

# **Systematic literature review of food safety and zoonotic hazards in the pig value chain in Uganda**

**Consultancy draft report (Ref C/13/058)**

**by**

**Michael Ocaido**

## **Abstract**

There has been no systematic review looking at the food safety and zoonotic hazards of the pig value chain in Uganda despite the fact that pork consumption has increased tremendously. This elevated pork consumption linked with increasing human population comes amidst increasing numbers of zoonotic cases in humans and food safety concerns in pigs such as blue pork. The aim of this review was to establish available data on food safety and zoonotic hazards in the pig value chain in Uganda over the last 23 years, and to compare it with the data obtained from other East African countries.

The review was conducted through search for hazards on online data bases including Pubmed, Cab direct, Web of Science, and Africa journals online, using pre-determined search criteria. Additional data was obtained through use of library resources and discussion with local experts. Application of exclusion criteria identified 82 relevant studies out of initial 2838 articles. Data on hazard investigated, year, location, sample size, husbandry type, climate, tests used and prevalence, risk factors, impact and control were extracted.

On specific zoonoses: studies on trypanosomiasis have been done in South Eastern and Western districts of Uganda. Prevalence in pigs ranged from 2.3% to 32.4%. In Kamuli and Mukono districts, 30.6% and 14.53% of the tsetse flies fed on pigs, respectively. There were no reports of role pigs as reservoir of human trypanosomes in pig keeping areas of Bugisu, Teso, Lango and Acholi region. A 2% prevalence of TB due to *M. bovis* in pigs was reported. Prevalence of non-tuberculous mycobacteria in pigs ranged from 3.1% to 39%. Risk factors for pig infection with these bacteria were free-ranging of pigs and use of water from valley dams. No studies on leptospirosis, campylobacter, erysipelas, relapsing fever and ectoparasites were done. However, all these zoonoses were reported in other East African countries. Ndumu virus was reported in Ugandan pigs for the first time. Prevalence of *Trichuris suis* in pigs in Uganda was 17% while *A. suum* was 40%. Outdoor production system of management was the key risk factor for parasite infection. There were no studies on brucellosis, anthrax, *Streptococcus suis*, Q-fever, influenza, rabies, ebola and *Ancylostoma* species in pigs in Uganda let alone other East African countries.

On food safety prevalence of porcine cysticercosis (PC) was high in northern Uganda, Lake Kyoga basin, South western Uganda and along transborder areas. Risk factors associated with high prevalence of PC were lack of latrines, lack of knowledge of transmission of PC, home slaughter of pigs, lack of pork inspection and free ranging of pigs. The prevalence ranged from 0.12 to 45%. Neurocysticercosis was highly prevalent in Uganda but exact prevalence has not been determined. No efforts to educate communities about porcine cysticercosis and neurocysticercosis have been instituted. No studies were available on: *Taenia hydatigena*,

*Trichinella* species, *Toxoplasma gondii*, *Sarcocystis suihominis*, *Alaria alata*, *Salmonella*, *Y. Enterocolitica*, *Giardia duodenalis*, toxigenic *E. coli*, Cryptosporidium, hepatitis E, pesticide and antibiotic residues, heavy metals, mycotoxins and blue pork in pigs in Uganda. Most of the rural pigs are housed in unhygienic muddy environments which predispose to soil and water-borne contaminants. All pig slaughter houses in Uganda lack basic hygienic standards and meat inspection was poorly executed. Uganda lacks effective food safety policy and food-borne disease surveillance system which would promote production of safe pork and control of zoonotic diseases which would be got from pig value chain.

In conclusion, this review study has highlighted the huge challenges facing food safety and zoonotic hazards in the pig value chain in Uganda. This review would serve as a good starting point for research and policy development to address above mentioned challenges in Uganda.

## **Introduction**

Pig production is becoming an important activity in Uganda. The National pig herd has undergone tremendous growth from 0.19 million in 1980 to 3.2 million in 2008 (Western Uganda and 2% in Karamoja (UBOS, 2009 and MAAIF, 2011)). This growth has been due to increased demand for pork and pork products by consumers, with the consumption per capita of pork in Uganda being estimated by FAO in 2007 to be at 3.4 Kg/person/year (CGIAR, 2011). The good attributes of pigs like high fecundity, high feed conversion rate, early maturity, short generation interval, minimal space requirements have made pigs a priority source of livelihood for over 1.1 million rural poor in 17.8% households in the rural and peri-urban communities in Uganda (UBOS, 2009).

Despite the positive aspects described above, like any other African country, in Uganda the major concern is being paid to satisfying hunger and little is being done about pork safety and zoonotic diseases that can be got from pigs. In the pig value chain pork safety involves protection of pork supplies from microbial, chemical and physical hazards that may occur at all stages of pork production that can be at pig husbandry level at farm, slaughtering, processing, transporting, retailing, distributing, preparing, storing and consumption in order to avoid food-borne illness. Likewise with increased interaction of humans and pigs there is a risk of transmission of zoonotic diseases between the two species. However, little has been known about pork safety concerns and practices; and zoonotic diseases that can be got from pigs in Uganda. It is against this background that a systematic literature review was done on available data on food safety and zoonotic hazards in the pig value chain in Uganda, and then compare the findings with the current knowledge available in other countries in East Africa.

## **Methodology**

This was a desk study conducted through (1) search of online databases (2) search of nutrient values in text books and online (3) visit of Makerere University library and (4) discussion with experts in the subject area.

### **Search of online databases**

Online databases were searched for one or a list of selected hazards affecting the pig value chain. The spectrum of hazards considered was as shown in Table 1. Initial searches were carried out to define suitable search algorithms and MeSH terms for application in the final search. Search algorithms employed were recorded (see Table 2). The searches were conducted in parallel by two reviewers in the following databases Pubmed, Cab direct, Web of Science, Africa journals online, Makerere University library and World Bank (20<sup>th</sup> March 2013 to 5<sup>th</sup> April 2013), among others. The study information on the hazards, title, abstracts and where possible full papers were retrieved and saved as separate files by hazard category.

**Table 1. List of selected hazards reviewed in the pig value chain in Uganda**

<b>Foodborne non-zoonotics</b>	<b>Foodborne zoonosis</b>	<b>Foodborne and direct zoonosis</b>
Antibiotic residues Heavy metals Mycotoxins (Ochratoxin A; Zearalenone) Pesticide residues <i>Yersinia enterocolitica</i> Blue pork	<i>Alaria alata</i> <i>Ascaris suum</i> Cryptosporidium  <i>Echinococcus</i> species. <i>Escherichia coli</i> (toxigenic) <i>Giardia duodenalis</i> Hepatitis E <i>Salmonella</i> species. <i>Sarcystis suihominis</i> <i>Taenia solium</i> , larval <i>Toxoplasma gondii</i> <i>Trichinella</i> species <i>Trichuris suis</i> <i>Campylobacter</i> species	Leptospirosis <i>Bacillus anthracis</i> <i>Brucella suis</i>  Q-fever ( <i>Coxiella burnetii</i> ) <i>Erysipelothrix rhusiopathiae</i> Influenza <i>Mycobacterium avium</i> Rabies <i>Sarcoptes scabiei</i> var. <i>suis</i> <i>Streptococcus suis</i> Trypanosoma species. Jiggers ( <i>Tunga penetrans</i> ) Ebola <i>Ancylostoma</i> species. <i>Borrelia duttonii</i>

**Table 2. Search terms used to identify published articles on the Food Safety and Zoonotic Hazards in the pig value chain in Uganda**

<b>Data base</b>	<b>Search algorithms</b>
Pubmed	((("Antibiotic residues" OR "heavy metals" OR mycotoxins OR "Yersinia enterocolitica" OR pesticides "OR „blue pork“ OR "Alaria alata" OR Ascaris suum OR Cryptosporidium OR Echinococcus OR "Giardia duodenalis" OR "Hepatitis E" OR "Sarcocystis suihominis" OR "Escherichia coli (toxigenic)" OR "Taenia solium_larval" OR "Toxoplasma gondii" OR Trichinella OR "Trichuris suis" OR Ancylostoma OR "Bacillus anthracis" OR "Brucella suis" OR campylobacter OR „relapsing fever“ OR Ebola OR "Erysipelothrix rhusiopathiae" OR Influenza OR Leptospirosis OR "Mycobacterium avium" OR Q-fever OR Rabies OR "Sarcoptes scabie var suis" OR "Streptococcus suis" OR Trypanosoma OR "Tunga penetrans" *[Title/Abstract])) AND Topic = (porcine OR pig OR pork OR pork product [Title/Abstract])) AND Topic =

	(Uganda OR Kenya OR Tanzania OR Rwanda OR Burundi*[Title/Abstract])
Cabdirect	Topic = (porcine OR pig OR pork) AND Topic = ("Antibiotic residues" OR "heavy metals" OR mycotoxins OR "Yersinia enterocolitica" OR pesticides OR "Alaria alata" OR Ascaris suum OR Cryptosporidium OR Echinococcus OR "Giardia duodenalis" OR "Hepatitis E" OR "Sarcocystis suihominis" OR "Escherichia coli (toxigenic)" OR "Taenia solium_larval" OR "Toxoplasma gondii" OR Trichinella OR "Trichuris suis" OR Ancylostoma OR "Bacillus anthracis" OR "Brucella suis" OR Ebola OR "Erysipelothrix rhusiopathiae" OR Influenza OR Leptospirosis OR "Mycobacterium avium" OR Q-fever OR Rabies OR "Sarcoptes scabie var suis" OR "Streptococcus suis" OR Trypanosoma OR "Tunga penetrans") AND Topic = (Uganda OR Kenya OR Tanzania OR Rwanda OR Burundi*)
World of Science	Topic = (porcine OR pig OR pork OR pork product) AND Topic = ("Antibiotic residues" OR "heavy metals" OR mycotoxins OR "Yersinia enterocolitica" OR pesticides OR "Alaria alata" OR Ascaris suum OR Cryptosporidium OR Echinococcus OR "Giardia duodenalis" OR "Hepatitis E" OR "Sarcocystis suihominis" OR "Escherichia coli (toxigenic)" OR "Taenia solium_larval" OR "Toxoplasma gondii" OR Trichinella OR "Trichuris suis" OR Ancylostoma OR "Bacillus anthracis" OR "Brucella suis" OR Ebola OR "Erysipelothrix rhusiopathiae" OR Influenza OR Leptospirosis OR "Mycobacterium avium" OR Q-fever OR Rabies OR "Sarcoptes scabie var suis" OR "Streptococcus suis" OR Trypanosoma OR "Tunga penetrans") AND Topic = (Uganda OR Kenya OR Tanzania OR Rwanda OR Burundi*)
African Journals online (AJOL)	Topic = (porcine OR pig OR pork OR pork product) AND Topic = ("Antibiotic residues" OR "heavy metals" OR mycotoxins OR "Yersinia enterocolitica" OR pesticides OR "Alaria alata" OR Ascaris suum OR Cryptosporidium OR Echinococcus OR "Giardia duodenalis" OR "Hepatitis E" OR "Sarcocystis suihominis" OR "Escherichia coli (toxigenic)" OR "Taenia solium_larval" OR "Toxoplasma gondii" OR Trichinella OR "Trichuris suis" OR Ancylostoma OR "Bacillus anthracis" OR "Brucella suis" OR Ebola OR "Erysipelothrix rhusiopathiae" OR Influenza OR Leptospirosis OR "Mycobacterium avium" OR Q-fever OR Rabies OR "Sarcoptes scabie var suis" OR "Streptococcus suis" OR Trypanosoma OR Tunga penetrans) AND Topic = (Uganda OR Kenya OR Tanzania OR Rwanda OR Burundi*)
World Bank	Topic = ("Antibiotic residues" OR "heavy metals" OR mycotoxins OR "Yersinia enterocolitica" OR pesticides OR "Alaria alata" OR Ascaris suum OR Cryptosporidium OR Echinococcus OR "Giardia duodenalis" OR Hepatitis E Sarcocystis suihominis OR Escherichia coli (toxigenic) OR "Taenia solium_larval" OR "Toxoplasma gondii" OR Trichinella OR "Trichuris suis" OR Ancylostoma OR "Bacillus anthracis" OR "Brucella suis" OR Ebola OR "Erysipelothrix rhusiopathiae" OR Influenza OR Leptospirosis OR "Mycobacterium avium" OR Q-fever OR Rabies OR "Sarcoptes scabie var suis" OR "Streptococcus suis" OR Trypanosoma OR Tunga penetrans) AND Topic = (Uganda OR Kenya OR Tanzania OR

	Rwanda OR Burundi*) AND (porcine OR pigs OR pork OR pork product)
--	---

## Study inclusion and exclusion criteria

The studies were screened for relevance by their titles and abstracts. Studies were selected as relevant if they provided information on the food safety and zoonotic hazards in the pig value chain in Uganda and / or other East African countries (Rwanda, Burundi, Tanzania and Kenya). Studies providing information on the pig animal source foods and nutrition were also sought. Relevant publications were subsequently grouped according to hazard studied. Some of the publications identified provided information on multiple hazards. A publication was excluded if:

**Date:** it was published was before 1990

**Language:** it was not written in English

**Country:** the country where published was not Burundi, Kenya, Rwanda, Tanzania, Uganda

**Animal species:** if the species was not porcine

**Content:** if the study did not refer to;

- i. Prevalence: presence of level of hazard in pigs, pork and pig products, people, or wildlife interacting with pigs
- ii. Impact: economic cost, DALYs, social or other burdens, environment
- iii. Control: risk factors, knowledge, control methods

## Process of retrieval and screening of literature

The PRISMA 2009 flow diagram was used to document the systematic review process: <http://www.prisma-statement.org/2.1.4%20-%20PRISMA%20Flow%202009%20Diagram.pdf>

Data was captured and recorded using Excel spread sheets. This included: (i) a download sheet in which all hits on the databases were recorded by title, author and journal/paper. Duplicates were removed and the studies were identified as relevant or not relevant. (ii) the screen sheet in which identified relevant studies were initially screened by title and abstract to identify the study type and subject (whether review, prevalence, impact or control), (iii) the data capture sheet for studies on prevalence, (iv) data capture sheet on which key information on risk factors and control was pasted, (v) a data capture sheet on which key information on impacts of the hazards was pasted, (vi) a sheet on which other key information on other areas of interest was pasted, and lastly, (vii) a sheet on which other references which seemed relevant but not in the hits on the data bases were captured.

