, on the other hand, buy fresh pork to prepare at home and are therefore able to inspect pork

before purchase. Despite the fact that both male and female consumers have observed cysts in the pork, their assumption was that the pork was just fatty. Focus group discussions participants noted (parentheses indicate discussion location and date):

“I saw pork with cysts in my village, but we had to bury it. It is a tradition in my family that our father slaughters for us a pig every 23rd December, but last year the pig which was slaughtered had cysts and my father had to bury it and slaughtered another one” (Makindye, 5 November 2017).

“I saw pork with cysts here in Kampala at one joint” (Nakawa, 7 November 2017).

After the sensitisation sessions on pork tapeworm, all focus group discussion participants indicated that when cystic pork is bought on their behalf, the pork would be returned to the seller. Participants generally indicated they would not buy cystic pork at the butcher, although some said they might purchase the cystic pork and request the pork handler ensure it is well prepared (dried). Although consumers were trained about the dangers of eating pork with cysts, most consumers noted that they cannot throw away what they have already bought but would rather cook the pork thoroughly in order to kill the cysts. Focus group discussion participants noted (parentheses indicate discussion location and date):

“We roast the pork very well until when it is fully roasted and just cook it in groundnuts, and we eat” (Makindye, 5 November 2017).

“In case we have sent someone else to pick for us, we take back the pork to the butcher, educate him about the dangers of consuming pork with cysts and also teach the consumers whom we will find in the butcher and urge them not to buy such pork again because it is not healthy” (Nakawa, 6 November 2017).

“When we see such pork, we advise the butcher person the effects of the tapeworm, and we also advise him not to sell, and if he refuses, we call the public veterinarian (Nakawa, 7 November 2017).

“When we see it on the butchery, we just call the concerned health people like the veterinary officer or Local Council administrators (LCs) at any level, and the owner should tell the community where he got the sick pork which was not inspected” (Nakawa, 6 November 2017).

8.3.6 Willingness to pay premium prices for pork certified as porcine cysticercosis-free

Men and women in both divisions indicated they were willing to pay more for pork certified as porcine cysticercosis-free as long as their safety is guaranteed. However, they noted that they have no control for food safety regulations and that in case food standard regulations are put in place, they would rather reduce the quantity of pork consumed and focus on quality. They noted (parentheses indicate discussion location and date):

“Life is important, and when lost, one can’t regain it. Thus, safety first” (Nakawa, 7 November 2017).

“Because we are concerned about our health, we would rather pay for expensive pork which is safe for our lives than eating the unsafe pork” (Makindye, 5 November 2017).

“I will buy and continue to eat pork irrespective of the price as long as the pork is safe for consumption” (Nakawa, 6 November 2017).

Although most consumers indicated their willingness to pay premium prices for pork certified as porcine cysticercosis-free, one consumer said if price increased, he would stop eating pork because it would be too expensive for him.

8.3.6.1 Preferred choice for different pork qualities

The focus groups were presented with photos of four categories of pork based on quality and price per kilogram, with prices based on prevailing quality-based market prices:



Choice A: UGX13,000 (US\$3.61)/kg (somewhat lean pork)



Choice C: UGX15,000 (US\$4.17)/kg (lean pork)



Choice B: UGX6,000(US\$1.67)/kg (leftover parts of pork and pig parts sold after slaughter)



Choice D: UGX10,000 (US\$2.70)/kg (fatty pork)

Each participant was asked to select their preferred type. Figure 11 shows that 58% of the consumers preferred choice C, the leanest and most expensive at UGX15,000 (US\$4.17) per kilogram, followed by 32% preferring choice A, which was the second-best quality and priced at UGX13,000 (US\$3.61) per kilogram. Choice B – leftover parts of pork and pig parts sold after slaughter priced at UGX6,000 (US\$1.67) per kilogram – was selected by 8% of participants, and 2% selected Choice D, fatty pork priced at UGX10,000 per kilogram.

The findings show that consumers' preference is tagged to quality of pork, although this may not necessarily translate to actual purchases due to budget constraints. They were also probably using price as a proxy for pork quality.

Figure 11: Preferred choice for pork consumers in the focus groups

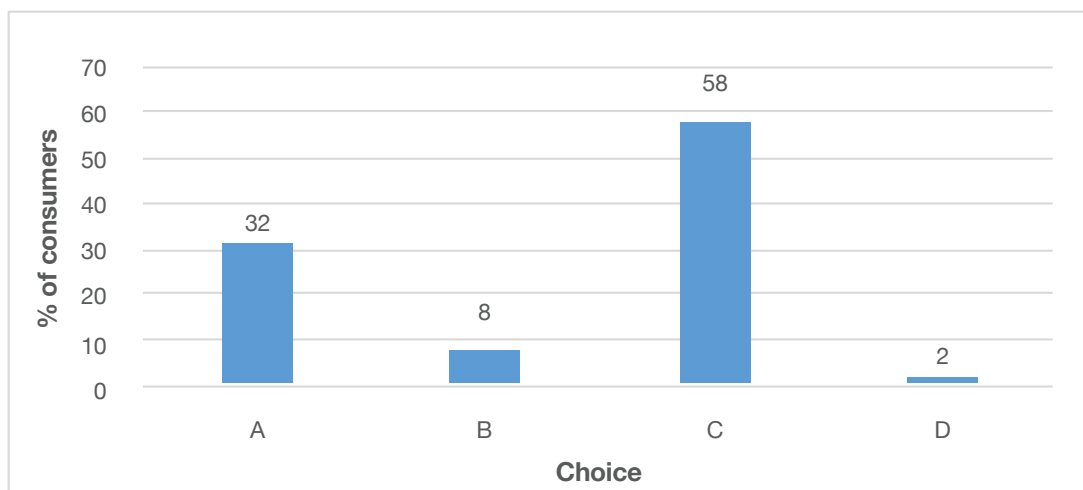
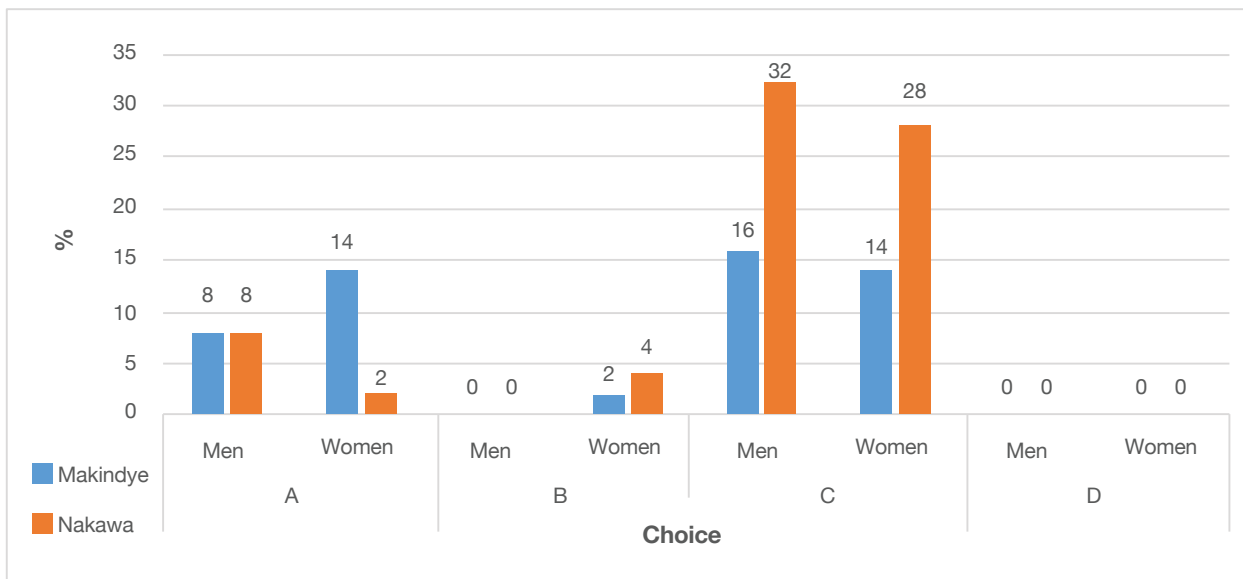


Figure 12 presents preferences for the pork quality choices based on gender. Both men and women in Nakawa division mostly preferred choice set C (32% and 28%, respectively) compared to Makindye (16% and 14%, respectively).

Figure 12: Preferred choice of pork by sex and division



About 32% selected choice C for pork type because it was perceived to be of good quality, not fatty and safe from diseases or infections; this was similar in all the focus group discussions and across gender and division. However, 14% of women in Makindye chose choice A because they considered the price of pork as favourable compared with 2% of the women in Nakawa; choice A was a mixture of bones and meat, and the participants indicated that ‘the nearer the bone, the sweeter the money’.

8.4 Consumers’ preference for safe food from animal sources

8.4.1 Socio-demographics

Participants’ mean age was 51 (table 12). Most of the respondents (43%) had attained secondary school-level education (‘O’ level), while 17% and 19% had university- and tertiary-level training, respectively (figure 13). Forty-two per cent of the consumers reported a total monthly household income above UGX400,000 (US\$111), while 30% have an income of less than UGX200,000 (US\$55.50) (figure 14).

Summary of findings	
•	Although consumers may be aware of safe foods, their preferences as depicted by actual purchases are driven by other factors (such as personal preferences versus food safety), and they may have a different perception of what is considered ‘safe food’.
•	Most of the consumer participants (85%) strongly agreed that it is important to protect their family’s health by ensuring they purchase safe food from animal sources.