## Selection of studies

The schematic of the search process based on application of inclusion and exclusion criteria, resulted in the final set of studies from which data was extracted is as shown in Figure 1. In total 82 relevant studies were obtained and data extracted.

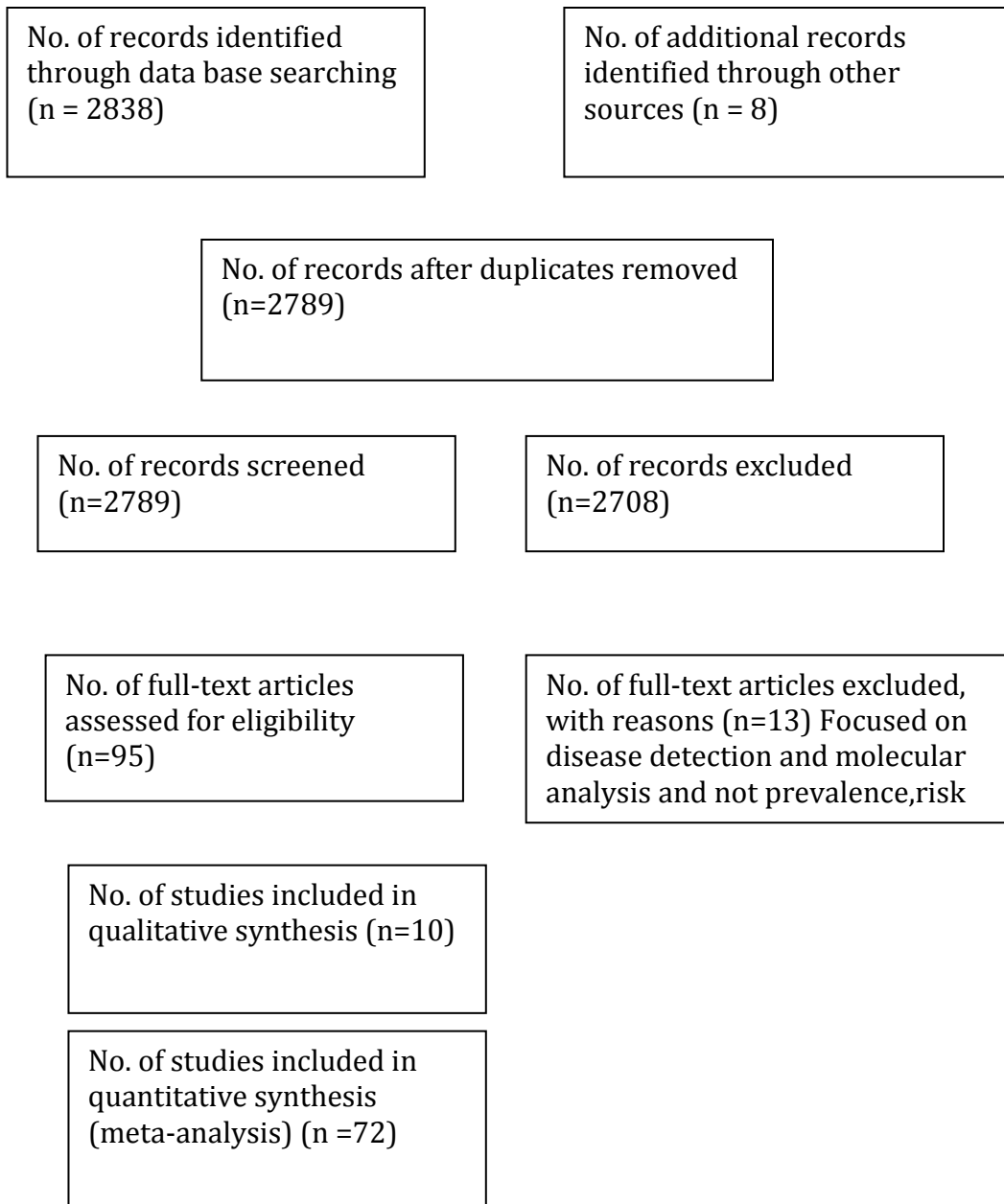


Figure 1: Schematic of the literature search

## Data extraction

Information on hazard studied, year, place, sample size, husbandry system, climate, tests used and prevalence, risk factors as well as impact were extracted from study abstracts and full papers for analysis. Publications documenting outbreaks or detection of the hazard were also considered.

## Data synthesis

The data on prevalence, risk factors and impact of food safety and zoonotic hazards were synthesized and summarized according to the concerned hazard. Studies reporting the hazard/outbreak were also considered for analysis. Median prevalence of each hazard was determined and trends in the prevalence of different hazards were assessed.

## Results

### Pig zoonoses

#### 1. Trypanosomosis

No work has been done in Tanzania, Rwanda and Burundi about the role of pigs in epidemiology of human trypanosomosis. Work has been done in Uganda (Katanguka-Rwahishaya *et al.*, 1996; Waiswa *et al.*, 2003; Waiswa, 2008; Biryomumaisho *et al.*, 2009 and 2013; and Balyeidhusa *et al.*, 2013) and Kenya (Ng'ayo *et al.*; 2005, Omolo *et al.*, 2009 and von Wissmann *et al.*, 2011).

First survey of trypanosomes to detect trypanosomes in pigs was done in 1994, which found prevalence of 32.4% in 64 pigs in Buikwe county Mukono district in Eastern Uganda (Katanguka-Rwahishaya *et al.*, 1996). *T. brucei* was accounting for 30% of trypanosome infections (hence giving a prevalence rate of 9.7%). This study postulated that some of the *T. brucei* species infecting pigs could be *T. brucei rhondensie* which was causing sleeping sickness in this area.

Later a study was done in South Eastern Uganda, which was reported by Waiswa *et al* (2003) and Waiswa (2008). This study found out that pigs played a major role in pig-human trypanosome transmission cycle in Kamuli and Mukono. During this study no *T. brucei* isolates were obtained from pigs sampled from Tororo. This study found an overall prevalence of trypanosomosis in pigs of 17.53% in South Eastern Uganda in Kamuli, and Mukono. Point prevalence of trypanosomosis in Kamuli was found to be 16.33% of which 82.48% were *T. brucei* subgroup infected, 30.6% of which were human infective when determined using human serum resistance test and 75% were carrying Serum Resistant Associated (SRA) gene when analysed by the Polymerase Chain Reaction (PCR). In Mukono point prevalence of trypanosomes was 22.92% in pigs, of which 85.51% were *T. brucei* subgroup, 26.09% of which were human infective when detected using a human serum resistance test and 31.58% having SRA gene when determined by PCR. It was also shown that 30.6% and 14.53% of tsetse flies

(*Glossina fuscipes fuscipes* a sole trypanosome vector) in the area were getting their meals from pigs in Kamuli and Mukono, respectively.

Another study reported by Biryomaisho *et al.* (2009) and (2013) found overall prevalence of trypanosomosis of 2.3 % (n=9, of which eight had mixed infections involving *T. congolense* and *T. brucei* and one having *T. vivax* infection only) among 386 pigs reared in smallholder farms in Kasese, Jinja and Rakai districts as detected using a microhaematocrit centrifugation technique (MCHT). No trypanosome was detected from 133 pig blood samples taken in Kasese.

A study was done to determine prevalence of Human Animal Trypanosomosis (HAT) in pigs in North-Western Uganda in counties of Terego, Moyo, Koboko and West Moyo (Balyeidhusa *et al.*, 2013). Trypanosome infection rate determined using MHCT was found to be 15.5% among pigs. No trypanosome was detected in West Moyo. TBR-PCR detected highest trypanosome infection rate among pigs of 21.7% as compared with other domestic animals: cattle had 14.5%, dogs (12.4%), sheep (10.8%) and goats (3.2%). All the 417 trypanosome positive samples collected from domestic animals including pigs during this study were negative by PCR to both forms of human animal trypanosomes (*T. b. gambiense* and *T. b. rhodesiense*).

No reports of role pigs as reservoir of human trypanosomes in pig keeping areas of Bugisu, Teso, Lango and Acholi region in Uganda.

Three studies have been done on pigs and trypanosomosis in Kenya. Two studies on prevalence (one Teso district and the other in Busia district) and one on tsetse control. Ng'ayo *et al* (2005) reported a prevalence of 19.2% (n=10, that is 3 for *T. brucei*, 5 for *T. vivax*, 1 for *T. congolense* savannah and *T. simae*) detected using PCR in 52 free range pigs from five villages (Amoni, Obuchun, Ongariama, Amasse and Rukada) in Teso district in Western Kenya. One of infected *T. brucei* pigs had *T. brucei* which tested positive for human SRA gene hence linking it to *T. brucei rhodensie* infection. This implied that pigs were acting as a reservoir of Human African Trypanosomosis (HAT) (sleeping sickness).

Another study reported by von Wissmann *et al.* (2011) determined prevalence of trypanosome infection rates in Busia district, Western Kenya of 11.9% out of 2773 livestock sampled in 545 households. *T. b. Rhodensiense* was detected in 2.9% of the pigs (9/312) as compared to cattle 1.5% (19/1260). It was found that the chance of a *T. brucei* species infected pig being infected with *T. b. rhodesiense* was high. Forty seven point four percent (n=9) of 19 *T. brucei* species infected pigs were infected by *T. b. rhodesiense* than in *T. brucei* species infected cattle (17.3%; 19/110). Pigs were shown to be a reservoir human sleeping sickness hence a risk to the local communities.

Omolo *et al.* (2009) reported a study done in Kenya and Democratic Republic of Congo in which it was found that incorporation of monitor lizard and pig odour in tsetse traps would increase the number of *Glossina fuscipes fuscipes* and *Glossina fuscipes quanzensis* attracted to the tsetse traps, respectively, indicating that these odours could be useful control tools for tsetse flies hence trypanosomosis.



## 2. Tuberculosis

The first documentation of tuberculosis (T.B) in pigs in Uganda was done by Muwonge *et al.* (2012). Mesenteric lymph nodes of 1000 pig carcasses slaughtered in 31 slaughter houses in Buwekula and Kassanda counties in Mubende district were examined for mycobacterial lesions. One hundred and fifty mesenteric lymph nodes suspected to be tuberculous, were subjected to standard mycobacteriological isolation and identification methods (PCR). It was found that 2% (3/150) were positive for *M. bovis* (spoligotype SB 1469). All these pigs were from Madudu subcounty.

No other study of T.B. in pigs has been done elsewhere in Uganda and East Africa.

## 3. Non-tuberculosis mycobacteria

The first report of isolation of non-tuberculous Mycobacteria in pigs in Uganda and East Africa as a region was done by Muwonge *et al.* (2010). A total of 997 pigs (53.7% male and 46.3% female) from 31 different slaughterhouses in Mubende district were randomly examined for 5 months on daily basis for the presence of lesions comparable with TB and mycobacterial infections. Pathologic tissue samples were collected for culturing and isolation of mycobacteria. A prevalence of *Mycobacterium* species of 9.3% and 3.1% was detected by necropsy examinations and culture isolation, respectively. The highest prevalence of mycobacterial infection was recorded in Buwekula County (the mixed agro-pastoral zone) and the lowest was in Kassanda County (pastoral zone).

Another follow up study was done to characterise the type of non-tuberculous mycobacteria isolated from slaughter pigs in Mubende district (Muwonge *et al.* 2012). A total of 363 lymph nodes were collected from pigs slaughtered in Mubende district and cultured for the presence of mycobacteria. Isolates were identified by 16S rDNA gene sequencing. Mycobacteria were detected in 39 % (n=143) of the examined lymph nodes of which 63 % (59/93) were lymph nodes with gross lesions typical of mycobacteriosis and 31% (84/270) were lymph nodes with no visible lesions. Nineteen per cent of the isolated mycobacteria were *Mycobacterium avium*, of which 78% and 22% were *M. avium* sub sp. *Hominissuis* and *avium*, respectively. Other mycobacterial species included *M. sensuense* (16%), *M. terrae* (7%) and *M. asiaticum* (6%). This study found free range systems more prone to non-tuberculous infection than pigs housed indoors (OR = 3.0; P = 0.034). Also use of water from valley dams than water from bore holes (OR = 2.0; P = 0.049) was a risk factor associated with high prevalence of mycobacteria in slaughter pigs in Mubende district.