Table 12: Mean age of the respondents

	Observations	Mean	Standard deviation	Minimum	Maximum
Age	47	50.6	14.4	23	83

Figure 13: Highest attained education level reported by respondents

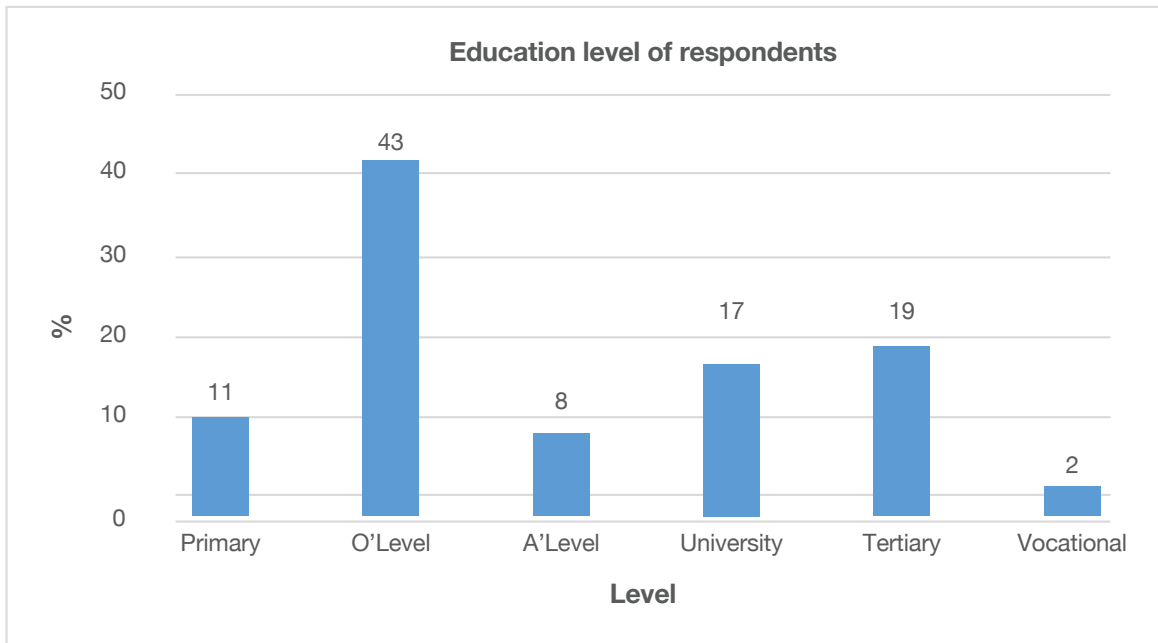
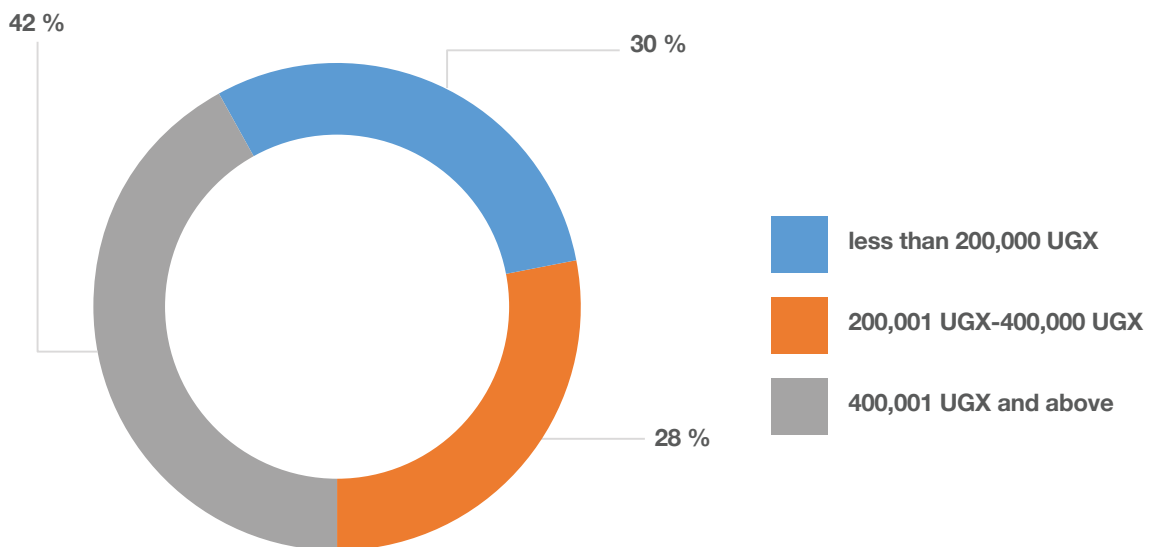


Figure 14: Average monthly household income reported by the respondents



8.4.2 Results of simulated egg market

Regular eggs were the most preferred and purchased eggs by the consumers, with participants purchasing an average of three regular eggs (table 13). The preference for regular eggs was attributed to the yellow yolk and belief that it is more nutritious relative to other egg types. Each consumer purchased on average one each of the other egg types. Fifty-four per cent of the eggs purchased were regular eggs (table 14). The 'safest' egg (free from antimicrobial residue and Newcastle disease) amounted to 24% of the purchased eggs. The pattern was not any different to any degree of statistical significance across gender (table 15).

Table 13: Type of eggs purchased by respondents

Egg type	Number	Mean	Standard deviation	Minimum	Maximum
Regular eggs	47	3.0	2.6	0	8
Antimicrobial residue-free eggs	47	0.6	0.9	0	4
Eggs from Newcastle disease-vaccinated hens	47	0.5	1.3	0	5
Eggs free from antimicrobial residue and Newcastle disease	47	1.2	1.6	0	4

Table 14: Total numbers of eggs purchased by respondents

Egg type	Total number purchased
Regular eggs	128 (54.2%)
Antimicrobial residue-free eggs	29 (12.3%)
Eggs from Newcastle disease-vaccinated hens	23 (9.7%)
Eggs free from antimicrobial residue and Newcastle disease	56 (23.7%)
Total	236

Table 15: Type of eggs respondents purchased by gender

Egg type	Men	Women
Regular eggs	60 (50.4%)	68 (58.1%)
Antimicrobial residue-free eggs	11 (9.2%)	18 (15.4%)
Eggs from Newcastle disease-vaccinated hens	16 (13.4%)	7 (6.0%)
Eggs free from antimicrobial residue and Newcastle disease	32 (26.9%)	24 (20.5%)
Total	119 (100.0%)	117 (100.0%)

The results show that although consumers may be aware of safe foods, their preferences as demonstrated by actual purchases is driven by other factors (such as personal preferences) rather than food safety. Consumers' regular purchasing habits could also play a role – they may be used to purchasing regular eggs and may have never experienced any food safety challenges. The percentage of purchased eggs free from antimicrobial residue and Newcastle disease is relatively high compared to only antimicrobial residue-free or only Newcastle disease-free, showing interest in purchasing safe products even when the price is high. Additionally, most of the consumers also expressed concern about lack of labelling and adequate information regarding food safety in market outlets to guide purchases.

8.4.3 Perceptions about safe products from animal sources

Most of the consumers (85%) strongly agreed that it is important to protect their family's health by ensuring they purchase safe foods from animal sources (table 16). About half (49%) of the consumers were concerned about unsafe foods from animal sources in the markets, and an equal number felt safe foods from animal sources do exist in the market but are too expensive for them. Thirty-two per cent strongly disagreed that even if animal source foods are well cooked there is no risk associated with their consumption; this could be attributed to the fact that consumers learned prior to egg selection that some antimicrobial residues cannot be destroyed even with cooking.

Table 16: Consumers' perceptions about safe animal-source products

Level of agreement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I believe it is important to protect my family's health by ensuring that I buy safe animal-source foods.	0	0	0	7 (15%)	40 (85%)
I am concerned about unsafe animal-source foods supply in our market.	1 (2%)	4 (9%)	1 (2%)	18 (38%)	23 (49%)
I feel that safe animal-source foods are normally too expensive.	3 (6%)	8 (17%)	2 (4%)	11 (23%)	23 (49%)
I believe that if the animal-source foods are well cooked, there is no risk associated with its consumption.	15 (32%)	7 (15%)	4 (9)	12 (25%)	9 (19%)

8.5 Therapeutic products profiling

8.5.1 Dewormers sold to pig farmers

In this study, the participant drug stockists listed 21 brands of dewormers sold to pig farmers and pig health service providers (table 17). None of the drugs mentioned as currently sold contain oxfendazole. Only albendazole was mentioned as a drug that could treat tapeworms. However, when the interviewer visually inspected drug shop shelves in Masaka, Erafen 5 (with fenbendazole as its active ingredient) was found. Praziquantal is available in Uganda, but was not found in this survey; it has been used to treat pig tapeworm in combination with albendazole.

Summary of findings
<ul style="list-style-type: none"> • There appears to be substantial demand for livestock dewormers in Uganda. • The market for dewormers is relatively crowded; there are 21 brands of dewormers. Active ingredients include ivermectin, levamisole, piperazine, albendazole and fenbendazole. • Animal health service providers preferred ivermectin, while farmers preferred levamisole and albendazole. • Most other drugs are cheaper per dose than Paranthic 10% (active ingredient oxfendazole), which is an important consideration for farmers. • Albendazole and Erafen 5 (active ingredient fenbendazole) were mentioned as potential competitors for oxfendazole. However, fenbendazole has side effects and treatment requires multiple doses, which may limit its widespread use. • Participants ranked farmers as the most important market segment for dewormers, followed by animal health service providers. Most farmers (68 to 80%) deworm their pigs an average two times per year. • The market appears to be quite price-sensitive, with the most sales for the cheapest drugs. • The promotion mechanisms that are most used by the distributors are door-to-door marketing and advertising through radio, newspapers, and television. • For the TSOL18 vaccine-oxfendazole combination to be competitive (viewed simply as a dewormer), it should be priced between US\$1.62 and US\$6.11.

Table 17: Active drug ingredients and number of brands given by drug stockists

Active ingredient	Number of brands
Ivermectin	10
Levamisole	7
Piperazine	2
Albendazole	2

Competitors to oxfendazole fall into two categories: drugs that can be used to treat pig tapeworm and drugs that treat parasites in pigs. For treating pig tapeworm, oxfendazole is considered the most attractive (and possibly only effective) drug. It is effective in a single-dose scheme, superior to praziquantel and albendazole, and leaves pork with a clean, marketable carcass (Lightowlers, 2013). Fenbendazole is also reported to be effective (Mkupasi et al., 2013); it significantly decreases the number of cysts, although it has side effects and requires multiple doses (Mkupasi et al., 2013). According to the stockists, there is currently no demand for a product that treats pig tapeworms; instead, farmers and animal health workers want products that treat pig parasites. This is partly because there are currently no well-suited products for this, but also because there is no general awareness of the problem.

Additionally, when examining drug competition, it is important to look at all drugs that treat pig parasites. Table 18 provides information on competing brands that also treat tapeworm, including Paranthic 10% (active ingredient oxfendazole). Table 19 discusses competing brands that treat parasites in pigs. The tables help provide information and context relevant to marketing oxfendazole:

- Most other drugs are cheaper per dose than Paranthic 10%, which is an important consideration for farmers.
- Ivermectin will also treat mange, a visible and common problem, which is a unique selling point and important advantage
- Erafen 5 packaging has a picture of a pig. However, a picture could easily be added to Paranthic 10% or a brochure provided with a picture of a pig; a picture is not a unique selling point.
- Many drugs don't list the dosage for pigs on the label. This is a limitation for the animal health specialist market segment. However, it is very easy for this information to be added (if the drug is licenced for use in pigs), so this is not the basis for a permanent market issue.
- The oxfendazole market could be an important criterion in the future, as farmers in East Africa have a strong preference for 'tried-and-true' brands.
- Means of administration is also an important factor. Paranthic 10% is a drench, as are levamisole and albendazole. Ivermectin is injectable. Farmers may prefer drenches because they are unfamiliar with injections. For animal health workers, injections are often easier.

Table 18: Competing brands that also treat tapeworm (assuming demand exists)

Brand name	Active ingredient	Animals on pictured on packaging	Animals treated	Dosage for pigs listed on label	Contra-indications	Years on market in Uganda	Price for treating a 10kg pig (US\$)
Albafas	Albendazole	Shoats, cattle	Shoats, cattle	Not indicated (30mg/kg body weight (BW) for three days)*	Don't treat pregnant animals in their first 3 months	3-5	0.28
Dabendazole	Albendazole	Shoats, cattle	Shoats, cattle	Not indicated (30mg/kg BW for three days)*	Don't treat animals in first trimester	5	0.24
Albendazole	Albendazole	Shoats, cattle	Shoats, cattle	Not indicated (30mg/kg BW for three days)*	Not indicated	>15	
Erafen 5**	Fenbendazole	Shoats, cattle, pigs, poultry	Shoats, cattle, pigs, poultry	Not indicated (9mg/kg BW for seven days)*	Not indicated	0.3	0.077/dose
Paranthic 10%***	Oxfendazole	None	Cattle, swine	30 mg/kg BW single dose	Don't use with animals of known hypersensitivity	0	0.16

*Obtained from literature (Gonzalez et al., 1995)

**For comparison purposes

***Competing product

Table 19: Competing brands that treat parasites in pigs

Brand name	Active ingredient	Animals on pictured on packaging	Animals treated	Dosage for pigs listed on label	Contra-indications	Years on market in Uganda	Price for treating a 10kg pig (US\$)
Kelamectin	Ivermectin	Cattle	Cattle, shoats, pigs	1ml/33kg body weight (BW)	Only given subcutaneously	20	0.02
Wormcid 150mg	Levamisole	Cattle, pigs, shoats	Cattle, pigs, shoats	1 tablet/up to 20kg pig (single dose)	Oral	>20	0.05
Ascazin	Piperazine citrate	Poultry	Poultry, shoats, dogs, cats, cattle	Not indicated (5g mixed into feed for all animals)	Oral	10-15	0.17
Paranthic 10%***	Oxfendazole	None	Cattle, swine	30 mg/kg BW	Don't use with animals of known hypersensitivity	0	0.16

**For comparison purposes

***Competing product

Pricing deserves special attention because poor farmers are highly cost sensitive. Cost per deworming for a 10-kilogram pig is higher for Paranthic 10% compared with Erafen 5 – and, unlike the other drugs, this does not include mark-up. Table 20 provides details on mark-ups for the different drugs as reported by the drug stockists. Albendazoles might seem more expensive, but they are not indicated for treatment of porcine cysticercosis. For competitor drugs, a 35% mark-up was added on top of the drug’s price when sold to stockists by the distributors. Piperazines had the lowest mark-up, while levamisoles had the least mark-up added. Most of the drug distributors give price sheets to the drug stockists. For Paranthic 10%, a mark-up of 28% would be feasible since it’s a drench as an albendazole. The high standard deviations reported are due to large differences between purchase and sale price for some of the products. For example, 100 tablet Wormcid packet (levamisole) had a distribution price of UGX9250 but could be sold to as high as UGX25000 to the farmers.

Table 20: Mark-ups for the different drugs as reported by the stockists (%)

Generic names	Masaka		Bukedea		Total	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Ivermectin	36.1	136.7	32.1	48.4	34.8	115.0
Levamisoles	54.8	137.2	15.9	64.2	39.3	115.0
Piperazines	19.6	8.1	37.5	0.0	22.2	10.1
Albendazoles	28.0	29.8	33.4	10.9	30.5	22.4

8.5.2 Customers for dewormers (market segments)

The two major customers for dewormers are farmers and animal health service providers, which includes veterinarians and para-veterinarians. Some stockists also sell drugs to other stockists and organisations. Most customers are farmers (56% in Masaka and 83% in Bukedea) (figure 15); however, other actors may buy in larger quantities. There are more animal health service providers that are operating in Masaka than Bukedea, and these professionals are better informed and can be critical to a new product’s successful market penetration. The drug stockists were asked to rank customers by order of importance, and farmers were ranked as the most important customers followed by animal health service providers (figure 16). This was because farmers comprise the largest number of their customers and pay higher prices than animal health service providers, who are better informed and tend to bargain. Organisations such as the National Agricultural Advisory Services and some local non-governmental organisations were ranked third because they are seasonal customers.

Figure 15: Drug stockists' customers for dewormers in Masaka and Bukedea

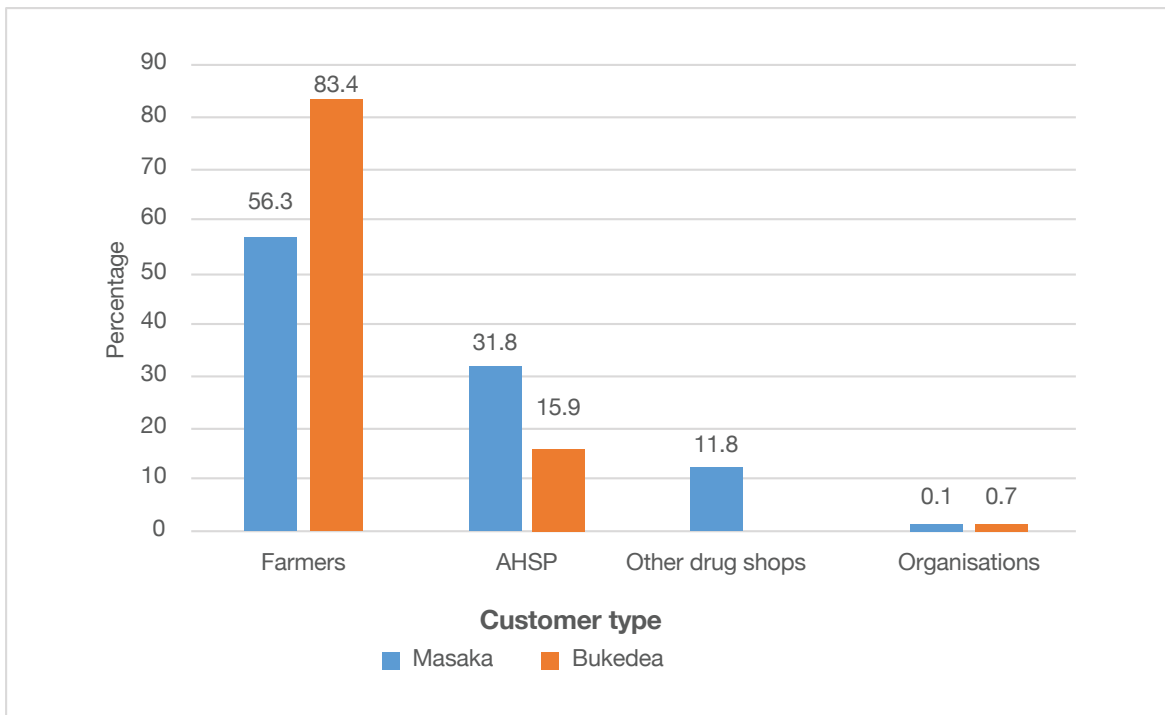


Figure 16: Rankings of customer importance by the drug stockists

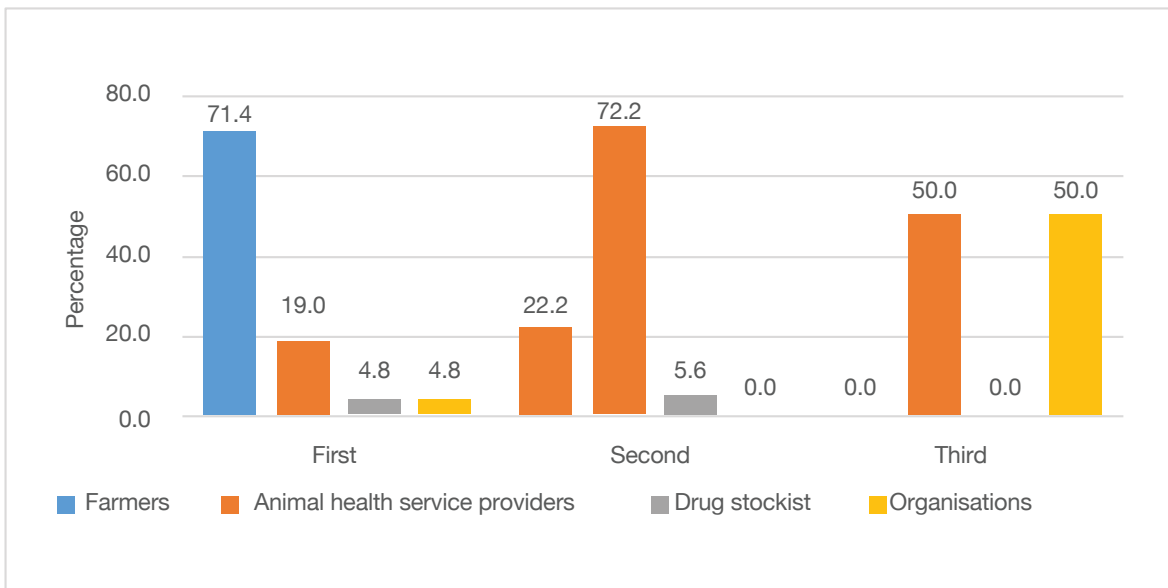
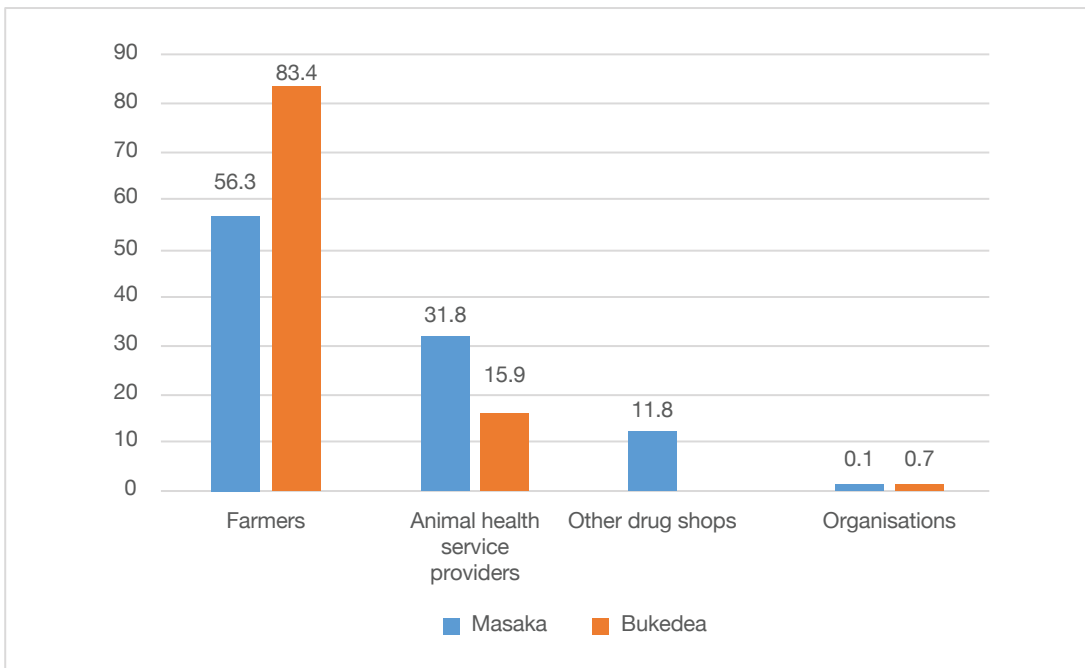


Figure 17: Drug stockists' customers for dewormers in Masaka and Bukedea



Other studies suggest that albendazole is the most popular treatment (used by 90% of farmers), followed by levamisole and ivermectin (Doble, 2007). However, albendazole's adverse effects after treatment of porcine cysticercosis include prostration, anorexia, lethargy, and death after a single dose of 50mg/kg, and lethargy and anorexia after three consecutive doses of 30 mg/kg (Mkupasi et al., 2013). This makes it not recommended for the treatment of porcine cysticercosis in pigs by most manufacturers.

The drug stockists were asked to estimate the percentage of farmers that deworm in their districts and the number of times they deworm. They indicated that an average of 68% of farmers who own pigs deworm their pigs about six times a year with a range of one to 12 times and most farmers deworming twice a year. Little difference existed between the districts in terms of the number of times dewormed and the percentage of farmers that deworm. The drugs stockists indicated that in Bukedea, peak sales occur during the rainy season and low sales occur in the dry season. In Masaka, 55% indicated that there were no peak and low seasons, while the others indicated the same trend as in Bukedea. The reason for the high sales in the rainy season was that the pigs are prone to becoming infected with worms then. However, even the 32% of druggists that don't deworm present an opportunity for the TSOL18 vaccine-oxfendazole combination.