## 4. Leptospirosis

No study has been done to detect leptospirosis in pigs in Uganda, Kenya, Burundi and Rwanda. One study has been done in Tanzania (Kessey *et al.*, 2010).

From 385 serum samples collected from healthy pigs in Morogoro Municipality, Tanzania 4.42% (n=17) of these were positive for *Leptospira* antibodies using microscopic agglutination test. Microscopic agglutination test for antibodies was done against live cultures of six known *Leptospira interrogans* serovars: *Pomona*, *Icterohaemorrhagiae*, *Ballum*, *Tarassovi*,

*Grippytyphosa* and *Hardjo*. Also two leptospiral organisms were isolated from the aseptically collected urine samples (n=214).

## **5. Campylobacteriosis**

No study has been done to detect infection of pigs with *Campylobacter* in Uganda, Kenya, Burundi and Rwanda. One study has been done in Tanzania (Mdegela *et al.*, 2011). The prevalence of thermophilic *Campylobacter* in slaughtered pigs (n=66) in Morogoro slaughter slabs was 66.7% while contamination rate of dressed carcasses was 10.6%. Of the *Campylobacter*-positive carcasses, five (12.2%) were from the animals which were also positive to *Campylobacter*. The isolation rate of *Campylobacter* in the cecum was higher (34.8%) compared to the small intestines (28.8%) and colon (16.7%). *Campylobacter jejuni* was the most prevalent species constituting 74% of all isolates, while *Campylobacter coli* was 26%.

## **6. Relapsing fever**

Role of pigs in the epidemiology of human relapsing fever have been done in Mvumi area in Central Tanzania. No studies have been done in Uganda, Kenya, Burundi and Rwanda. The first study was when it was found that 42.5% (N=51) of 120 soft ticks (*Ornithodoros porcinus*) collected from 8 households in Mvumi Mission near Dodoma were infected with *Borrelia duttoni* a causative agent of relapsing fever (Mitani *et al.*, 2004). It was also found that another soft tick *O. moubata* infesting pigs, was also capable of maintaining and transmitting *B. duttoni* to humans in relapsing fever endemic areas like Tanzania (Tabuchi *et al.*, 2008).

Another study was done on dynamics of soft ticks in human households (McCall *et al.*, 2011). *Ornithodoros* soft tick infestation of the 122 households in villages in Mvumi hospital in central Tanzania was found to be high (47%). Pig pens also were tick infested (16%) and were more likely to be so if they were located close to tick infested households ( $p<0.001$ ). PCR screening of peripheral blood found *Borrelia duttoni* infections in both chickens (11%) and pigs (8.9%). In a mark-recapture experiment, ticks released in pigpens were recaptured inside human bedrooms. When offered chickens as hosts, over 20% of ticks fed.

Culter (2010) reported that relapsing fever was listed among the top ten causes of children mortality under five in Tanzania.

## **7. Brucellosis**

No study was done to determine prevalence of brucellosis (*Brucella suis*) in pigs in East Africa. After reviewing literature on brucellosis in sub-Saharan Africa McDermott and Arimi (2002) found that in East Africa, the occurrence and epidemiology of brucellosis in pigs was poorly understood.

## **8. Anthrax (*Bacillus anthracis*)**

There were no reports of *Bacillus anthracis* in pigs in all the East African countries

**9. Erysipelas (*Erysipelothrix rhusiopathiae*)**

There were no reports of *erysipelas* in pigs in Uganda, Rwanda, Tanzania and Burundi. However two outbreaks have been reported in Kenya (Wabacha *et al.*, 1998 and Frienship and Bilkei, 2007). Wabacha *et al.* (1998) reported that ten pigs from a herd of 181 pigs in a medium-scale, semi-closed piggery in Kiambu District, Kenya, contracted the clinical disease during July/August 1997. Also Frienship and Bilkei (2007) reported a concurrent outbreak of *Erysipelothrix rhusiopathiae* and *Clostridium novyi* occurring in a large outdoor pig-breeding unit in Kiambu district in Kenya resulting in high mortality.

**10. *Streptococcus suis***

There were no reports of *Streptococcus suis* in pigs in all the East African countries

**11. Q-fever**

There were no reports of Q-fever in pigs in all the East African countries

**12. Influenza**

There were no reports of influenza in pigs in all the East African countries

**13. Rabies**

There were no reports of rabies in pigs in all the East African countries

**14. Ebola**

There were no reports of ebola virus in pigs in all the East African countries

**15. Ndumu virus**

One study was done in which Ndumu virus was first isolated in pigs in Uganda (Masembe *et al.*, 2012). Serum samples from 16 domestic pigs were collected from five regions in Uganda and pooled accordingly and screened for the presence of RNA and DNA viruses using a high-throughput pyrosequencing method.

**16. Zoonotic nematodes**

**16.1. Trichuris**

Based on genetic analysis of *Trichuris* species (*Trichuris suis* and *Trichuris trichuria*) obtained from naturally infected pigs and humans in Uganda, it was shown that there was hybridization of the two species suggesting that *T. suis* could act as a zoonosis where humans and pigs live in close proximity (Nissen *et al.*, 2012 and Damiana *et al.*, 2012).

One study has been done to determine prevalence of nematodes in pigs in Kabale in South Western Uganda through faecal examination (Nissen *et al.*, 2012). Out of 106 pigs examined, 91% had nematode eggs and 17% had *Trichuris suis* eggs. When a postmortem (PM) was done on 15 pigs positive with *T. suis* eggs, adult *T. suis* worms (ranging from 6-58 worms in number) were recovered from 67% (n=10) of the pigs. Low number of adult worms recovered was associated with deworming.

One study has been done to determine prevalence of nematodes in pigs in Busia district in Western Kenya through faecal examination (Kagira *et al.*, 2012). Examination of faecal samples from 306 free range pigs from 135 farms gave overall prevalence of 84.2% of pigs with worm infestation and Eggs Per Gram (EPG) of faeces of 2,355 per pig. Seven percent of the pigs had *Trichuris suis* infestation.

## **16.2. *Ascaris suum***

One study done in Kabale in South Western Uganda (Nissen *et al.*, 2012) found 40% infestation of pigs with *Ascaris suum*. On doing a PM on 15 pigs positive with *T. suis* eggs, adult *A. suum* worms (ranging from 1-36 worms) were recovered from 73% (n=11) of the pigs.

In Kenya, two studies reported *A. suum* in pigs. One study reported by Nganga *et al.* (2008) examined 115 gastrointestinal tracts from 61 growers and 54 adult pigs between February 2005 and January 2006 and found *Ascaris suum* prevalence of 28.7%. According to these authors, these parasites were mixed infections with other helminths and the highest worm counts were detected in the out door production systems of management. Also in another study done in pigs in Busia district in Western Kenya (Kagira *et al.*, 2012) found 18% prevalence of *A. suum* among the pigs.

Three studies done on pig slaughter abattoirs and slabs recovered adult *A. suum* worms in Tanzania. A prevalence of 8.1% was reported among 731 pigs examined in 24 privately owned pig slaughter slabs in Dar es Salaam city (Mkupasi *et al.* 2011). A prevalence of 44.3% of *A. suum* was reported among 70 pigs examined in 3 slabs in Northern Tanzania receiving pigs from Mbulu district (Ngowi *et al.*, 2004). A review of 3 year pig slaughter records in Arusha abattoir in Northern Tanzania revealed that out of 13,310 of pigs slaughtered, Ascariasis was found to be the only cause of liver condemnation in 4.03% of the pigs (Mellau *et al.*, 2011). Porcine ascariasis caused economic losses due to liver condemnations.

In an earlier study, Esrony *et al.* (1997), investigated the prevalence, burden and types of gastrointestinal helminths in 424 local and cross-bred pigs kept under different management systems in two climatic zones in the Morogoro region of Tanzania. According to this study, fecal examination revealed that 53% of the pigs excreted worm eggs in their faeces. The prevalence of *A. suum* was 12%. Climate where the pigs were raised seemed to have influence on the infection of the pigs. The local breeds in the Mgeta location with tropical highland climate were reported to have significantly higher prevalence and mean EPG values than the cross-bred animals in the semi-arid area. Age was also a risk factor. The piglets were reported with significantly lower prevalence of helminthosis than the weaners, growers and adults in both local and cross-bred animals.

### 16.3. *Ancylostoma* species

There were no reports of *Ancylostoma* species in pigs in all the East African countries

## 17. Zoonotic ectoparasites

No studies have been done to study ectoparasites of pigs in Uganda, Kenya, Rwanda and Burundi. One survey of ectoparasites has been done in Tanzania (Braae *et al.* 2013). Only one farmer perception survey on constraints to pig production was done in Kenya (Kagira *et al.*, 2010).

Survey was done on prevalence of ectoparasites in Mbeya region of Tanzania among 128 farmers (96 practising confinement and 32 free range). The prevalence of ectoparasites on pigs within confinement and free-range production systems was 24% and 84%, respectively (Braae *et al.*, 2013).

### 17.1. *Tunga penetrans*

*Tunga penetrans* was found in 5% and 13% of pigs within confined and free-range systems, respectively, in Mbeya region of Tanzania (Braae *et al.* 2013). Outbreaks of jiggers have occurred with high prevalence in Uganda (Jawoko, 2011) and Tanzania (Mazigo *et al.*, 2012). In Uganda jigger outbreaks have occurred with pigs being incriminated as a source in Busoga (Colley, 2010) and Kitgum (Daily Monitor, 2013).

### 17.2. *Haematopinus suis*

A louse *Haematopinus suis* was the most prevalent (20% among confined pigs and 63% among free-range pigs) in Mbeya region of Tanzania (Braae *et al.*, 2013).

*Haematopinus suis* infestations were considered to be the most pig important diseases by 71% (n=129) of small holder farmers in free range production in Busia in Western Kenya. Only 38% had history of spraying pigs (Kagira *et al.*, 2010).

### 17.3. *Sarcoptes scabiei* var. *suis*

Kambarage (1991) first documented infection of pigs with *Sarcoptes scabiei* var. *suis* in Tanzania and these pigs were successfully treated with 20% phosmet at a dose rate of 20 mg/kg body weight. Braae *et al.* (2013) reported also two percent of pigs were found infested with *Sarcoptes scabiei* var. *suis* among free ranging pigs in Mbeya region in Tanzania..

## Pork safety

## 18. Cysticercosis

## Uganda

There are 7 reports on prevalence of porcine cysticercosis (PC) in Uganda ( Anyazo (1999), Kisakye and Masaba, 2002, Phiri *et al.*, 2003, Waiswa *et al.*, 2009; Nsadhha *et al.*, 2010; Nsadhha *et al.*, 2011 and 2012). One was literature review, 2 abattoir surveys, 4 lingual and 2 serological surveys.

Preliminary surveys in 1998 and 1999 at slaughterhouses in Kampala indicated a prevalence of porcine cysticercosis of 0.12-1.2% (Phiri *et al.*, 2003). Also a rural survey reported by Anyazo (1999) and Phiri *et al.* (2003) in northern Uganda in Moyo county in Moyo district in 1999 indicated a prevalence of 34-45% in pigs slaughtered in selected villages .

Later another survey of 297 pigs slaughtered in Kampala reported by Kisakye and Masaba (2002) and Phiri *et al.* (2003) indicated that pigs from the central region of the country (n=214) were negative for cysticercosis while 33.7% (n=28) of the pigs coming from the rural Lira district (n=83) in the north were positive. Only 7.23% (n= 6) of positive carcasses were condemned for human consumption but if strict national meat inspection guidelines had been followed, that is carcasses with more than 7 cysts be condemned, then 20 carcasses should have been condemned (71.4% of the positive carcasses). During the same study, It was found that transplacental infection of foetuses due to PC occurred in one infected sow. Interestingly 8 piglets foetuses removed from this sow coming from Lira district were all harbouring cysts of *T. solium*.

Waiswa *et al.* (2009) reported the first sero-prevalence of porcine cysticercosis to be done in South Eastern Uganda in Kamuli and Kaliro and found 8.6% of 480 pigs sero positive. Twenty six percent (138/528) of households did not have latrines.

The second study in Kamuli and Kaliro reported by Nsadhha *et al.* (2010) determined the risk factors for high presence of cysticercosis in pigs as lack of latrine use, free ranging of pigs and ignorance on transmission of PC.