The estimated cost of deworming can be calculated using the number of times the farmers deworm pigs, along with the prices from table 17 and several assumptions:

- Farmers deworm an average of six times a year (two to three times a year being previously reported by the veterinarians).
- The cheapest dewormer that treats tapeworms on the market costs US\$0.077 per 10-kilogram pig (Erafen 5), and the most expensive dewormer costs US\$0.28 per 10-kilogram pig (Albafas).

These data and parameters indicate that deworming would cost a farmer between US\$1.62 (if the farmer deworms six times a year using Erafen 5) and US\$6.11 (if the farmer deworms six times a year using Albafas). The cost can go a bit higher since the pigs gain weight and the calculation is based on a 10-kilogram pig. To be competitive, the TSOL18-oxfendazole combination (viewed simply as a dewormer) should be within this price range. If demand could be created for other unique features (e.g., control of cysticercosis), there might be additional willingness to pay.

8.5.3 Promotion of new products

The drug stockists were asked about how they got to know about the new products on the market (table 21). Most drug stockists heard about new dewormers through radio, newspaper, or television advertisements (85%) and the distributors marketing the dewormers directly in their shops (75%). Mobile phone calls are an emerging communication pathway. This means that if the TSOL18-oxfendazole combination is to be promoted, it could use advertisements and promotion through distributors.

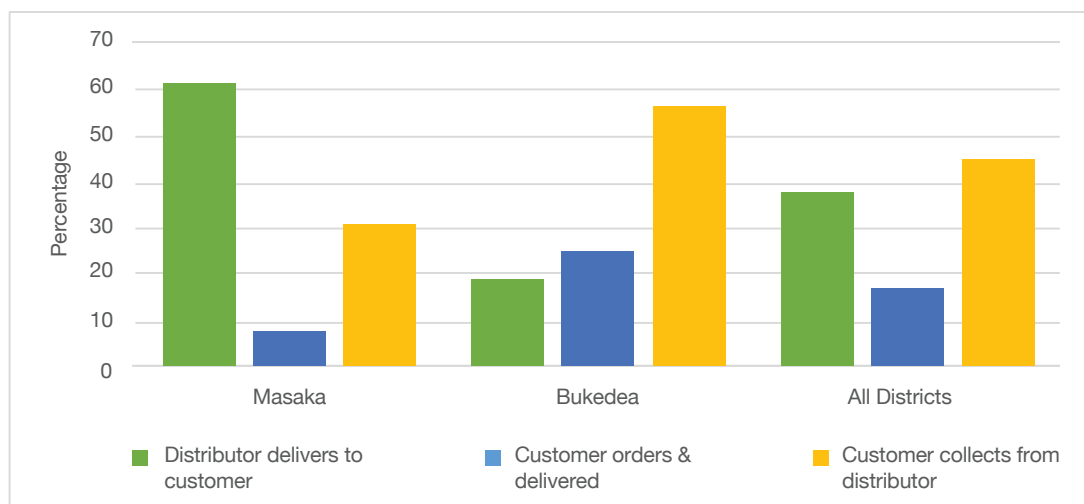
Table 21: Ways drug stockists learn about new products

Promotion mechanism	% of drug stockists that access	% of vaccine stockists that access
Advertisements (radio, newspapers, TV)	85	60
Distributors goes door to door marketing	75	40
Distributor makes phone calls	45	20
Distributor gives leaflets/catalogues, posters	35	60
Distributor conferences/seminars	15	50
Sales promotions	15	30
Internet	15	10
Other drug stockists	5	10
Becoming an agent	0	20

8.5.4 Distribution mechanisms for dewormers

The drug stockists were asked how they receive the drugs and vaccines from the distributors, shown in figure 18. The drug stockists had three options: having the distributor come to their shop on a scheduled date for that region; calling the distributor in case of stock outages and having the drug sent through any means of transport they choose (with the transport costs incurred by the stockist); and going to the distributor and collecting the drugs themselves. In Masaka, 61.5% of the drugs and vaccines were delivered by the distributors; 31% of the drug stockists collected them from the distributor. In Bukedea, these two options were chosen almost equally. For all the districts, 44.8% of the drug stockists reported that they collect the drugs from the distributor, 37.9% have the distributor deliver the drugs during their routine visits and the rest send their orders for delivery to the distributors. The pharmaceutical companies Norbrook and Eram have the most brands on the market and could be possible partners in distributing the oxfendazole dewormers.

Figure 18: Participants' reported distribution channels for drugs and vaccines



8.5.5 Distribution mechanisms for vaccines and challenges

Stockists were also asked about vaccine suppliers. Eight companies were mentioned (table 22), although they distribute mostly poultry vaccines. Eram, Norbrook, and Everictory were ranked as the most important distributors of vaccines because of reliability, quality assurance, and delivery to shops. The vaccine stockists in Bukedea mentioned as a supplier 'Container Village', an area in Kampala where drug and vaccine importers are found. In Masaka, drug stockists mentioned the government typically supplies vaccines for lumpy skin disease and foot and mouth disease (both for cattle); thus, if a drug inspector finds them in a druggist's stock, they have to provide an explanation. Other vaccines like Peste des Petits Ruminants (PPR) and those for dogs can only be ordered on client request. Generally, for poultry vaccines, the Newcastle disease vaccine is the most in-demand because most poultry farmers have either experienced related economic losses or seen/heard about the severity of the disease.

Stockists mentioned power shortages (80% of participants) and expensive equipment (40% of participants) as major challenges they faced. One drug stockist mentioned that the National Drug Authority has set up guidelines that require an inverter to stock vaccines in case of power shortages or a paraffin-run refrigerator.

Table 22: Companies that supply vaccines in Masaka and Bukedea districts

Name of supplier
Eram
Eagle Vet
Global Vet
Everictory
Norbrook
Last chance shop
'Container village'
Brentec Investment

8.6 Willingness of service providers to sell the TSOL18 vaccine and oxfendazole

8.6.1 Channels to access/buy the vaccines and drugs

The veterinarians and para-veterinarians who participated in the study reported accessing the drugs within their localities, especially in the district's major town. In Masaka, the veterinarians and para-veterinarians access the drugs from the municipality (especially in Katwe-Butego sub-county, where most drug stockists are located). There are few drug shops in the rural areas because of the annual charges (about UGX300,000, or US\$86) and strict rules imposed by the National Drug Authority:

- Floors, ceiling, and walls made of washable materials that don't flake off.
- Premises have a regular and sufficient supply of water.
- Minimum floor area of four square meters.
- Premises supervised by a person holding a bachelor's degree in veterinary medicine or an animal husbandry officer.

In rural areas, drugs are mostly delivered by the veterinarians working in those areas or farmers go to towns to buy drugs. However, the veterinarians said farmers mostly source drugs by themselves.

Of the municipality's drug shops, 44% stock vaccines together with other veterinary drugs. There is no single shop in town that stocks only vaccines. All shops stock mostly vaccines for poultry diseases (e.g., Newcastle disease, infectious bronchitis, and Marek's disease). The few vaccines stocked for other animals include the rabies vaccine

for cats and dogs and (in a few drug shops) lumpy skin disease vaccine in cattle. Some veterinarians (28% of the service providers) sourced some drugs from Kampala (about 130 kilometres from Masaka); the reason for travel was that drug stockists do not stock some brands needed by veterinarians.

Table 23 lists the actors in the drug market in Masaka and Bukedea. Masaka has an estimated nine veterinarians with a bachelor's degree in veterinary medicine; of these, seven are employed by the government, while the rest are in private practice. In Bukedea, there are three veterinarians with a bachelor's degree in veterinary medicine, all working with the district's local government.

Table 23: Actors in the drug market in Masaka and Bukedea districts

District	Actor	Approximate #	Interviewed
Masaka	Para-veterinarians	40-60	14 (28%)
	Veterinarians	9	0 (0%)
	Drug stockists*	14	11 (78%)
	Vaccine stockists	8	8 (100%)
Bukedea	Para-veterinarians	52	10 (19%)
	Veterinarians	3	2 (67%)
	Drug stockists	10	10 (100%)
	Vaccine stockists	2	2 (100%)

*Including vaccine stockists

8.6.2 Access to information for new products in the market

Access to information on new drugs was the same in both districts, with respondents indicating they receive information from:

- Distributors who usually organise seminars to train veterinarians on the use of the new drugs
- Radio and television advertisements
- Promotions by the distributors offering slightly lower prices
- Drug stockists putting posters and leaflets about the new drugs on shop doors
- Colleagues

Summary of the findings

- Generally, dewormers are more accessible than vaccines to the veterinarians in both Masaka and Bukedea districts.
- Vaccines are more accessible in Masaka versus Bukedea district. The vaccines that are more accessible are almost all for poultry; access to vaccines for other livestock is sporadic.
- The dewormers used by the veterinarians and pig farmers fall in the drug categories of ivermectins, levamisoles, albendazoles, and piperazine citrates. The veterinarians prefer ivermectins, specifically the brands Noromectin and Keramectin, while the farmers prefer levamisoles (preferred brand Wormcid)
- The price range for injectable dewormers was UGX7,000 to UGX20,000 (US\$2 to US\$5) per bottle (of either 50 millilitres or 100 millilitres). The range for oral dewormers was UGX200 to UGX6,000 (US\$0.05 to US\$2), with tablets being cheaper than the liquid drenches.
- More than 75% of farmers deworm their pigs two to three times a year. In both districts, the charge for deworming ranged from UGX2,000 to UGX5,000 (US\$0.60 to US\$ 1.50).
- Most veterinarians would not deworm pigs that are not in their area of operations because it would make deworming unaffordable for the farmers.
- One challenge in Bukedea was almost all vaccines being out of stock out except for the thermal stable Newcastle disease vaccine.
- The para-veterinarians in Masaka were not aware of porcine cysticercosis, while those in Bukedea were aware of the disease.
- In both districts, veterinarians would be willing to sell the TSOL18 vaccine only if the price is not more than UGX3,000 (US\$0.90), the vaccine efficacy is proven, the disease is publicised, and the benefits of vaccination are well articulated for the farmers.

8.6.3 Transportation of vaccines

In Masaka, veterinarians and para-veterinarians use several types of equipment when transporting vaccines depending on the distance of the farmer, number of animals, number of farmers, and errands the veterinarian needs to run before vaccinating. This equipment include iceboxes, floaters, flasks, and polythene bags (table 24); the vaccine stockist supplies the ice. This is the same equipment used in Bukedea district. In both districts, the veterinarians and para-veterinarians indicated that they use bags, polythene bags, and boxes for the drugs.

Table 24: Equipment used for vaccines

Equipment	Reason for choice
Ice box	Long distances to travel, many animals to vaccinate, few errands
Floaters	Received cases when one could not access an icebox and the distance is far
Flasks	Distance is short, few animals, veterinarians has just started practicing
Polythene bags	Distance is very short, no errands

8.6.4 Dewormer use by veterinary professionals and farmers

In Masaka, the veterinarians preferred to use ivermectin because it is easy to administer without significant retraining on pigs and because it can control both external and internal parasites with minimal dosage. It is also very effective against mange; farmers can easily see the effect of the treatment. Most veterinarians were guarded on the use of injectable levamisole, especially those recommended for subcutaneous administration. This is because if the drug were injected intramuscularly by mistake, the pig would die in a few minutes. Veterinarians and para-veterinarians do not use oral levamisole; they indicated farmers prefer these because they don't require technical expertise to administer.

In Bukedea, the veterinarians and para-veterinarians said drenches are cheaper in the field than ivermectin and farmers prefer oral drugs because administration is very simple. Most farmers don't know there are injectable dewormers and some would not believe their pigs had been dewormed if the veterinarians used injections. In both districts, the veterinarians and para-veterinarians said that the farmers who self-administer dewormers to their pigs prefer the levamisole brand Wormcid because it is easier to use and some farmers believe that it helps in fattening the pigs. The veterinarians and para-veterinarians preferred brands of ivermectins called Noromectin and Keramectin because they use a lower dosage for effectiveness and don't require follow-up; the other brands require going back after a week to administer another dose, making it expensive for farmers (Table 25).

Table 25: Pig dewormers used in Masaka and Bukedea districts

Drug groups	Brand names	Price in UGX (pack size)	Administrative method
Ivermectin	Ivermectin	20,000 (100ml)	Subcutaneous
	Closamectin	20,000 (50ml)	
	Noromectin	13,000-15,000 (100ml)	
	Tectin	8,000 (50ml)	
	Kelamectin	15,000 (100ml)	
	Vermectin	10,000 (50 ml)	
Levamisole	Levacide	7,000 (100ml)	Oral
	Levamisole injectable	7,000 (100ml)	
	Wormcid drench	3,000 (125ml)	
	Wormcid tablets	200 (tablet)	
	Vet worm drench	3,000 (125ml)	
	Vet worm tablet	200 (per tablet)	
Albendazole	Albendazole drench	4,500 (120ml)	Oral
	Albendazole tablets	500 (per tablet)	
Piperazine citrate	Ascarzine	6,000 (per pack of 100g)	Oral
	Ascalex	4,000 (per pack of 30g)	

8.6.4.1 Price, administration, and frequency of deworming

In Masaka, the veterinarians and para-veterinarians who participated in the study charged an average price for deworming a pig of about UGX3,000 (US\$0.90) per animal, including transport. If the farmer is very close to the area where the veterinarian operates, they are generally charged only UGX2,000 (US\$0.60) per pig. However, the cost can rise to UGX5,000 to 8,000 (US\$1.40 to \$2.30) if the distance is far. In Bukedea, the cost of deworming depends on the financial status of the farmer, type of dewormer, and distance from the farmer to the veterinarian. But on average the veterinarians and para-veterinarians in Bukedea charges UGX1,000 (US\$0.30) per piglet,

UGX2,000 (USD\$0.60) per gilt, and UGX5,000 (US\$1.40) for the adult pigs. If the farmer is too far, then the veterinarian waits to attend to that farmer until there are other cases in that area; this was also the case in Masaka.

There are three major method of administration to pigs – oral, subcutaneous, and intramuscular – with the method used depending on the instruction sheet that comes with the drug. In both districts, all veterinarians and para-veterinarians preferred the use of injectable drugs rather than oral administration because pigs are very difficult to restrain and bite syringes when receiving dewormers orally. Veterinarians and para-veterinarians normally recommend that farmers use the oral dewormers when self-administrating because they have a wide safe margin and are easy to apply.

In Masaka, about 75% to 100% of the pig farmers deworm their pigs. Normally, the farmers deworm pigs an average three times a year. Those that don't deworm use local herbs (e.g., one called 'lusiti'). In Bukedea, farmers deworm two or three times a year, and the decision to deworm depends on the harvest time since this is when farmers have extra income to buy the drugs. In both districts, veterinarians and para-veterinarians mentioned that farmers normally deworm during the rainy season.

8.6.5 Willingness to sell the TSOL18 vaccine-oxfendazole package

In Masaka, all of the para-veterinarians that attended said that they had never heard of porcine cysticercosis but knew about the tapeworm. In Bukedea, all of the veterinarians were aware of the condition and said the region even has a local name, 'ikuri', because the disease is said to resemble a cowpea (a staple cereal in that region). The disease is so serious in their community that no trader would buy a diseased pig. This high level of awareness was probably due to a farmer who had to refund a trader's money because when the district veterinary officer inspected the pig and found cysts, he burnt the pork. The fact that the vaccine trials with GALVmed are happening there could also be a contributing factor.

In Masaka, all participating service providers were willing to sell the vaccine as long as it did not cost more than UGX3,000 (US\$0.90) to the farmer to attain immunity; this means that the drug stockists need to sell the dose at about UGX1,000 (US\$0.30). They said that the farmers could only accommodate those prices if the vaccine's value is demonstrated to them. The veterinarians preferred the vaccine packaged in 20 mL units because it would bring the transaction costs (for example, transport) down for deworming/vaccination 20 pigs.

In Bukedea, the veterinarians and para-veterinarians said they would be willing to sell the vaccine if it is priced between UGX3,000 and 5,000 (US\$0.90 to \$1.40), the vaccine efficacy is proven, and it is accessible and easy to store. They believe there is a market for the vaccine because the disease is common in their district. Additionally, farmers in Malera sub-county, where the vaccine was tested, are aware of its benefits in controlling porcine cysticercosis. The vaccine would lose market potential if it were priced substantially more than the dewormers. Veterinarians and para-veterinarians said the vaccine should not exceed UGX3,000 (US\$0.90) in cost to the farmer. Most farmers know that vaccination is a public good that is supposed to be provided by the government at a subsidised price or even free of charge.

Summary of the findings

- The most commonly distributed livestock dewormers in Uganda are albendazole, levamisole, ivermectin, and piperazine.
- Most animal vaccines distributed in Uganda target cattle, poultry, shoats, and (to a lesser extent) dogs and cats.
- There is no vaccine for pigs distributed in Uganda.
- The mark-up for the distributor (in Kampala) and drug stockist (in the district) was 30%.
- Poor cold chain is a challenge to the vaccine quality.
- Given its current form (cost of product and packaging) and based on their experience with livestock vaccines, the participating distributors said they probably would be willing to distribute the product if it were subsidized by the government.
- Even though oxfendazole is more expensive than competing dewormers for other parasites than cysts, there is an opportunity for it to capture some market share because it is a broad-spectrum dewormer on top of being effective against porcine cysticercosis.
- The fact that the vaccine and dewormers are not packaged together make the combination unattractive to distributors because of anticipated challenges in acquiring both products at the same time when needed.
- The model for product adoption most likely to be effective is for it to be presented as a public good.

8.7 Potential for large drug distributors to market TSOL18 vaccine and oxfendazole

8.7.1 Pig dewormers and oxfendazole distributed in Uganda

The distributors interviewed indicated that the most commonly distributed livestock dewormers in Uganda are albendazole, levamisole, ivermectin and piperazine. Specific pig dewormers distributed proportionately are ivermectin (60%, mainly because it can protect against both internal and external parasites), levamisole (20%), and piperazine (20%). The interviewed distributors did not stock oxfendazole, but stocked a benzimidazole called fenbendazole that has similar effects but needs multiple doses to clear cysts. This could be a substitute for oxfendazole. However, the distributors mentioned that there is a brand of oxfendazole in the registration process at the National Drug Authority.

8.7.2 Stocked livestock vaccines and pricing strategies

Most animal vaccines distributed in Uganda target cattle, poultry, shoats, and (to a less extent) dogs and cats. For cattle, distributed vaccines target contagious bovine pleuropneumonia, foot and mouth disease, brucellosis anthrax, and lumpy skin disease. For poultry, the most common vaccine are for Newcastle disease, gumboro, infectious bronchitis, Marek's disease, fowl typhoid and fowlpox; for dogs and cats, rabies vaccine is the most stocked. No vaccine is stocked for pigs by the interviewed distributors. For the poultry vaccines, most of the time only exotic breed are vaccinated, and the Newcastle disease vaccine is the most sold. The distributor mentioned that vaccines are not as marketable as the drugs, mainly because farmers prefer curative rather than preventive measures. Vaccines targeting diseases with a high mortality rate (e.g., Newcastle disease) get higher market share because farmers can directly see the effect of the diseases on their flock.

When it comes to determining the price, distributors add a 15% margin for transport from the manufacturer to Kampala and a 30% mark-up on drugs (for distributor profit). The distributor mentioned that most of the drug stockists they supply in different districts add a 30% mark-up. Example of costs at the distributor level include: for lumpy skin disease, UGX800 (US\$0.22) without distributor profit and UGX1,500 (US\$0.42) with distributor profit; and for foot and mouth disease, UGX5,500 (US\$1.53) without profit and UGX6,200 (US\$1.72) with profit. The distributors were then introduced to the TSOL18 - oxfendazole combination and informed the distributor about the country where the drugs were manufactured and the price per dose. From this the distributors simulated the following figures on the cost of the combination TSOL18-Oxfendazole in Uganda; UGX8,000 without profit (i.e., at the distributor's warehouse); UGX10,000 to 11,000 (US\$2.70 to US\$3.00) with distributor's profit; and UGX15,000 to 20,000 (US\$4.20 to US\$5.50) with profit for the stockist in the district. If needed, veterinarian fees would cost about UGX5,000 (US\$1.40), meaning the farmers would pay a total of about UGX25,000 (US\$6.90) per pig. This implies that the product will not be competitive given that farmers may not be able to afford it considering the fact that their major expenditures which is in dewormers is around US\$1 annually.

8.7.3 Distribution of vaccines

The typical vaccine distribution process works as follows:

- From the airport, the importer picks up vaccines packed in insulated containers with icepacks from the airport cold room and transports them on a non-refrigerated truck.
- At the distributor's warehouse, vaccines are kept in a cold room until they are sold.
- Vaccines are packaged depending on the quantity required by customers: Vaccines are transported in insulated material with ice packs for those purchasing in bulk quantities, and temperature monitors are included in the packaging so a cold chain is maintained, especially for government purchases to their cold room. Those purchasing individual doses or less stock are required to have a flask and ice packs before vaccines are sold.

Challenges do occur for drug stockists selling to farmers, as there is poor packaging to maintain a cold chain, vaccine reconstitution, and ignorance of cold chain maintenance amongst the farmers.

8.7.4 Willingness to distribute the TSOL18 vaccine-oxfendazole package

According to the distributors, vaccine uptake is generally low in livestock due to farmers' lack of knowledge on vaccine use and its direct benefits to the farmer. Its benefits are more public health-focused, making the product less attractive to farmers; Farmers would incur minimal loss if they do not use the proposed vaccine. In addition, cheaper options for eliminating tapeworms are available on the market. Given these challenges, the distributors would be willing to stock the vaccine if the government is involved by making it mandatory to vaccinate against porcine cysticercosis. This speaks to the need for integrated 'One Health' approach.

On the use of the TSOL18 vaccine-oxfendazole combination, the distributors mentioned that it is better if both products are sold together (as recommended) by the same distributor. It would also be better if the manufacturer packaged the dewormer in tablet form and it were administered as single dose.