Nsadhha *et al.* (2011) reported the findings of a survey which was done to determine spatial inter-relatedness of epilepsy, porcine cysticercosis and taeniosis in Lake Kyoga Basin in Uganda. Porcine Cysticercosis was determined using lingual palpation. Presence of latrines and prevalence of porcine cysticercosis, taeniosis and epilepsy in the household in the last five years was determined through household interviews. Percentage response of households and pigs with cysticercosis were as shown in Table 2. The mean percentage latrine presence was  $37.8 \pm 4.8\%$ , prevalence of porcine cysticercosis was  $12 \pm 2.4\%$ , taeniosis  $18 \pm 4.8\%$ , epilepsy  $23.2 \pm 3.2\%$  in Kyoga basin.

Table 2. Percentage presence of latrines and prevalence of porcine cysticercosis, taeniosis in the household in the last five years

	Percentage			
	Presence of latrine	Porcine cysticercosis	Taeniosis in home last 5 years	Epilepsy

Buyende	54.3	12	15	22
Kayunga	48.6	8.3	6.9	26
Kaliro	36.9	6.2	36	23
Apac	23	7.4	22	11
Oyam	33	19	9.6	22
Kaberamaido	30.9	19	19	35

Nsadhha *et al.* (2012) reported that porcine cysticercosis was endemic at transborder areas of Uganda in Arua, Busia and Kibale, and along major border transit route via Masaka with seroprevalence between 10-27% and lingual prevalence of 3-8% (see Table 3). Three pigs per household were sampled in 48 households per district. This study showed that the active pick and carry mode of roasted pork vending at the transit points along the major trade routes and at commercial border points of Uganda was a possible route of infection of man by *Taenia solium*. The tongue lesions alone were not conclusive for diagnosis of cysticercosis in pigs since all the eight pigs with doubtful lesions on postmortem were positive, with 25% (n=2) of them having heavy cyst infestation with an average of a cyst per every 4cm<sup>2</sup> of muscles in pectoral, thigh and brain tissues.

Table 3. Percentage prevalence of cysticercosis at transborder areas of Uganda in Arua, Busia and Kibale and Masaka

	Lingual examination	Serodiagnosis
Arua	8	27
Busia	5	10
Kibale	3	14.5
Masaka	6	15

No studies have been done in Teso region in Eastern Uganda.

## Tanzania

There are 7 reports on prevalence of porcine cysticercosis in Tanzania (Phiri *et al.*, 2003, Ngowi *et al.*, 2004a, Ngowi *et al.*, 2004b, Boa *et al.*, 2006, Ngowi *et al.*, 2010, Mkupasi *et al.*, 2011 and Mellau *et al.*, 2011). Of these studies, 1 was a review, 3 were postmortem and 4 lingual examinations.

According to Phiri *et al.* (2003) cysticercosis was first detected in late 1980s in Tanzania, when pigs exported to Kenya from the northern highland district of Mbulu were found to be heavily infested with cysticercosis on slaughter. Retrospective studies were done on records from slaughter slabs in Mbulu which gave prevalence ranging from 0.41-4.88%.

In 1993, a postmortem survey was carried out in pig slaughter slabs in northern highlands (Arusha, Moshi and Mbulu) which indicated 4.5-37.7% prevalence of cysticercosis (Phiri *et al.*, 2003).

Between December 1997 and March 1998, another study was done on 3 slaughter slabs that receive pigs from Mbulu (a district endemic for porcine cysticercosis) in northern Tanzania reports (Ngowi *et al.*, 2004a). Seventy carcasses of pigs between 1 and 2 years old were examined. The examination involved ante-mortem lingual examination by pig traders for cysticercosis followed by post-mortem inspection at the abattoir. No cysticercosis was found. The lack of cases of porcine cysticercosis in this study compared to previous studies suggested that pig traders were conducting their own ante-mortem lingual examinations before purchasing pigs in the rural communities where the parasite was still highly prevalent.

Later high prevalence of 17.4% (village-specific range 3.2-46.7%) of porcine cysticercosis in 770 live pigs examined by lingual examination in 21 villages of Mbulu District, northern Tanzania was reported by Ngowi *et al.* (2004b). Prevalence of porcine cysticercosis was considerably higher in pigs reared in households lacking latrines than in those reared in households that were using latrines. About 96% of the pigs were kept under free-range conditions.

Further study in Mbulu, found prevalence of cysticercosis to be 7.3% (N=784) in 42 villages by lingual examination of pigs aged 2-12 months (Ngowi *et al.*, 2010). This study also showed that spatial maps were very useful in identifying clustering of the cysticercosis where control efforts should be directed in case of limited resources.

In southern highlands zone (Mbeya, Iringa and Ruvuma) of Tanzania where more than 60% of pigs under the small-scale production system are raised, Boa *et al.* (2006), reported overall prevalence of 9.5% (173/1832) by lingual examination among pigs. Prevalence per district was found to be 7.6% (55/722) in Chunya district, 8.4% (68/808) in Iringa district and 16.9% (n=51/302) in Ruvuma district. In this study risk factors were identified as free-ranging of pigs, home slaughtering of pigs and pork not being inspected, lack of latrine and barbecuing.

Among 24 privately owned pig slaughter slabs in Dar es Salaam city, Tanzania, a prevalence of cysticercosis of 5.9% was found among 731 pigs examined (Mkupasi *et al.*, 2011). All slaughter pigs in Dar es Salaam originated from different regions. Based on the region of origin, the status of porcine cysticercosis was 8.2% for Dodoma (n = 98), 8.2% for Manyara (n = 260) and 6.9% for Mbeya (n = 116).

In Arusha abattoir in Northern Tanzania a review of 3 year pig slaughter records revealed that out 13,310 of pigs slaughtered 1.397% (n=186) of the carcasses were totally condemned due to cysticercosis (Mellau *et al.*, 2011) and this caused economic loss.

## **Kenya**

Two studies have been done on prevalence of porcine cysticercosis among pigs in Homa bay district (Eshitera *et al.*, 2012) and Busia district in Western Kenya (Kagira *et al.*, 2012) among free ranging pigs.

In Homa Bay district in Kenya a survey carried in 2010, a prevalence of PC of 32.8% (70/32) and 5.6% (22/ 392) was found by the Ag-ELISA and lingual inspection of cysticerci,



respectively. The most important risk factor for porcine cysticercosis in the Homa Bay area was for pigs to belong to farms with no latrine and free-ranging of pigs.

In Busia District, Kenya, seroprevalence of cysticercosis of 4% (n=11) was found among 284 pigs tested and 9% of farms out of 182 smallholder farmers (Kagira *et al.*, 2012) had pigs which tested positive. Risk factors at farm level were identified as: free-range pig keeping (100%), history of human taeniosis infection in a family (51%), slaughtering of pigs at home (20%), lack of meat inspection (15%) and absence of latrines (15%). The only significant ( $\chi^2 = 4.4$ ,  $P = 0.034$ , odds ratio (OR) = 3.8) risk factor associated with the occurrence of cysticercosis was lack of latrines at household level. The study shows that porcine cysticercosis is prevalent in free-range pigs in Busia District, Kenya and thus control measures need to be instituted.

### **Burundi**

Meat inspection detected cysticercosis in 2% and 39% of pigs in 2 localities, respectively, in Bururi province, Burundi (Newell *et al.*, 1997).

### **Control of porcine cysticercosis in pigs**

No practise and study has been done in Uganda on treatment of porcine cysticercosis. One study has been done in Tanzania (Sikasunge *et al.*, 2008). A study was done to assess the effect of treating *Taenia solium* infected pigs with oxfendazole (OFZ) on viability and clearance of cysticerci and the corresponding persistence of specific antibody isotypes and circulating cysticercal antigen (CCA). Twenty infected pigs were subjected to treatment with OFZ and treated pigs were killed at 1, 4, 8 and 26 weeks post treatment. It was showed that OFZ killed muscular cysticerci over a period of 4 weeks but failed to kill cerebral cysticerci. Antibodies, CCA responses and clearance of dead cysts from the meat, depended on the cyst intensity of individual pigs at time of treatment since both antibody and CCA correlated with intensity of cysticerci at necropsy ( $r=0.441$ ,  $P=0.005$ ;  $r=0.654$ ,  $P<0.001$ ), respectively. IgG1 responses were the best indicator of treatment efficacy because they were predominant in both infected treated and control pigs and disappeared early after treatment. Both Ab/Ag-ELISA failed to detect cysts in the brain, though dead cysticerci took 26 weeks to clear from the meat.

### **Neuro cysticercosis**

#### **Uganda**

No serological surevy has been done to determine prevalence of neurocysticercosis in Uganda. However one study was done (Nsadha *et al.*, 2011) to determine prevalence of epilepsy by interviewing households in Lake Kyoga basin which is endemic with porcine cysticercosis. Prevalence of epilepsy in Lake Kyoga basin as perceived by the communities was as shown in Table 1.

#### **Burundi**

In Burundi, 3 studies have been done (Nzisabira *et al.*, 1992, Newell *et al.*, (1997) and Nsengiyumva *et al.*, 2003). Burundi was the first country to get concerned with neuro-cysticercosis in East Africa. Prompted by the diagnosis of two cases of neuro-cysticercosis in patients from the Kayaza province, a study was conducted to determine the prevalence of neurocysticercosis among patients who presented with more than two convulsive seizures (Nzisabira *et al.*, 1992). Among patients with convulsive seizures, 62.5% had neuro-cysticercosis. Diagnosis was established using 3 criteria: positive ELISA reaction in blood and/or cerebrospinal fluid; presence of cysticercosis in subcutaneous node. It was found that all patients investigated ate pork.

Newell *et al.* (1997) reported a study which was done in the province of Bururi in Burundi, where 103 epileptics and 72 control subjects from the same households were examined for cysticercosis. Antigen was detected by enzyme-linked immunosorbent assay in 4.9% of epileptic persons and in 4.2% of controls. Antibody was detected by enzyme-linked electroimmunotransfer blot assay (EITB) in 11.7% of epileptics and in 2.8% of controls. Cysticercosis was significantly more frequently diagnosed by EITB in people with a history of taeniosis than in those without such a history. The prevalence of taeniosis in school children ranged between 0-1.0%.

A prevalent matched case-control design was used in the Kiremba area in Burundi, between March and April 2001 to evaluate a role of cysticercosis in causing epilepsy (Nsengiyumva *et al.*, 2003). One case with epilepsy was matched to two control subjects, according to their age. Cases were subjects who had shown at least two unprovoked epileptic seizures within a 24 hour time range and who lived in the Kiremba area. The control subjects also lived in Kiremba and had neither neurologic illness nor kinship with the people with epilepsy. Seropositivity for cysticercosis was the exposure variable. Three hundred twenty-four prevalent cases, with onset of epilepsy between 1950 and 2000, and 648 age-matched controls were included. It was found that there was a link between cysticercosis infestation and the occurrence of epilepsy (odds ratio, 3.8; 95% confidence interval, 2.5-5.1). The attributable risk for cysticercosis was 50% (95% confidence interval, 42-57%) in this population. Cysticercosis was found to be a very important disease in this area because 31.5% of the control subjects screened turned positive for this parasite.

## **Tanzania**

There was one study. Blocher *et al.* (2011) reported a study which followed 212 people with epilepsy (PWE) for 28.1 months in Tanzania. CT scans were performed, and serum and cerebrospinal fluid (CSF) of selected PWE were analysed. PWE with NCC (n=35) were more likely to be older at first seizure (24.3 vs. 16.3 years,  $p=0.097$ ), consumed more pork (97.1% vs. 73.6%,  $p=0.001$ ), and were more often a member of the Iraqw tribe (94.3% vs. 67.8%,  $p=0.005$ ) than PWE without NCC (n=177). PWE and NCC who were compliant with anti-epileptic medications had a significantly higher reduction of seizures (98.6% vs. 89.2%,  $p=0.046$ ).

This study found that the electroimmunotransfer blot, developed by the Centers for Disease Control and Prevention, was more sensitive for detection of PWE with NCC than a commercial western blot, especially in PWE and cerebral calcifications.

## **Neuro cyticercosis control**

### **Education**

No education efforts have been done to control porcine cysticercosis in Uganda. One study was done in Tanzania and one also in Kenya.

One study to determine effectiveness of health and pig-management education intervention in reducing the incidence rate of porcine cysticercosis has been done in Tanzania in Mbulu District, northern Tanzania, between April 2002 and July 2004 among 827 pig-keeping households from 42 villages that were randomly selected (Ngowi *et al.*, 2008). It was found that knowledge about the transmission and prevention of porcine cysticercosis was improved by more than 42%. The intervention had a significant (20%) reduction in the reported cases of household consumption of infected pork. Education had a considerable 57% decrease in the incidence rate of porcine cysticercosis as measured by antigen-ELISA in sentinel pigs. Public education could lead to a reduction of the risk of infection in humans.