8.7.5 Suggestions for distribution mechanism and uptake of the TSOL18-oxfendazole package

The interviewees discussed three strategies for a distribution mechanism of the vaccine and evaluated their likelihood of success:

- Strategy 1 (*Low*): The product is fully managed by distributors (the current mechanism). The distributor imports the vaccine, launches it, trains other distributors and their networks focusing on areas with high pig population, and uses equipment for the cold chain in place (electricity).
- Strategy 2 (*Medium*): A consumer-driven/certification model, with proof of vaccination certification presented at slaughter. In this way, vaccine uptake can be promoted via self-regulation in the market.
- Strategy 3 (*High*): Vaccine as a public good, convincing the government of the human/public health impact (e.g., epilepsy) and ensuring farmers understand their roles in the transmission of the disease

and its impact on humans. A ‘One Health’ approach by the Ministry of Livestock and Health could be used and the vaccine subsidised by government. This strategy could involve a government initiative, as with mosquito nets; a government initiative to buy vaccines from importers in bulk would minimise costs to farmers. This strategy would involve pig value chain actors and focus on areas with high pig densities and commercial farms.

Table 26 summarises distributors’ recommendations for the TSOL18 vaccine-oxfendazole product.

Table 26: Recommendations given by distributors

Area	Recommendations
Product packaging	<ul style="list-style-type: none"> • <i>Option 1:</i> Have the same distributor for the TSOL18 vaccine and oxfendazole. • <i>Option 2:</i> Package the TSOL18 vaccine and oxfendazole together.
Dewormer	<ul style="list-style-type: none"> • Explore if the dewormer can be formulated into a tablet form instead of drenching.
Vaccination	<ul style="list-style-type: none"> • Use collective vaccination to reduce the transaction cost of the veterinarian. • Consider training vaccinators. • Consider that vaccine quality indicators are useful (feedback through mobile phone is used in Uganda) but expensive.
National Drug Authority	<ul style="list-style-type: none"> • Organise training on how to maintain the cold chain.
Consumers	<ul style="list-style-type: none"> • Raise awareness and educate consumers.
Distribution	<ul style="list-style-type: none"> • Consider that a monopoly is the best way to distribute a product to control its quality. According to one of the distributors, the East Coast fever vaccine is unattractive from a business perspective because there are two distributors in Uganda and the profit is minimal. • Streamline the competition and deploy ethical standards across all distributors. Companies do not have same standard operating procedures for marketing, which affects product quality because distributors all manage the product their own way. Authorities must deploy standards and streamline competition.
Awareness channels	<ul style="list-style-type: none"> • Use a combination of personal contact and broadcasting to raise awareness. Personal contact (e.g., group meetings with farmers) is more effective but expensive and limited in terms of the number of farmers reached. Broadcasting (e.g., radio) can reach more farmers but is less effective because some farmers do not have radios.

8.8 Stakeholder meeting

Results from the stakeholder meeting focused on describing current models for delivery and distribution of livestock vaccines and dewormers, as well as suggestions for improved distribution for the TSOL18-oxfendazole package.

8.8.1 Vaccine distribution channels

For the TSOL18 vaccine-oxfendazole combination to cover the entire country, the distributor would need to use the existing distribution method, including:

- Route sales, in which the distributor would deliver oxfendazole directly to drug shops countrywide.
- Real-time delivery for the vaccine to maintain the cold chain. However, in the beginning this would be a challenge, since TSOL18 would be a new vaccine and thus orders likely would not be as forthcoming as for well-established vaccines.

To distribute a new product on the market, the distributor first identifies the drug stockists that have a high turnover in each district and targets them for early adoption of the product; the distributor would specifically target from this list the drug stockists that they have worked with for a long time and that have earned their trust. They explain the new product to the stockists and supply it on credit (excluding vaccines that are supplied by cash-on-delivery basis). The distributor then checks on the drug stockist to see product performance and gain feedback. The distributor gives only a small amount of stock to reduce the drug spending a lot of time on the shelves. From this, it can be deduced that very few samples would be imported in the first year of the TSOL18 vaccine while the product is being assessed.

8.8.2 Vaccines sold alongside other drugs in Uganda

In Uganda, only the vaccine for East Coast fever is sold alongside another drug. It is distributed by two companies in Uganda, Scope Vet and Eram, and is administered with oxytetracycline. The distributors sell the vaccine and the drug as different products. The challenges faced in distributing the East Coast fever vaccine include:

- To stock it, one needs liquid nitrogen – a scarce commodity.
- Animals need to be monitored for seven days, a disincentive for adoption.
- Training is needed on administering the drug; few veterinarians are currently trained, which leads to low use.
- Since the East Coast fever vaccine is live, some animals might die; this scares off farmers from adopting its use and thus disincentivises it being stocked in drug shops.

The East Coast fever vaccine's key similarity to the TSOL18 vaccine is that it is administered alongside another drug. The East Coast fever vaccine is promoted independently from the drug it is administered with, although they are used concurrently. Also, only vaccine distribution is limited to authorized distributors; oxytetracycline is distributed by many entities under different brand names. This same strategy could be adopted for oxfendazole and the TSOL18 vaccine, leaving vaccine distribution to a few distributors and letting all oxfendazole brands on the market be used.

Additionally, the East Coast fever vaccine demonstrates how distribution can be hampered if the vaccine has characteristics that would affect farmers' adoption. In this case, all of the vaccine's distributors have well-developed distribution networks, but the vaccine has failed to penetrate the market even when there are no competing products and the distributors do not face any competition. From this case, the TSOL18 vaccine needs to look at factors that would keep farmers from vaccinating their pigs, especially in terms of the price of the vaccine.

8.8.3 Recommendations for large-scale, sustainable private sector distribution mechanisms

For large-scale distribution of the TSOL18 vaccine-oxfendazole package, the vaccine always has to be available in the country to limit any shortages. It would be easier to use the current system in place, real-time delivery and use of vaccine stockists. The challenge is that some areas have pigs but very few vaccine stockists. In such areas, the veterinary practitioners and extension staff are the best option to fill this role for farmers. In such areas, the closest vaccine stockist is treated as priority in distribution (i.e., scheduled first when they send in orders). Other avenues for distribution would need to be explored, such as sending the vaccine through the courier bus services (although the distributor would need to educate the courier service providers on how to handle the vaccines and invest in coolers to transport the vaccine). For oxfendazole, the normal distribution mechanisms used for other drugs can be adopted (route sales).

One key challenge for TSOL18 vaccine distribution is that most of the distributors import drugs and vaccines only two to three times a year, so the distributor that has the contract must also have the capacity to stock enough vaccines. Additionally, the TSOL18 vaccine targets a disease of low economic importance to farmers, so sales would not be very high – meaning that the cost of distributing the drug would affect the final product price to the

farmer. Another key challenge is that the vaccine industry is highly regulated, with more regulations set to take effect on the distribution of vaccines.

The stakeholder meeting participants agreed that for successful distribution, there should be enough of a market for the product. In this case, the TSOL18 vaccine should be affordable enough to create farmer demand. This would make the distribution sustainable because there would be a market pull.

8.8.4 Models for product promotion

Since the TSOL18 vaccine can only be administered by professional animal health service providers and not by farmers, the best promotional model would be through giving seminars. Additionally, promotion posters can be distributed to the drug stockists, although they first need to be approved by the National Drug Authority.

Another model for product promotion is using the traditional extension system to promote the vaccine, through public extension staff in each sub-county conducting trainings and promoting awareness of porcine cysticercosis in their areas of jurisdiction. This would be costly but would lead to a lot of coverage in the country. Additionally, another suitable promotion model would be large-scale awareness-raising of porcine cysticercosis as zoonosis. This could be done over television and radio but would still need approval from the Ministry of Health. If this is done, then vaccine promotion would be relatively easy. The challenge is convincing ministry officials that this disease is worth the effort, which can only be done if ministry officials are convinced with numbers on taeniasis cases and epilepsy due to cysts.

9. Discussion

9.1 Methods to support adoption of the TSOL18 vaccine-oxfendazole combination

9.1.1 *Willingness to pay*

The results from the market studies provide insight into the potential of marketing the porcine cysticercosis vaccine and dewormer as a private good. Pig farmers' choice behaviour indicates that if the vaccine is to be marketed as a private good, then the market would require a premium price to be paid for vaccinated pigs. However, the traders' choice behaviour for porcine cysticercosis-vaccinated pigs, shows substantial preference for pigs with high carcass weight. Furthermore, the premium-price attribute is not statistically significant. It is the dewormer component that may result in extra weight due to a reduction in worm burden. Although the participating traders are concerned about consumer health, most believed that control of porcine cysticercosis is the role of the government and should therefore subsidise the cost of the vaccine. The perceptions of large drug distributors and animal health service providers match those of traders. They believe that porcine cysticercosis control should be promoted through a public good channel because its negative impacts are much more visible in human health than in animal health. Hence, there is a need to engage the government to make this vaccination mandatory.

This exercise demonstrated that farmers have a high propensity to hold onto money (high time preference and high discount rate) and would therefore not want to spend much money on the vaccine and costs associated with vaccination administration; this was demonstrated by the high willingness to pay for a vaccine with low administration costs and low frequency of administration. Quality assurance was an important attribute highlighted by farmers and consumers alike. Farmers preferred a vaccine with a viability indicator, showing the importance of quality assurance for the vaccine and veterinary products. Pig farmers in Uganda have reported poor performance for products such as vaccines and dewormers, which is due to the use of adulterated products and poor handling and misuse. So incorporating a quality tracer in the vaccine would be of interest to farmers, would provide reassurance and could improve perception and uptake. The Pan African Veterinary Vaccine Centre (AU-PANVAC) of the African Union provides international independent quality control service for veterinary vaccines produced in and imported to Africa, so in addition to manufacturer's quality control testing, batches of the TSOL18 vaccine should be submitted to AU-PANVAC to provide additional reassurance.

Participating consumers of food from animal sources raised concerns about lack of labelling, certification, and clear food safety information in retailers selling this type of food. This implies that in addition to consumer sensitisation, demand for the vaccine requires clear certification schemes for porcine cysticercosis-free pork from pigs that have been vaccinated.

9.1.2 *Product distribution*

The TSOL18 vaccine-oxfendazole package has potential for market capture if the package's price range is similar to conventional pig deworming. Combining the vaccine with a dewormer such as oxfendazole would make it slightly less favourable for the veterinarians since they dislike administering oral dewormers; oxfendazole and even other derivatives of benzimidazoles are not dewormers that veterinarians use in Uganda. In that regard, it is important that the safety, efficacy and quality benefits of this brand are clearly presented to veterinarians and farmers to gain the acceptance of these important stakeholders. Mass awareness of porcine cysticercosis should be carried out, especially to the para-veterinarians and in areas where the disease is not reported, to enable veterinary professionals to effectively market the vaccine to farmers. Given the high trust that pig farmers have in veterinarians and para-veterinarians, these professionals can be effective in terms of information sharing.

To avoid conflicts of interest amongst distributors, increase motivation to distribute, and make quality control easier, franchising for drug distribution should initially be given to just one distributor. The promotion costs should be borne by the manufacturer, as this would reduce the final price and thus potentially improve uptake. Training extension staff in pork inspection on porcine cysticercosis would also promote adoption because it would increase the number of reported cases and also make traders aware of the condition.

Given farmers are considered the most important customers for the vaccine-dewormer combination, alternative delivery mechanisms may need to be explored (e.g., via community animal health workers). Vaccines are popular where disease has a high economic impact; currently, the economic impact of cysticercosis is limited, and more incentives need to be created to encourage uptake. Animal health service providers could potentially play a role in growing the market.

9.1.3 Cost of the product

Reports indicate that a retail price of around US\$1 per dose is an acceptable limit for smallholder farmers to be able to purchase the vaccine (Bardosh et al., 2014). In this study, a maximum retail price of US\$0.90 per treatment is what farmers said they could afford; this matches what they regularly spend to deworm their pigs (Bardosh et al., 2014).

9.1.4 Formulation of the vaccine

Ideally, one vaccine dose should provide lifetime protection for pigs; in many traditional pig-breeding areas where pigs are free-roaming, the life of a slaughter pig is about 12 months. According to Pedersen et al. (2000), this might be possible by using delayed- or pulse-release vaccine formulations or by using live recombinant vaccine vectors such as salmonella. Another option could be combining the porcine cysticercosis vaccine with African swine fever vaccine (if available) since African swine fever is generally farmers' most-feared disease causes them more direct losses; or a respiratory disease vaccine such as Porcine Reproductive Respiratory Syndrome (PRRS).

9.1.5 Public or private good?

An important question concerning the sustainability of a vaccination programme is: who will pay for the vaccine – the pig farmer or the government? The answer to this question depends on whether the vaccine is considered a public good from which the community benefits or a private good from which the farmer benefits. However, the farmers benefit only if they get premium prices, and it is important to note that pig farmers are not willing to spend more than what they do for regular deworming; based on this study, the product would cost at least 10 times regular deworming, making it unaffordable for farmers. Benefits to the community are the decline and eventual disappearance of *T. solium* tapeworm carriers and, in the long term, neurocysticercosis. It may be a sufficient justification for a government to fund a vaccination campaign against *T. solium* cysticercosis. In this study, all the interviewed value chain actors and stakeholders suggested that considering the high cost of the vaccine, it should be considered a public good if eradication must be achieved.

9.2 Roles of sensitisation in the uptake of the product

A study in Tanzania found that health education intervention significantly improved knowledge of and attitudes towards *T. solium* cysticercosis control and thus would reduce the consumption of infected pork (Ngowi et al., 2008). It recommends that health education, particularly targeting women, be integrated as an essential component of prevention and control programmes for *T. solium* infections. Sensitisation would go a long way in increasing vaccine uptake, especially in areas where disease prevalence is low. All value chain actors should be targeted, including farmers, traders, drug stockists, animal health service providers, and public health practitioners.

The models that could be used in sensitisation would differ depending on the value chain actor:

- **Farmers** should be aware of porcine cysticercosis, its impact on pigs and public health, and how to control it. The benefits of vaccination should be demonstrated to them, and they should be trained on basic best practices in pig husbandry and management (including pig housing using affordable materials and feeding). Farmers should also know how and when to report a disease and have access to deworming regimens for their pigs.
- **Traders** should be aware of the disease and its impacts on human health. The role and importance of live pig inspection should be emphasised, and they should be trained on basic tongue palpation techniques in the absence of a qualified veterinarian.
- **Veterinarians** should be aware of the disease and control options, including vaccination. Their diagnostic capacities should be enhanced, especially tongue palpation, to reduce the number of infected pigs reaching the market. Veterinarians should be used to reach farmers given their close working proximity.
- **Veterinary drug distributors** have long been the primary drug distribution model used in Uganda, according to key informant interviewed during the stakeholder meetings. Because the vaccine is a biological and policy issue, radio and television advertisements cannot be used because they are banned by law. If this model is used, then the vaccine manufacturer contracts with the distributor to promote the vaccine. Since the TSOL18 vaccine-oxfendazole combination would be new and have no competing products, the distributor would be hesitant to pick up the cost. Because oxfendazole has some competitive advantage over other dewormers and is a single dose, the distributor could take on the drug's promotion cost.
- **Public health practitioners'** training should focus on disease diagnosis since this would lead to improved meat inspection; any carcass rejected due to the disease would lead to more awareness amongst traders.
- **Government/policymakers**, specifically health officials, should be convinced of porcine cysticercosis' importance, especially economically. This could happen through detailed studies to estimate the disease's monetary impact, which could prompt funding to raise awareness of the disease and methods of elimination (including vaccinating pigs). This would help increase vaccine uptake and would reduce distributors' costs related to sensitisation.

The bundling of the two products together presents some marketing challenges. Due to government regulations around vaccine advertising, TSOL18 can only be advertised using seminars and targeting technical personnel. Oxfendazole can be advertised through radio, television, and other methods; however, if only oxfendazole is advertised this way, it would have higher coverage of oxfendazole and would affect vaccine adoption (with people opting to deworm rather than vaccinate). Given this predicament, the awareness-raising phase would need to be the first step undertaken prior to advertisement. Then seminars could be arranged countrywide for vaccine promotion.

9.3 Actors' roles in creating a cost-effective, sustainable process

The major actors in the drug and vaccine value chain are the manufacturer, the distributor, drug stockists, animal health service providers, pig farmers, and traders. The National Drug Authority, the Ministry of Agriculture, Animal Industries, and Fisheries, the District Veterinary Department, and extension service providers in the sub-counties also help create an enabling environment in terms of the value chain. For the TSOL18 vaccine-oxfendazole combination, these actors would all need to play a role to create a cost-effective, sustainable process:

- **The drug distributor** would organise seminars at the district level for the drug stockists, district officials, and animal health service providers. In these seminars, the distributors would explain porcine cysticercosis epidemiology and prevalence rates, as well as how the vaccine would reduce and consequently eradicate *T. solium* cysticercosis. The distributor would also talk about the pricing and the locations where the vaccine could be found, as well as the means of delivery.

- **The district veterinary department** could conduct district awareness campaigns for the disease using their extension staff. This could include staff calling for village meetings for smallholder farmers, educating them about the disease and making them aware that *T. solium* cysticercosis can be vaccinated against (without mentioning the TSOL18 vaccine specifically). The campaign's cost should be borne by either the manufacturer or the local government if it is convinced that the disease is worth eliminating.
- **Drug stockists** would make smallholder pig farmers aware of the vaccine and *T. solium* cysticercosis through posters and educating customers that come to buy another pig-related drug. They could also offer to vaccinate pigs for their customers as a service. The drug distributor must supply stockists on time.
- **Animal health service providers** are the most significant category of actors in terms of dealing directly with farmers on drug administration. They should be used to reach many farmers during awareness campaigns through a training-of-trainers approach.
- **Pig traders** should be used as the change agent since they are more likely to find *T. solium* cysticercosis in the pig when slaughtered and the economic impact affects them most given that they cannot easily identify the disease at the point of purchase.

10. Recommendations

10.1 Marketing the vaccine as a private or public good

The potential for marketing the TSOL18 vaccine-oxfendazole combination as a private good is low given the status quo; the market doesn't reward food safety. Farmers are willing to pay for the vaccine only if premium prices are guaranteed, while traders' willingness to pay premium prices is based on higher pig weight, consumers' willingness to pay for safe food, and services providers' willingness to market the product. There are several barriers to market entry that need to be addressed to improve the market environment:

- The cost of the product is high and must be significantly reduced if it is to be promoted as a private good, possibly through subsidising.
- The intervention's benefits need to be made visible to farmers and traders.
- Some of the product's characteristics need to be revised to meet the reality in the field.
- The capacities of animal health service providers need to be enhanced in diagnosis and treatment of the disease.
- The enabling policy environment for distributors needs to be improved.
- The impacts of porcine cysticercosis should be acknowledged and its control given momentum by the government.

The rising pig population and pork consumption in Uganda presents an opportunity for marketing the product, although porcine cysticercosis is not a priority disease to farmers like African swine fever (probably because economic losses from African swine fever are evident versus from porcine cysticercosis). Therefore, significant awareness and sensitisation is needed to achieve impact at scale for the control of porcine cysticercosis. This cannot be done by farmers alone; all value chain actors and stakeholders should be involved, with a clear push by the government.

10.2 Marketing opportunities and barriers

About 1.1 million households rear pigs in Uganda (UBOS, 2009). The survey also indicated that 68% of pig farmers deworm at least twice per year. The farmers that deworm are more likely to take up the vaccine since they can afford deworming, which would mean that 748,000 households could potentially vaccinate their pigs; districts with high porcine cysticercosis prevalence would have higher penetration rates than those with low prevalence rates. Assuming a penetration rate of 1%, this would mean that 74,800 households would vaccinate their pigs. The highest market potential would be in Eastern Uganda; though the pig populations are low there compared to the other regions, the prevalence rate is high – making vaccine adoption quite easy and fast.

The market distribution structure would be based on one or two local large distributors selling to the many local retailers serving as drug stockists; these stockists would in turn sell the vaccine to the trained technical personnel (veterinarians and para-veterinarians) and sell oxfendazole to the farmers since these are packaged as different products. The vaccine has no competing products since the disease is not vaccinated against in Uganda, but the dewormer oxfendazole has competing products – Wormcid, a levamisole, has the largest market share in deworming pigs, followed by the ivermectins used by the technical personnel for deworming; there is also a fenbendazole (Erafen 5) on the market that competes directly with oxfendazole since it targets tapeworm and can be used in deworming pigs. Even though fenbendazole is on the market, it is still a new product and can be outcompeted by oxfendazole since the former requires several doses.

The major market segment for the porcine cysticercosis vaccine would be veterinarians and para-veterinarians. If

they are convinced by the results of the vaccine, then the farmers would adopt it since most farmers rely heavily on these professionals for any uptake of new products. To a lesser extent, if the government is convinced that the disease is critical, then they could also be potential customers; for example, for diseases like foot and mouth disease, the major customer is the government.

10.2.1 Market entry points

The value proposition of the porcine cysticercosis vaccine is more tailored to public health benefits rather than economic benefits, with the deworming component giving it economic benefits. Thus, the vaccine needs to be sold as a product solving a public health need. This would mean that there is a need to demonstrate porcine cysticercosis' correlation with cases of epilepsy in humans in Uganda to attract policymakers. In the meantime, since deworming is an acceptable and routine animal husbandry practice, the value proposition could focus on reducing deworming times (though the vaccine only fights one type of worm). Another (improbable) idea is to encourage manufacturers to develop multi vaccines as they do for shoats/ cattle and poultry so there is added value in vaccinating against more than one disease; for this, it would be imperative to rely on the private sector since the bulk of veterinary vaccination is through this sector, which has an established distribution mechanism.

10.2.2 Barriers to market entry

Some distributors in Uganda have exclusive agreements to distribute specific products from manufacturers. This type of agreement would be difficult to use in terms of the TSOL vaccine-oxfendazole combination, and some of these distributors have well-established sales routes and market share. The National Drug Authority has strict guidelines for registering vaccines that can sometimes be cumbersome. Additionally, farmers' poor attitude towards vaccination is one of the biggest barriers to entry. This can be easily demonstrated with the free rabies vaccines that are also not easily taken up by farmers. Farmers are more used to deworming their pigs, and it is a cheaper option compared to the TSOL18 vaccine, meaning farmers might not use the vaccine since its price is far too high compared to conventional dewormers.