One study was done to determine the effectiveness of teaching methods in control and prevention of human neurocysticercosis in Western Kenya (Wohlgemut *et al.*, 2010). A questionnaire was administered to 282 Kenyan farmers, followed by a workshop, a second questionnaire, one-on-one training, and a third questionnaire. It was found that people who attended workshops were more likely to know how *T. solium* causes epilepsy in humans in the third visit than the second ( $P = 0.001$ ). The likelihood that farmers would tether their pigs 100% of the time, limiting exposure to tapeworm eggs, increased after the first ( $P < 0.001$ ) and second visits ( $P < 0.001$ ). Farmers were more likely to have heard of *Cysticercus cellulosae* in the second ( $P = 0.001$ ) and third visits ( $P = 0.007$ ), and to know how pigs acquire infection in the second ( $P = 0.03$ ) and third visits ( $P = 0.003$ ). Farmers with at least a grade 8 education were more likely to know how *T. solium* was transmitted to humans in the second ( $P = 0.001$ ) and third visits ( $P = 0.009$ ), and were more likely to understand the relationship.

### **19. *Taenia hydatigena***

No studies done in Uganda. Ngowi *et al.* (2004a) reported a prevalence of *Taenia hydatigena* of 1.4% among 70 pigs examined in 3 slabs in northern Tanzania receiving pigs from Mbulu district.

### **20. *Trichinella* species**

No studies done in Uganda. One attempt was in Tanzania in Mbulu slaughter slabs and no *Trichinella* species was detected in the pork carcasses (Ngowi *et al.* 2004a).

### **21. *Toxoplasma gondii***

There were no documented studies of *T. gondii* in pigs from all the East African countries. However, all the countries reported studies documenting the occurrence of *T. gondii* in humans.

### **22. *Sarcosystis suihominis***

There were no documented studies of *Sarcosystis sui hominis* in pigs from all the East African countries.

### **23. *Alaria alata***

There were no documented studies on *Alaria alata* in pigs from all the East African countries. There were even no reports of studies done on *Alaria alata* in humans in all the East African countries.

### **24. Salmonellosis**

No explicit studies have been done on presence of *Salmonella* organisms in pigs and pork in Uganda. One study was done on typhoidal *Salmonella* in children with diarrhoea and slaughter animals in Kampala district (Nasinyama *et al.*, 1998). This study found that 8.1% of stools of patients with acute diarrhoea in Kampala district had *Salmonella* infection, with 69.2% of isolates exhibiting antibiotic resistance. However this study did not characterize the isolates. Outbreak of typhoid fever associated with food contamination was reported in Uganda 2008 (Mensah *et al.*, 2012a).

Another study reported by Kalule *et al.* (2012) compared the plasmid profiles and drug susceptibility of *Salmonella* isolates from humans (n=58) and food of animal origin (n=34) in Uganda. Foods of animal origin (cattle, chicken, pigs, eggs and milk) was collected from markets around the country and stored at Central Diagnostic Laboratory, College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University. It was found that 76% of meat and meat products were contaminated with *Salmonella* species. Drug resistance was tested against 8 drugs (tetracyclines, ampicillin, chloramphenicals, nalidixic, trimethoprim-sulhamethoxazole, ciprofloxacin, ceftriaxone and tetracycline). Among the human isolates 98.3% (57/58) and in animal isolates 94.1% (32/34) were susceptible to ciprofloxacin. Of the isolates 82.7% (48/58) and 85.3% (29/34) from humans and animals, respectively, were resistant to trimethoprim-sulhamethoxazole. Fifty four percent (n=50) of all isolates were resistant to at least 3 antibiotics and only 2.2% (n=2) were susceptible to all the seven drugs. Only 45% of isolates were sensitive to all the three drugs (chloramphenical, nalidixic and ciprofloxacin) commonly used for treatment against salmonellosis in Uganda. The resistance pattern to these commonly used drugs was that the *Salmonella* isolates were more resistant to chloramphenical and sensitive to nalidixic and ciprofloxacin.

A study was done to characterise isolates and antibiotic resistance of *Salmonella* collected from pigs in Kenya and was reported by Kikui *et al.* (2007) and (2010). In this study the overall prevalence of *Salmonella* on pig carcasses was 19% and 8.6% in faeces samples. However Kikui *et al.* (2010) reported *Salmonella* prevalence of 13.8% (n=16) of 116 samples collected from randomly selected pigs at the Ndumbuni abattoir in Nairobi. Three *Salmonella enterica* sub-species *enterica* serovars, namely *Saintpaul* (*S. Saintpaul*), *Braenderup* (*S. Braenderup*), and *Heidelberg* (*S. Heidelberg*), were identified, with *S. Saintpaul* being the predominant serovar. Antimicrobial resistance was found in 35.7% of all the isolates. The *S. Heidelberg* isolates were susceptible to all the antimicrobial agents tested. Multidrug resistance was found in 7.1% of the resistant *Salmonella* isolates. Plasmids were only detected in *S. Heidelberg*. Ampicillin resistance was based on expression of a bla(TEM) gene, while chloramphenicol,

streptomycin, and tetracycline resistances were encoded by the genes *catA1*, *strA*, and *tet(A)*, respectively.

## **25. *Yersinia enterocolitica***

There were no reports of investigations of *Y. enterocolitica* in pigs in Uganda, Rwanda, Burundi and Tanzania. There was only one old report of *Y. enterocolitica* in pigs from Kenya, but even this one was in 1988 (Turkson *et al.*, 1988). In this paper rectal swabs or faecal samples from 992 domestic animals and 97 human patients in the Nairobi area were cultured for *Y. enterocolitica*. Only one isolate of *Y. enterocolitica* was recovered from one of the 150 healthy pigs examined, indicating a prevalence of 0.7% .

## **26. *Giardia duodenalis***

There were no documented studies of *G. duodenalis* in pigs from all the East African countries. However, with the exception of Burundi, all the other countries have reported the occurrence of *G. duodenalis* as an important public health pathogen.

## **27. Toxigenic *Escherichia coli***

No documented studies of toxigenic *Escherichia coli* in pigs from all the East African countries were found. There were even no reports of toxigenic *Escherichia coli* in humans in Burundi, Rwanda and Tanzania.

## **28. *Cryptosporidium***

The literature review did not find studies on *Cryptosporidium* in pigs in any of the East African countries. However, *cryptosporidium* infections in humans have been reported in all the 5 countries of East Africa.

## **29. Hepatitis E**

There was total lack of studies on Hepatitis E in pigs in all the East African countries. However, with the exception of Rwanda, the other East African countries reported occurrence of Hepatitis E in people.

## **30. Foodborne non-zoonotics**

### **30.1. Pesticides residues, antibiotic residues, heavy metals and mycotoxins**

There were no reports of investigations of pesticide and antibiotic residues, heavy metals and mycotoxins (Ochratoxin A; Zearalenone) in pork in all the East African countries.

### **30.2. Blue pork**

There are reports of occurrence of blue pork in Uganda, whose cause is not known upto today (Wendo, 2002 and All Africa, 2005).

## **Risk factors for pork safety**

The pigs are slaughtered in unhygienic conditions in Uganda including the co-operative owned Wambizi abattoir in Kampala. Teljer (2012) reports that in Gulu, slaughter places are in open, small, poorly equipped, waste flows freely and easily accessible by other animals / pigs and flies. Pezo and Rösel (2012) reiterated that there are several possible risk factors that may compromise pork safety in Wambizi abattoir in Kampala. These include: the location of the abattoir in a flood prone site, no restriction to access to abattoir facility, lack of abattoir basic infrastructure, incomprehensive inspection; poor condemnation; no protective clothing for workers, no medical check up for workers and no records of pork inspection.

Elsewhere in East Africa, the situation was the same in Tanzania (Mkupasi *et al.* 2011) and Kenya (Kikuvi *et al.*, 2007 and 2010); and Mkupasi *et al.* 2011) reported that all the 24 privately owned pig slaughter slabs in Dar es Salaam city, Tanzania, were sub-standard; wrongly located, poorly designed and constructed and lacked most basic requirements for a slaughter house. Because of inadequate slaughtering, disposal and cleaning facilities; the slaughter slabs were under unhygienic condition with questionable safety, soundness and wholesomeness of the pork produced.

Another risk factor for production of unsafe pork is poor unhygienic housing of pigs practised in Uganda. Muhanguzi *et al.* (2012) reported that 98% of pig farmers in Central Uganda housed their pigs in local unhygienic mud houses. Similar situation was observed in Gulu district (Teljer, 2012), like elsewhere in Uganda where free range and backyard pigs are kept, they are housed in muddy conditions under tree shades, open roofed and mud wattled huts.

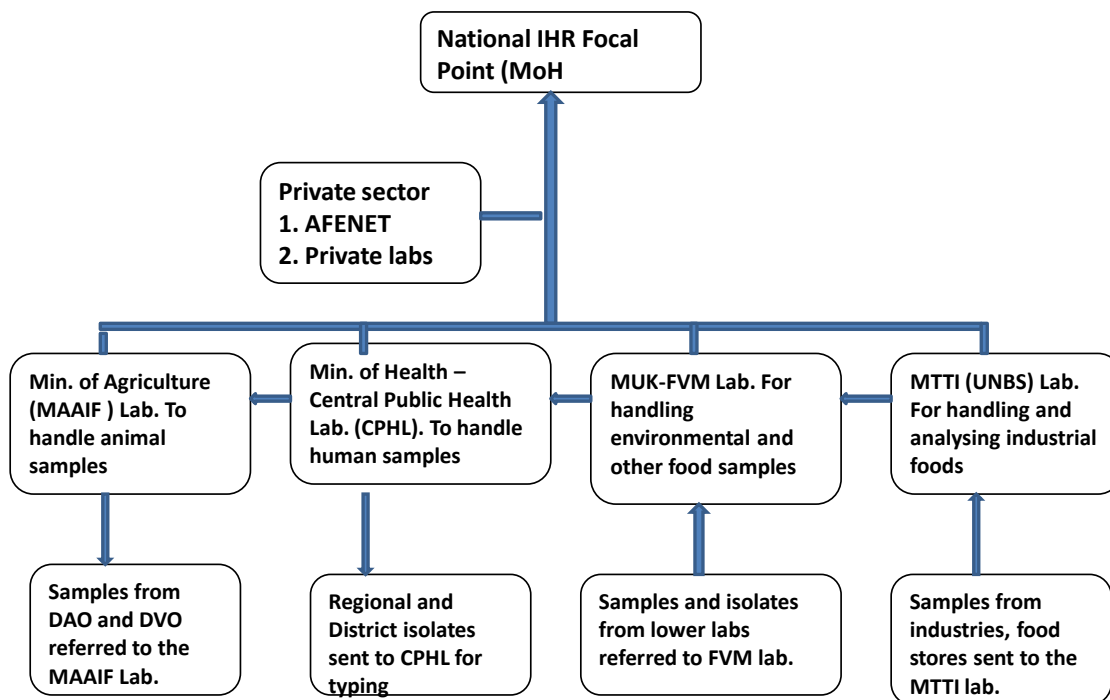
Free ranging pig systems predispose pigs to diseases that make pork unsafe. Most (90%) of the pig production systems in Uganda were free ranging scavenging systems or backyard systems of production (CGIAR, 2011). The similar situation was seen in Western Kenya (Kagira *et al.*, 2010, Kagira *et al.*., 2012 and Thomas *et al.*, 2013). Thomas *et al.* (2013) observed that in western Kenya pigs travelled an average of 4,340 m in a 12 hr period and had a mean home range of 10,343 m<sup>2</sup> (range 2,937-32,759 m<sup>2</sup>) within which the core utilisation distribution was found to be 964 m<sup>2</sup> (range 246 -3,289 m<sup>2</sup>) with pigs spending on average 47% of their time outside their homestead of origin.

Home slaughter makes pork unsafe because it is uninspected. Most pork in rural Uganda is home slaughtered (Teljer, 2012). Sixty six percent of pigs slaughtered in Kisumu are home slaughtered without pork inspection (Kagira *et al.*, 2010).

Uganda's lack of government policy on food safety hinders practise of production of safe pork. According Barungi (2010) the rate of evolution of the food safety system in Uganda is very slow. The Food and Drug Act which is the main law that currently governs food safety in Ugnada was enacted in 1964 and in 1993 (WHO, 2003 and Barungi, 2010). In 2003, Uganda Food and Nutrition policy / strategy was developed (MAAIF and MOH, 2005) to guide in formation of food safety policy. Currently there is draft Food Safety Bill intended to replace 1964 Food and Drugs Act which awaits approval by Parliament. However, this draft does not solve the coordination challenge as food safety remains under the control of many Ministries and Departments; and the infrastructure fragmented (Barungi, 2010). WHO (2003) provides guidelines and procedures of developing food safety policy and laws.

According to WHO (2007) report, in 2003, data from WHO African region indicated that out of 45 countries that had proposed food control legislation only 13 countries had enacted laws. Uganda was among those that had not enacted. In 2006 that 29 countries had National Authorities that had established food safety standards based on Code Alimentarius guidelines.

Poor food-borne disease surveillance system is another factor that promoted provision of unsafe pork (Mensah *et al.*, 2012a and 2012b). In Uganda Ministry of health is trying to establish laboratory based food-borne disease surveillance system ( see Figure 2) (Mensah *et al.*, 2012b).