10.3 Sensitisation approaches and materials needed

Sensitisation would target several audiences, and for each, sensitisation would be about the disease or the vaccine. Due to policy restrictions, sensitisation via radio and television should focus on disease awareness without promoting the vaccine. Meetings with the technical professionals should provide concrete evidence that due diligence was done in the trials and also present a safety surveillance system that is going to be used. The promotion of the TSOL18 vaccine and oxfendazole would be at the district level with technical personnel from the drug stockists and public and private veterinarians operating within the district. Additionally, pig traders are important change agents since they buy the vaccinated pigs. Proper training on the effects of the disease and its impact on their sales will increase vaccine uptake amongst farmers (Table 27).

Table 27: Different sensitisation approaches for stakeholders

Audience	Key stakeholders	Message types	Materials needed	Sensitisation approach
Scientific audience	Technical staff from the Ministry of Health; Ministry of Agriculture, Animal Industries, and Fisheries; National Drug Authority; research organisations; universities; and National Livestock Resources Research Institute; district veterinary officers	Trends related to the disease, prevalence, trial results	Publications, reports	Workshops, national and international conferences
Animal health practitioners, drug stockists	Public and private practitioners, district drug stockists	Trial results, vaccine efficacy, value proposition, distribution mechanism, pricing, promotion strategies, equipment needed	Posters, demonstration videos, price lists	National
Pig farmers and traders	Pig farmers and traders	Disease transmission mechanism, disease diagnosis and prevention	Translated posters of the disease transmission cycle in local languages, illustrations (photos of the disease)	Use of village meetings, radio and TV messages

10.4 Key opportunities and challenges

Key opportunities for the TSOL18 vaccine-oxfendazole combination in Uganda include:

- Pig population density is highest in East Africa, so there is market demand for the product.
- TSOL18 is the first vaccine for pigs in Uganda, which gives it an edge in the untapped market of pig vaccines in Uganda.
- There is a fairly developed distribution network, so the manufacturer doesn't need to develop a new network.
- There are areas with high porcine cysticercosis prevalence rates (above 20%), such as Moyo, Kayunga, Kaliro, Kayunga, Kiberamaido, Apac, and Amolator.
- Consumption of pork is increasing in Uganda, as is the income of the population, so related food safety issues are increasingly important to consumers. Because porcine cysticercosis is a food safety issue, there is a good platform for vaccination campaigns.
- Neurocysticercosis exists in Uganda, and the government has recognised it as a serious disease, yet the role of porcine cysticercosis is not yet fully appreciated.
- There is willingness amongst pig value chain actors to combat the disease.

Challenges for the TSOL18 vaccine-oxfendazole combination in Uganda include:

- Diagnosis of the disease in pigs is difficult because only post-mortem examination can give the best results. This leads to cases being common at places of slaughter without the consumer's knowledge.

This means that farmers cannot be aware of the condition in their herds. Thus, pen-side diagnostic tests should be made available.

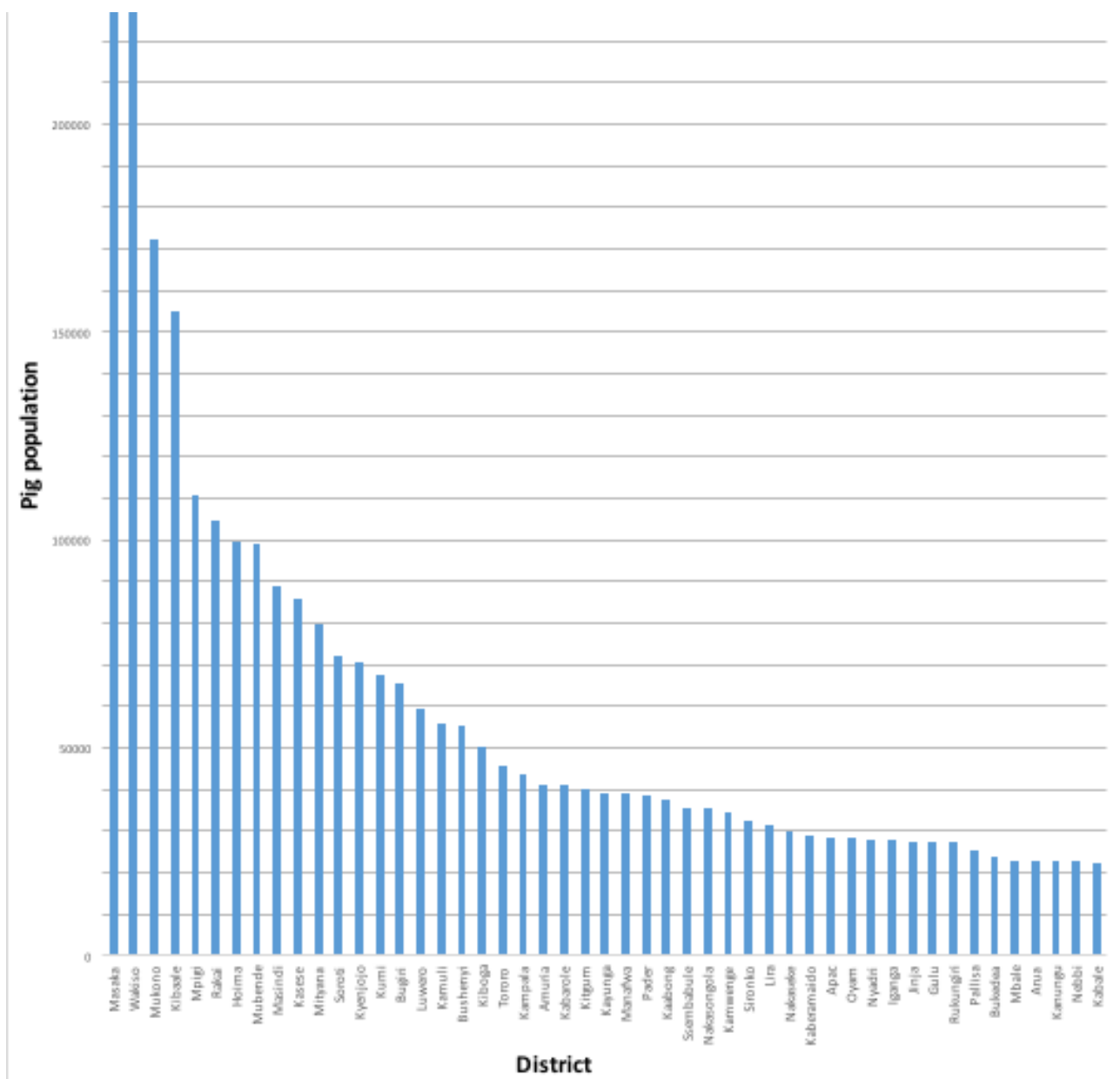
- Poor meat inspection leads to fewer carcasses being condemned, which in turn leads to underestimation of the disease burden and to traders not regarding the disease as significant.
- The policy that vaccination can only be carried out by veterinarians is challenging in terms of increased transaction costs and limited coverage of veterinarians.
- The cost of the vaccine is high, which makes it challenging for farmers. A new affordable vaccine formulation should be researched.

10.5 Key interventions to improve livelihoods for resource-limited stakeholders

The key related intervention that can improve resource-limited stakeholders' livelihoods is organised group vaccination campaigns. The veterinary practitioner could organise to vaccination for 20 households with one pig providing schedules and notifications that there will be vaccination. This would reduce transport costs that would have been incurred by a single household. Also, involvement of communities in the control of porcine cysticercosis is key. This could be done through the creation of community trainers using a human health platform (such as with community control of malaria).

10.6 Relevant policy issues that enhance or hamper TSOL18 vaccine delivery

Existing policy issues do not just affect the TSOL18 vaccine, but all veterinary vaccines. The new proposed requirements for prequalifying drug shops that stock vaccines will reduce the number of available drug stockists to distribute the vaccines and thus reduce coverage. There is also a new policy that veterinary drugs have to be tested and assign a new expiry date every three years; this would lead to increased costs to the distributor.



Annex 1: Distribution of 90% of the pig population per district (UBOS, 2009)

Annex 2: Prevalence studies on porcine cysticercosis in Uganda

District	Prevalence (%)	Test	Risk factor(s)	Reference	
Moyo	37.7	Post-mortem (slaughter slabs)	-	UBOS, 2009	
Kampala	9.4	Post-mortem (Wambizzi abbatoir)	-	(Anyanzo, 1999)	
Kamuli/Kaliro	8.5	B158/B60 Ag-Elisa	Absence of pit latrines	Kisakye and Masaba, 2002)	
Oyam	9.4	Tongue examination	Free range	(Waiswa et al., 2009)	
Apac	7.7	Tongue examination	-		
Amolator	8.2	Tongue examination	-		
Kaberamaido	6.9	Tongue examination	-		
Kamuli	12.9	Tongue examination	-		
Kaliro	4.1	Tongue examination	-		
Arua	27	-	-		
Busia	11	-	-		
Kibale	14.2	-	-		(Nsadha et al., 2010)
Masaka	15	-	-		
Kayoga	21.5	HP10 Ag-Elisa	Free range	(Nsadha et al., 2011)	
Kaliro	23.2	HP10 Ag-Elisa	Free range		
Kiberamaido	20.3	HP10 Ag-Elisa	Free range		
Apac	28.1	HP10 Ag-Elisa	Free range		
Amolator	33.9	HP10 Ag-Elisa	Free range		
Soroti	18.0	HP10/B158/B60 Ag-Elisa	Free range; absence of pit latrines		(Nsadha et al., 2014)
Masaka	11.7	HP10/B158/B60 Ag-Elisa	Absence of toilet; lack of knowledge	(Kungu et al., 2017)	
Mukono	11.2	HP10/B158/B60 Ag-Elisa	Absence of toilet; lack of knowledge		
Kamuli	13.5	HP10/B158/B60 Ag-Elisa	Absence of toilet; lack of knowledge		
Lira	6.9	HP10 Ag-Elisa		(Kungu et al., 2019)	
Moyo	13.2	HP10 Ag-Elisa			
Moyo	37.7	Post-mortem (slaughter slabs)	-	(Kungu et al., 2017c)	
Kampala	9.4	Post-mortem (Wambizzi abbatoir)	-	(Anyanzo, 1999)	
Kamuli/Kaliro	8.5	B158/B60 Ag-Elisa	Absence of pit latrines	(Kisakye and Masaba, 2002)	

Annex 3: Cards with pictorial profiles describing the differences in traits and the levels to demonstrate each choice set to survey respondents - pig farmers

Annex 4: Questionnaire covered socioeconomic aspects such as location of the farm and other household and farm level characteristics

Annex 5: Questionnaire on pig farmer's willingness to pay for porcine cysticercosis vaccine (TSOL 18 vaccine-oxfendazole)

Annex 6: Questionnaire on Uganda pig traders willingness to pay for porcine cysticercosis vaccinated pigs

Annex 7: Guideline for Focus Group Discussion on Uganda consumers' perceptions on animal source foods safety

Annex 8: Guideline for Focus Group Discussion on Uganda pork consumers' perceptions on pork safety, with a focus on porcine cysticercosis – free pork

Annex 9: Questionnaire for animal health service providers on pig farmer use of wormers and willingness to sell TSOL 18 and oxfendazole

Annex 10: Tool for product profiling (TSOL 18 vaccine and oxfendazole 10% (PARANTHIC))

Annex 11: Tool for key informant interviews with veterinary drug and vaccine importers in Uganda

Annex 12: Guideline for stakeholder discussion on recommendations on the potential for large scale sustainable private sector distribution mechanisms of TSOL 18 vaccines in Uganda.

Annex 13: Study consent forms

Annex 14: Images and photos

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