**Figure 2: for the laboratory based foodborne disease surveillance , Ministry of Health, Uganda (Mensah *et al.*, 2012).**

## Discussion

### Zoonoses

Although not much research has been done on most of the zoonotic hazards in Uganda, studies done on trypanosomosis (Waiswa *et al.* 2003 and Wiaswa, 2008) in Kamuli and Mukono in South-Eastern Uganda have clearly highlighted pigs as the major reservoir of human trypanosomosis. The major trypanosomosis cycle was a human-pig-tsetse cycle. Pigs were providing a major blood meal to vector *Glossina fuscipes fuscipes*. Similarly, in Western Kenya in Teso district (Ng'ayo *et al.*, 2005) and Busia district (von Wissmann *et al.*, 2011) pigs were reservoir of human trypanosomosis. This implies that when doing trypanosomosis control, pigs should as well be considered. Pigs should therefore be sprayed using deltamethrin products and treated with prophylaxis and curative trypanocidals. The usual practice has been that trypanosomosis control has been done on cattle alone.

On contrary, in North western Uganda, although pigs had the highest infection rates (21.7%), they did not carry human animal trypanosomes whether *T. b. gambiense* or *T. b. rhodesiense* (Balyeidhusa *et al.*, 2013). This could be due to the fact that there were no carriers of human trypanosomosis in this area. The high prevalence trypanosome infection rates in pigs other than other domestic animals show that pigs were most commonly tsetse fly bitten domestic animal.

In Teso, Lango and Acholi areas which were recently invaded by tsetse flies no studies have been done to determine the role of pigs in epidemiology of human trypanosomosis. These areas currently have high burden of animal and human trypanosomosis. It is therefore paramount that surveys should be done to determine pig trypanosome species infection rates in these areas and ascertain the role of pigs in the epidemiology of HAT.

Studies done by Omolo *et al.* (2009) recommend that monitor lizard odour kairomones and pig odour should be incorporated in tsetse traps in order to increase their trapping efficiency for *Glossina fuscipes fuscipes*. Alternatively this monitor lizard odour kairomones should be incorporated together with deltamethrin spray products so that more tsetse is attracted after spraying hence having a high tsetse knock effect hence improving the efficiency of the tsetse fly control efforts.

Much as impressive research has been done on pig trypanosomosis, a lot is still desired. Most of the studies were based on establishing the prevalence and reservoir analysis. Many gaps still occur especially on control, delineation of risk factors and impact assessment. The latter are vital for understanding the disease dynamics and development of policies for its effective control and prevention.

For the case of tuberculosis, the report of occurrence of *M. bovis* (Muwonge *et al.*, 2012) in slaughter pigs in Uganda is interesting. Moreover the findings that the isolates *M. bovis* spoligotype SB 1469 strain found were identical to a spoligotype previously reported by Oloya *et al.* (2007) and (2008) from humans and cattle in the Karamoja (North eastern) part of the Uganda bear great public health significance. Therefore, arguably, there is a need for close cooperation between Medical and Veterinary professionals in designing and implementing control and prevention measures that will safeguard the public from pigs as a potential source of TB in Uganda.



Apart from *M. bovis*, the reports reviewed showed that pigs were a significant source of Non-Tuberculosis Mycobacteria (NTM). Indeed Muwonge *et al.* (2010) documented the first occurrence of NTM in pigs of 9.3% by postmortem and 3.1% by culture in Uganda and East Africa as a region. Later NTM isolates were characterized (Muwonge *et al.*, 2012). These authors found that mycobacteria were present in 39% of cultured lymph nodes from slaughtered pigs in Mubende district of Uganda. Sixty three per cent were from lymph nodes with macroscopic lesions compatible with mycobacteriosis and 31.4% were from those without lesions. The high presence of mycobacteria in normal lymph nodes suggests that a considerable amount of mycobacteria could be missed at inspection. Therefore stringent pork inspection practice should be executed to reduce the human exposure. Given the lack of appropriate meat inspection practices in the majority of pig slaughter houses in Uganda and East Africa at large, the human exposure to NTM through pork seems to be high.

Apparently the high prevalence of NTM reported in pigs in Mubende was reportedly due to rearing of pigs in free or semi free range management systems. The free ranging pigs had a higher risk of exposure to environmental mycobacteria because of their food scavenging behaviour. Usually pigs are not provided with supplementary feeds. It was further shown that water from valley dams or water holes had significantly higher mycobacteria than water from bore holes (Kankya *et al.*, 2010). This is because valley dam water was being harvested as a water runoff from the hilly terrains. Therefore collects microbes as it flows from hill tops to valley dams. Such water was being shared with humans, pigs, cattle and wildlife thus exposing these animals to the NTM.

This study has shown that *M. avium* is the most commonly detected *Mycobacterium* in lymph nodes of pigs accounting for 19% of the positive NTM isolated species. *M. avium* subsp. *hominisuis* were more prevalent than *M. avium* subsp. *avium*. *M. avium* subsp. *avium* was isolated from 4.3% (4/93) of the lymph nodes with lesions, and 2.1% from lymph nodes without macroscopic lesions. This is the first documentation of *M. avium* subsp. *avium* and *M. avium* subsp. *hominisuis* in pigs from Uganda. The former is pathogen for birds and its presence in pigs indicates pig contact with infected birds. This is true given the free range and tethering system of keeping pigs in Mubende district. NTM therefore become very important zoonotic organisms in Uganda, given that 50% of the AIDS patients are likely to develop infections due to *M. avium*. Besides, Ugandans are predominantly a pork consuming community. Most of the pigs consumed in urban areas like Kampala trace their origin to rural areas like Mubende.

Other mycobacterial species other than *M. avium* were isolated from the pigs included *M. senuense* (16%), *M. terrae* (7%) and *M. asiaticum* (6%). *M. terrae* and *M. senuense*. These organisms had earlier been isolated from the environments in Mubende district (Kankya *et al.*, 2010), further suggesting that the free range pigs could acquire the infection by these bacteria from the environment. *M. terrae* has been known to cause urinary tract infections and chronic tenosynovitis. *M. asiaticum* can cause extra pulmonary infections.

Since no studies have been done on leptospirosis in pigs in Uganda, it is unknown whether this hazard is a problem in the country. However a study was done in Tanzania (Kessey *et al.*, 2010) in which 4.42% of pigs had *Leptospira* antibodies against six known *Leptospira interrogans* serovars: *Pomona*, *Icterohaemorrhagiae*, *Ballum*, *Tarassovi*, *Grippotyphosa* and *Hardjo*. This shows that leptospirosis is a potential zoonotic public health risk in Uganda since it is present in Tanzania, a country that shares extensive border with Uganda that is characterized by frequent cross-border livestock movement. This disease also causes economic losses to the

pig industry. Studies should therefore be done to determine the prevalence of this disease in pigs in Uganda and also assess its status in humans who handle the pigs and pork products.

No study has been done to detect infection of pigs with *Campylobacter* in Uganda, however, one study in Tanzania found a prevalence of thermophilic *Campylobacter* of 66.7% in slaughtered pigs and 10.6% in dressed carcasses. Arguably, this suggests possible risks of infection to people in Uganda, through consumption of contaminated pork or through contact with infected pigs. Campylobacteriosis is a common form of food-borne illness causing gastroenteritis characterized by diarrhea, dysentery, fever and abdominal pain. Studies should therefore be done to determine prevalence of *Campylobacter* in pigs and contamination in pork in Uganda.

The studies done in Tanzania (Mitani *et al.*, 2004, Tabuchi *et al.*, 2008 and McCall *et al.*, 2011) have shown that relapsing fever is endemic in Tanzania with pig-soft tick-human cycle of *B. duttoni* occurring. Culter (2010) reported that relapsing fever is listed among the top ten causes of children mortality under five in Tanzania. Since both soft ticks (*Ornithodoros porcinus* and *O. moubata*) are present in Uganda, there is a possibility that relapsing fever is also endemic in Uganda. Therefore studies should be done to determine the role of soft ticks and pigs in the epidemiology of relapsing fever in Uganda.

No study was done to determine the prevalence of brucellosis (*Brucella suis*) in pigs in Uganda. After reviewing literature on brucellosis in sub-Saharan Africa, McDermott and Arimi (2002) found that in whole of East Africa, the occurrence and epidemiological dynamics of swine brucellosis are poorly known. There is therefore an urgent need to carry prevalence studies of brucellosis in pigs considering the fact that *B. suis* is a key zoonosis and one of the most virulent *Brucella* to humans.

Except in Kenya, there were no reports of Erysipelas outbreaks in pigs in Uganda, Rwanda, Tanzania and Burundi. However with occurrence of two outbreaks in Kenya (Wabacha *et al.*, 1998 and Frienship and Bilkei, 2007), there is a possibility that this disease goes unnoticed in Uganda.

On the other hand the finding that pigs act as a vertebrate reservoir of Ndumu virus (NDUV) in Uganda (Masembe *et al.* 2012) is significant. NDUV had prior only been isolated from culicine mosquitoes. NDUV therefore represents a potential emerging zoonotic pathogen given that there is increasing risk of human-pig-mosquito contact due to increasing pig production arising from the exponentially rising pork demand.

There were no literature documenting studies of *Streptococcus suis*, Q-fever, influenza, rabies, and ebola in pigs in all the East African countries. These are all very important zoonosis with great public health significance. Surveillance systems should be put in place to detect occurrence these diseases in pigs.

The reviewed literature has shown that *Ascaris suum*, a known zoonotic nematode of pigs, is highly prevalent in Kabale in South western Uganda (Nissen *et al.*, 2012). Similarly 3 studies done in Kenya showed high prevalence of *A. suum* (Esrony *et al.*, 1997; Ngowi *et al.*, 2004 and Nganga *et al.*, 2008). This means that routine de-worming of pigs should be done. Zoonotic potential of this worm should be considered when using pig manure for fertilizing vegetables for human consumption especially if eaten as salads.

On a similar note recent studies (Nissen *et al.*, 2012) have shown that *Trichuris suis* is a potential zoonosis in Uganda. Further studies are highly warranted to explore transmission dynamics in sympatric areas where pigs and humans live in close proximity. Only one study was done in Kabale, Uganda, which reported a prevalence of 17% among pigs (Nissen *et al.*, 2012).

No reports have been made about prevalence of *Ancylostoma* species in pigs in Uganda. This is interesting considering that there are several reports of prevalence of *Ancylostoma* species in humans in Uganda. It is possible that pigs are acting as a source of these nematodes to humans. Studies should therefore be done to determine prevalence of *Ancylostoma* species in pigs in Uganda.

Similarly no studies have been done on ecto-parasites of pigs in Uganda. Only one survey was done in Tanzania (Braae *et al.*, 2013), in which prevalence of 2% of *sarcoptes scabiei* var. *suis* and 13% of *Tunga penetrans* in free ranging pigs in Mbeya district was found. Interestingly jigger outbreaks are very common in Uganda (Colley, 2010, Jawoko, 2011 and Daily Monitor, 2013) and the role of pigs in maintenance of *Tunga penetrans* fleas needs to be fully understood and documented.

## **Pork safety**

This work has demonstrated that the prevalence of porcine cysticercosis (PC) is high in Uganda in northern Uganda (Anyazo, 1999 and Phiri *et al.*, 2003), Lake Kyoga basin (Nsadha *et al.*, 2010 and 2011), South western Uganda (Waiswa *et al.*, 2009) and along transborder areas (Nsadha *et al.*, 2012). The risk factors associated with high prevalence of PC were lack of latrine use, lack of knowledge of transmission of PC, home slaughter of pigs, lack of pork inspection and free ranging of pigs (Anyazo, 1999; Waiswa *et al.*, 2009; Nsadha *et al.*, 2010 and 2011). Elsewhere in Tanzania, high prevalence of PC has been reported in Northern highlands of Arusha, Moshi and Mbulu (Phiri *et al.*, 2003, Ngowi *et al.*, 2004, Ngowi *et al.*, 2010; Mellau *et al.*, 2011) and southern highlands of Mbeya, Iringa and Ruvuma (Boa *et al.*, 2006). Similar findings on prevalence of PC have been seen in Kenya where two studies detected high prevalence of PC among pigs in Homa bay district (Eshitera *et al.*, 2012) and Busia district in western Kenya (Kagira *et al.*, 2012) among free ranging pigs.

Prevalence of PC in central Uganda has been low (Kiskaye and Masaba, 2002 and Peso and Rosel, 2013). This is due to confinement of pigs (Muhangazi *et al.*, 2012) and good latrine coverage. No studies have been done in eastern Uganda in Teso region where a high population of pigs occur. Studies are therefore recommended to study prevalence of PC in this region.

The prevalence of PC has been monitored using abattoir surveys, lingual examination, postmortem examination and Ag-ELISA serological test. Ag-ELISA and Post-mortem examination have been very sensitive than lingual examination. In Uganda, Nshada *et al.* (2012) reported that tongue examination was not conclusive because all pigs with doubtful lesions on postmortem were positive, with 25% of them having heavy cyst infestation with an average of a cyst per every 4cm<sup>2</sup> of muscles in pectoral, thigh and brain tissues. The same was found to be true in survey that was done in Homa Bay district where a prevalence of PC among pigs was found to be 32.8% and 5.6% by the Ag-ELISA and lingual inspection, respectively (Eshitera *et al.*, 2012). Future PC surveys should adopt serological surveys so as to pick up the missed cases

when lingual inspection is done. However, lingual inspection could be done by pig traders for screening out pigs with obvious PC lesions before buying them as was done in Tanzania (Ngowi *et al.*, 2004).

Spatial clustering (mapping) of cases of PC in pigs in PC endemic areas could help identify hot spots where control efforts for PC should be directed as evidenced by works reported by Nsadhha *et al.* (2011) in Uganda and by Ngowi *et al.* (2010) in Tanzania.

No practice and study has been done in Uganda for treatment of cysticercosis in pigs. One study has been done in Tanzania (Sikasunge *et al.*, 2008) to assess the effect of treating *Taenia solium* infected pigs with oxfendazole (OFZ). It was shown that treatment of pigs with cysticercosis with OFZ could be done in combination with other intervention measures. However, the cost-effectiveness of the treatment intervention needs to be assessed.

No serological surveys has been done to determine prevalence of neurocysticercosis in Uganda. Nsadhha *et al.* (2011) only reported prevalence of epilepsy which was determined by interviewing households in Lake Kyoga basin in relationship with people with taeniosis. It is therefore very urgent to carry out serological survey for prevalence of neurocysticercosis in humans in endemic areas with porcine cysticercosis so as to establish true prevalence of neurosysticercosis. In East Africa, Burundi was the first country to get concerned with neuro-cysticercosis as exhibited by 3 studies so far done (Nzisabira *et al.*, 1992; Newell *et al.*, 1997 and Nsengiyumva *et al.*, 2003).

No efforts to educate the communities about porcine cysticercosis and neurocysticercosis in Uganda. A study done in Tanzania showed that education considerably (57%) decreased the incidence of porcine cysticercosis as measured by antigen-ELISA in sentinel pigs hence leading to reduction of the risk of infection to humans (Ngowi *et al.*, 2008). Similarly in Kenya according to Wohlgenut *et al.* (2010) it was found that Grade 8 education could enhance learning from written material on how PC was transmitted. Workshops followed by individual on-farm training enhanced knowledge acquisition and behavior changes towards good pig management practices. Training of local government extension workers could contribute to the sustainability of this project. This shows that Uganda should adopt education of communities about epidemiology of cysticercosis and neurocysticercosis as a way of creating awareness about their dangers and measures to curb them.

No studies on *Taenia hydatigena* and *Trichinella* species have been reported in pigs in Uganda. However, elsewhere Ngowi *et al.* (2004) reported a *Taenia hydatigena* prevalence of 1.4% among slaughter pigs in Mbulu in Tanzania. These authors also investigated for Trichinellosis, but no *Trichella* was detected in the pork carcasses (Ngowi *et al.*, 2004a). The abattoir surveys should be done to determine the prevalence of *Taenia hydatigena* in pigs in Uganda and *Trichnella* species surveillance should be inbuilt in the pork inspection system..

There were no documented studies of *T. gondii*, *Sarcosystis suihominis* and *Alaria alata* in pigs from all the East African countries. However, all the countries reported studies documenting the occurrence of *T. gondii* in humans. This is an important zoonotic pathogen. A potential role of pigs in epidemiology *T. gondii* in Uganda should be investigated. On the other hand *Sarcocystis suihominis* is a zoonotic coccidian protozoan. Humans acquire intestinal sarcocystosis through the ingestion of raw or improperly cooked pork containing mature *Sarcocystis suihominis*. Pigs

serve as the intermediate hosts. While the trematode, *Alaria alata*, an intestinal parasite of different carnivore species, mesocercarial stages may infect almost all vertebrate species, including humans, and, in particular, omnivorous scavengers such as wild boars which serve as paratenic hosts for the parasite. It would be interesting to find out the occurrence of *Sarcosystis suihominis* and *Alaria alata* in pigs in Uganda and the potential role of these pigs in the epidemiology of these parasites.

The presence of *Salmonella* in pigs at slaughter and the consequent cross-contamination of pig carcass present a significant pork safety hazard. No explicit studies have been done on the presence of *Salmonella* organisms in pigs and pork in Uganda. Nasinyama *et al.* (1998) did isolate *Salmonella* from slaughter animals in Kampala but did not characterize the species and subspecies of *Salmonella*. They only reported that 69.2% of *Salmonella* isolates exhibited antibiotic resistance. Another study reported by Kalule *et al.* (2012) indicated that a majority of *Salmonella* isolates from food of animal origin including pigs were resistant to commonly used drugs against salmonellosis and there were multi drug resistant isolates. There was evidence of drug resistance transmission from animals to man through plasmid mediation. The drug resistance could be developed by misuse of antibiotics when treating pigs by farmers by not following prescribed guidance. This therefore calls for urgent need to make policies and guidelines concerning prudent use of antibiotics in food animals including pigs in Uganda.

A similar study reported by Kikuvu *et al.* (2007) and (2010) was done to characterise isolates and antibiotic resistance of *Salmonella* collected from slaughter pigs and carcasses in Kenya. It has been shown that pigs serve as reservoirs of antimicrobial resistant *Salmonella* and slaughterhouse cross-contamination of pork is a food safety risk. It is therefore important that slaughterhouse hygiene should be improved to minimise contamination. This is very crucial since the hygiene of all pig slaughter houses in East Africa is very poor as reported in Uganda (Phiri *et al.*, 2003; Tejler, 2012; Pezo and Rösel, 2012) and Tanzania (Mkupasi *et al.* 2011).

There were no reports of investigations of *Y. enterocolitica* in pigs in Uganda, Rwanda, Burundi, Tanzania and Uganda. There was only one old report of *Y. enterocolitica* in pigs from Kenya, which reported 0.7% prevalence in pigs (Turkson *et al.*, 1988). This shows that pigs are a potential source of this pathogen to humans. Therefore active surveillance of this pathogen in pigs should be done.

There were no documented studies of *Giardia duodenalis* in pigs from all the East African countries. However, with the exception of Burundi, all the other countries have reported the occurrence of *G. duodenalis* in humans. Available evidence shows that *G. duodenalis* is highly endemic in East Africa and this calls for urgent studies to delineate their epidemiology including the potential role of pig.

Although no studies on toxigenic *E. coli* have been conducted in pigs, these animals can be important sources of this organism for humans. Humans especially pork handlers and vendors can contaminate pork with toxigenic *E. coli* and vice versa is true. Humans suffer illness due to infection by enterotoxigenic *E. coli* (ETEC) and Shiga-toxigenic *E. coli* (STEC). There is therefore a need to carry out studies to determine the prevalence and characterize *E. coli* isolates from pigs and humans with a view of studying their zoonotic potential in Uganda.

There were no documented studies on *Cryptosporidium* in pigs from all the East African countries. However, *Cryptosporidium* infections in humans have been reported in the 5 countries

of East Africa. Cryptosporidiosis is an emerging enteric zoonosis especially in children and is caused by *Cryptosporidium* parasites. The role of pigs in its epidemiology should be studied.

There were no documented studies of hepatitis E in pigs from all the East African countries. However, with the exception of Rwanda, the other East African countries reported occurrence of Hepatitis E in humans. In Uganda a large outbreak of hepatitis E occurred in Kitgum district of northern part of the country, of the 10,535 residents, 3218 had hepatitis E infection and there were 160 deaths last year (2012).

There were no reports on pesticide and antibiotic residues, heavy metals and mycotoxins in pork in all the East African countries. This is because the East African countries do not have a capacity to conduct risk analysis for veterinary drug and pesticide residues in edible tissues (Mitema, 2009).

Blue pork is of concern in Uganda, however, the cause of this condition is not known upto today (Wendo, 2002 and All Africa, 2005). No studies have been done due to lack of funding. There is therefore need to carry out investigations to establish the cause of this problem and ensure the safety of the pork consumed in Uganda.

### **Risk factors for pork safety**

Risk factors for production of unsafe pork include: unhygiene of pig slaughter places, free ranging of pigs, home slaughter (non-inspection), poor housing, poor handling of pork, lack of government policy on food safety, and poor food-borne disease surveillance system. The slaughter of pigs in unhygienic conditions in Uganda predisposes carcasses to contamination by environmental bacterial contaminants like non-tuberculosis mycobacteria, *Salmonella*, *E. coli* *Campylobacter* species, *Vibrio cholerae*, *Vibrio* species and *Shigella*. It has been shown that all pig slaughter houses in Uganda lack basic hygienic standards. Efforts should be made to develop basic hygienic slaughter houses where meat inspection is a requirement and is meticulously performed.

Most of the rural pigs are housed in unhygienic muddy environments which predispose to soil and water-borne contaminants which can contaminate pork during the slaughter process. Simple slated housing built using locally available materials like those built in Kabale (Nissen *et al.* 2011) should be promoted. Additionally thorough cleaning of pigs before slaughter should be done.

Over 90% of the pig production systems in Uganda are free ranging and backyard production systems (CGIAR, 2011). This means that pigs in these systems spend much of their time scavenging outside their homesteads, suggesting that these pigs may be exposed to infectious agents which compromise pork safety like *Taenia solium*, trichinellosis and toxoplasmosis. They are also predisposed to acquire zoonotic diseases like trypanosomosis and brucellosis. Farmers need to be educated to adopt pig confinement production systems.

Uganda does not have effective food safety policy. It has draft food safety bill which awaits approval. Like in most African countries (WHO, 2007) the draft bill has a number of ministries and institutions involved in food safety issues with apparent lack of coordination and clear mandates. This calls for a more organised policy which creates an efficient system that is

responsible for the safety of food at the National level. This policy should guide the necessary food safety actions which need to be taken to produce safe pork in Uganda.

There is need to strengthen surveillance systems for food-borne diseases. Field and laboratory based surveillance system for food-borne diseases should be strengthened and facilitated Nationally with WHO support (Mensah *et al.*, 2012b) to enable monitor food-borne diseases associated with pork. Specialists in microbiology and epidemiology from public health, veterinary and food sectors should be trained in isolation, identification and typing of microbial food contaminants like *Salmonella* species, *Campylobacter* species, *Vibrio* species and *Shigella* from farm to table.

Through WHO and WHO Global Food Infections Network (GFN) food-borne disease surveillance team should also be involved in monitoring antimicrobial resistance (AMR) in pork. GFN has developed principles of containment of AMR originating from use of antimicrobials in pig production value chains, and for reduction of dissemination of antimicrobial pathogens from pigs to man. Interventions are in areas on antimicrobial production, distribution and sales, antimicrobial use in animals and monitoring, strengthening monitoring of AMR and improvement of hygiene of food. For example, an integrated study is being done of antimicrobial resistance in *Salmonella*, *Campylobacter* species, *Escherichia coli* and *Enterococcus* species from gut of healthy food markets and retail meat markets in Kenya (Mensah *et al.*, 2012b). This study is being done in 10 main abattoirs in Nairobi (6), Mombasa (2) and Kisumu (2). Also isolates of these organisms are being got from patients from hospitals. Such a study can provide information on prevalence and antimicrobial resistance in pork of the above pathogens isolated from farms and pork retail outlets. Such a study will also decipher information on how antibiotic resistance of these organisms flows between pigs and man; and within the human population. Such a study if done in Uganda, would form a basis for formulating pork safety guidelines for improvement of handling pork and pork products at abattoirs and pork retail outlets and also could be a basis for development of a National policy on antibiotic use and control of antimicrobial resistance.

## Conclusions

This review has noted that pigs were the major reservoir of human trypanosomosis in South Eastern Uganda. No research has been done in Eastern and Northern Uganda about the role of pigs in the epidemiology of trypanosomosis. Pigs could also be a source of tuberculosis, non-tuberculosis mycobacteria, Ndumu virus, *A. suum* and *Trichuris suis*.

Though no studies have been done in Uganda, pigs are likely source of the following zoonoses: leptospirosis, campylobacteriosis, relapsing fever, brucellosis, erysipelas, helminthes notably *Ancylostoma* species and ecto-parasites especially *Tunga penetrans* as shown by studies elsewhere in East Africa.

There was total lack of research regarding the role of pigs as reservoirs of Q-fever, *Streptococcus suis*, rabies, ebola, anthrax and influenza in Uganda and East Africa at large.

There was a high prevalence of porcine cysticercosis in Northern Uganda and Kyoga basin, South western Uganda and along transborder areas. The risk factors associated with high

prevalence of PC were lack of latrine use, lack of knowledge of transmission of PC, home slaughter, lack of pork inspection, free ranging of pigs, poor cooking methods like roasting and babercueing. No studies have been done in Eastern Uganda Teso region where a high population of pigs occur. Lingual inspection is less sensitive than Ag-ELISA in determining the prevalence of PC. No practice and study has been done in Uganda for treatment of cysticercosis in pigs. No serological surveys has been done to determine prevalence of neurocysticercosis in Uganda. No efforts to educate communities about porcine cysticercosis and neurocysticercosis have been instituted.

No explicit studies have been done to isolate and characterise *Y. Enterocolitica*, *Salmonella* species and *E. coli* strains in pigs and pork in Uganda. Few studies done have shown that multidrug resistance could have developed by *Salmonella* isolates from pork and pigs. Slaughter cross contamination of pork with this bacteria occurs and presents a real pork safety risk.

No studies have been done on prevalence of *Taenia hydatigena*, *trichinellosis*, *T. gondi*, *Sarcosystis sui hominis*, *Cryptosporidium*, *Alaria alata*, *G. duodenalis* and Hepatitis E in pigs in Uganda. No studies have been done to determine the cause of prevalent blue pork in Uganda. Similarly no studies has been done to assess pesticide and antibiotic residues, heavy metals and mycotoxins (Orchratoxin A and Zearalenone) in pork in Uganda.

All pig slaughter houses and pig houses in Uganda are unhygienic and most of the pork consumed is uninspected or inadequately done. Uganda does not have effective food safety policy. There is less effective field and laboratory based surveillance system for food-borne diseases which should be monitoring food-borne diseases associated with pigs and pork.

## Recommendations

Pigs should be included in trypanosomosis control programmes. Research on the role of pigs in the dynamics of trypanosomosis in Teso, Lango and Acholi areas should be done. Strict pork inspection, raising of pigs in a clean environment and use of clean water for cleaning pig carcasses during slaughter should be practiced. Surveys should be done to establish the status of occurrence of: leptospirosis, campylobacteriosis, relapsing fever, brucellosis, erysipelas, Q-fever, *Streptococcus suis*, rabies, ebola, anthrax, influenza, helminthes (*A.suum*, *Trichuris suis* and *Ancylostoma species*) and ecto-parasites especially *Tunga penetrans* in pigs in Uganda.

Studies should be done to establish the prevalence of porcine cysticercosis among pigs in Teso and Bugisu region based on Ag-ELISA serological surveys. Serological surveys should be done to determine prevalence of neurocysticercosis in pigs in Uganda. This should be coupled with education of communities about porcine cysticercosis and neurocysticercosis.

Studies should be done to isolate and characterise *Y. enterocolitica*, *Salmonella* and *E. coli* strains in pigs and pork in Uganda. There is also a need to determine the cause of the prevalent blue pork and to conduct studies on pesticide and antibiotic residues, heavy metals and mycotoxins (Orchratoxin A and Zearalenone) in pork. Pork slaughter houses should adopt basic hygienic standards and designs where pork inspection is mandatory.



Simple basic slanting pig houses using local materials which can easily be cleaned should be built to confine pigs. Uganda should develop effective food safety policy that creates an efficient system that is responsible for the safety of food at the national level. This policy should guide the necessary food safety actions which need to be taken to produce safe pork. Field and laboratory based food-borne disease surveillance system, should be strengthened and facilitated to enable monitor zoonotics and pork safety hazards associated with the pig value chain.

## References

- All Africa (2005). Uganda - Shortage of funds delays blue pork study. All Africa 19<sup>th</sup> May 2005. <http://en.engormix.com/MA-pig-industry/news/uganda-shortage-funds-delays-t6654/p0.htm>
- Anyazo, T. (1999). Prevalence of cysticercosis cellulose in three subcounties of Moyo county, Moyo district, Uganda. Special Research Project, Faculty of Veterinary Medicine, Makerere University, Kampala.
- Balyeidhusa, A.S., Kironde, F.A. and Enyaru, J.C. (2012). Apparent lack of a domestic animal reservoir in Gambiense sleeping sickness in northwest Uganda. *Vet Parasitol.*, **187(1-2)**:157-67. doi: 10.1016/j.vetpar.2011.12.005. Epub 2011 Dec 19.
- Barungi, J. (2010). Time to review food safety measure in Uganda. <http://mobile.monitor.co.ug/Oped/-/691272/1068216/-/format/xhtml/-/9jn9c5z/-/index.html>.
- Biryomumaisho, S., Melville, S.E., Katunguka-Rwakishaya, E. and Lubega, G.W. (2009). Detection of natural *Trypanosoma vivax* infections in pigs with microhaematocrit centrifugation and amplification of ITS1 rDNA. *Onderstepoort J. Vet. Res.* **76(3)**:285-289.
- Biryomumaisho, S., Rwakishaya, E.K., Melville, S.E., Cailleau, A. and Lubega, G.W. (2013). Livestock trypanosomosis in Uganda: parasite heterogeneity and anaemia status of naturally infected cattle, goats and pigs. *Parasitol Res.*, **112(4)**:1443-50. doi: 10.1007/s00436-013-3275-9. Epub 2013 Jan 24.
- Blocher, J., Schmutzhard, E., Wilkins, P.P., Gupton, P.N., Schaffert, M., Auer, H., Gotwald, T., Matuja, W. and Winkler, A.S. (2011). A cross-sectional study of people with epilepsy and neurocysticercosis in Tanzania: clinical characteristics and diagnostic approaches. *PLoS Negl Trop Dis.* **5(6)**:e1185. doi: 10.1371/journal.pntd.0001185. Epub 2011 Jun 7.
- Boa, M.E., Mahundi, E.A., Kassuku, A.A., Willingham III, A.L. and Kyvsgaard, N.C. (2006). Epidemiological survey of swine cysticercosis using ante-mortem and post-mortem examination tests in the southern highlands of Tanzania. *Vet Parasitol.*, **139(1-3)**:249-255.

Braae, U.C., Ngowi, H.A. and Johansen, M.V. (2013) Smallholder pig production: prevalence and risk factors of ectoparasites. *Vet Parasitol.* pii: S0304-4017(13)00010-1. doi: 10.1016/j.vetpar.2012.12.058.

CGIAR (2011). Smallholder pig production and marketing value chain in Uganda. Background proposals for CGIAR research program on livestock and fish. ILRI, Nairobi.  
[http://cgspace.cgiar.org/bitstream/handle/10568/16970/LivestockFish\\_PigVCUganda.pdf](http://cgspace.cgiar.org/bitstream/handle/10568/16970/LivestockFish_PigVCUganda.pdf).

Colley, A. (2010). The Jigger invasion of Busoga Region. Uganda village project. Tuesday, November 30, 2010.  
<http://ugandavillageproject.blogspot.com/2010/11/jigger-invasion-of-busoga-region.html>.

Cutler, S.J. (2010). Relapsing fever--a forgotten disease revealed. *J Appl Microbiol.*, **108(4)**:1115-1122. doi: 10.1111/j.1365-2672.2009.04598.x.

Daily Monitor (2013) . Sixty seven people affected by jiggers in Kitgum. Daily Monitor Wednesday 3<sup>rd</sup> April, 2013. <http://www.monitor.co.ug/News/National/-/688334/1030916/-/cmi4ayz/-/index.html>.

Damiana, F., Ravasi, Mannus J. O'Riain., Faezah D. and Illing, N. (2012). Phylogenetic evidence that two distinct *Trichuris* genotypes infect both humans and non-human primates. *Plos One*, **7(8)**: e44187. Doi: 10.1371/journal.pone.0044187 PMCID: PMC3429462 1

Eshitera, E.E, Githigia, S.M., Kitala, P., Thomas, L.F., Fèvre, E.M, Harrison, L.J., Mwihi, E.W., Otieno, R.O., Ojiambo, F. and Maingi, N. (2012). Prevalence of porcine cysticercosis and associated risk factors in Homa Bay District, Kenya. *BMC Vet Res.* **8**:234. doi: 10.1186/1746-6148-8-234.

Esrony, K., Kambarage, D.M., Mtambo, M.M., Muhairwa, A.P., Kusiluka, L.J. (1997). Helminthosis in local and cross-bred pigs in the Morogoro region of Tanzania. *Prev Vet Med.* **132(1-2)**:41-46.

Friendship, C.R. and Bilkei, G. (2006). Concurrent swine erysipelas and *Clostridium novyi* infections associated with sow mortality in outdoor sows in Kenya. *Vet J.* **173(3)**:694-6. Epub 2006 Mar 3.

Jawoko, K. (2011). Jiggers outbreak in Uganda. *MAJ.* 2011 Jan 11;183(1):E33-4. doi: C 10.1503/CMAJ.109-3726.

Kagira, J.M. and Kanyari, P.W. (2010). Occurrence of risk factors for zoonoses in Kisumu City, Kenya : questionnaire survey. *East Afri. J. Public Health*, **7(1)**: 1-4.

- Kagira, J.M., Kanyari, P.W., Maingi, N., Githigia, S.M., Ng'ang'a, J.C. and Karuga, J.W. (2010). Characteristics of the smallholder free-range pig production system in western Kenya. *Trop Anim Health Prod.* **42(5)**:865-873. doi: 10.1007/s11250-009-9500-y. Epub 2009 Nov 15
- Kagira, J.M., Kanyari, P.N., Githigia, S.M., Maingi, N., Ng'ang'a, J.C. and Gachohi, J.M. (2012). Risk factors associated with occurrence of nematodes in free range pigs in Busia District, Kenya. *Trop Anim Health Prod.* **44(3)**:657-664. doi: 10.1007/s11250-011-9951-9.
- Kagira, J.M., Maingi, N., Kanyari, P.W., Githigia, S.M., Ng'ang'a, J.C. and Gachohi, J.M. (2010). Seroprevalence of *Cysticercus cellulosae* and associated risk factors in free-range pigs in Kenya. *J. Helminthol.*, **84(4)**:398-403. doi: 10.1017/S0022149X10000076.
- Kalule, J.B., Kaddu-Mulindwa, D.H. and Asiimwe, B.B. (2012). Antimicrobial drug resistance and plasmid profiles of *Salmonella* isolates from humans and foods of animal origin in Uganda. *Advances in Infectious Diseases* **2**: 151-155. Doi:10.4236/aid.2012.24025 published online December 2012 (<http://www.SciRP.org/journal/aid>).
- Kambarage, D.M. (1991). Treatment and control of sarcoptic mange: evaluation of treatment of both the pigs and environment. *Trop Anim Health Prod.* **23(1)**:59-62.
- Kankya, C., Muwonge, A., Dønne, B., Munyeme, M., Opuda-Asibo, J., Skjerve, E., Oloya, J., Edvardsen, V., and Johansen, T.B. (2011). Isolation of non-tuberculous mycobacteria (NTM) from pastoral ecosystems of Uganda: Public Health significance. *BMC Publ Health.* **11**:320. doi: 10.1186/1471-2458-11-320.
- Katunguka-Rwakishaya, E. (1996). The prevalence of trypanosomosis in small ruminants and pigs in a sleeping sickness endemic area of Buikwe County, Mukono district, Uganda. *Rev Elev Med Vet Pays Trop.* **49(1)**:56-58.
- Kessy, M.J., Machang'u, R.S. and Swai, E.S. (2010). A microbiological and serological study of leptospirosis among pigs in the Morogoro municipality, Tanzania. *Trop Anim Health Prod.* **42(3)**:523-530. doi: 10.1007/s11250-009-9455-z.
- Kikuvi, G.M., Ombui, J.N., Mitema, E.S. and Schwarz, S. (2007). Antimicrobial resistance in *Salmonella* serotypes isolated from slaughter animals in Kenya. *East Afr Med J.*, **84(5)**:233-239.
- Kikuvi, G.M., Ombui, J.N. and Mitema, E.S. (2010). Serotypes and antimicrobial resistance profiles of *Salmonella* isolates from pigs at slaughter in Kenya. *J Infect Dev Ctries.* **4(4)**:243-248.
- Kisakye, J.J.M. and Masamba S.C. (2002). *Cysticercosis cellulose* in pigs slaughtered in and around Kampala City. *Uganda Journal of Agricultural Sciences*, **7**: 23-24.
- MAAIF and MOH (2005). The national food and nutrition strategy. Final Draft report. Ministry of Agriculture, Animal Industry and Fisheries and Ministry of Health, Republic of Uganda.

MAAIF (2011). The Republic of Uganda Ministry of Agriculture , Animal Industry And Fisheries Statistical Abstract, 38–39. Retrieved from [www.agriculture.go.ug](http://www.agriculture.go.ug)\

Masembe, C., Michuki, G., Onyango, M., Rumberia, C., Norling, M., Bishop, R.P., Djikeng, A., Kemp, S.J., Orth, A., Skilton, R.A., Ståhl, K., and Fischer, A. (2012). Viral metagenomics demonstrates that domestic pigs are a potential reservoir for Ndumu virus. *Virology* **9**:218. doi: 10.1186/1743-422X-9-218.

Mazigo, H.D., Bahemana, E., Konje, E.T., Dyegura, O., Mnyone, L.L., Kweka, E.J, Kidenya, B.R. and Heukelbach, J. (2012). Jigger flea infestation (tungiasis) in rural western Tanzania: high prevalence and severe morbidity. *Trans R Soc Trop Med Hyg.* **106**(4):259-63. doi: 10.1016/j.trstmh.2011.12.001. Epub 2012 Feb 10.

McCall, P.J., Hume, J.C., Motshegwa, K., Pignatelli, P., Talbert, A. and Kisinza, W. (2007). Does tick-borne relapsing fever have an animal reservoir in East Africa?. *Vector Borne Zoonotic Dis.* **7**(4): 659-666.

McDermott, J.J. and Arimi SM. (2002). Brucellosis in sub-Saharan Africa: epidemiology, control and impact. *Vet Microbiol.*, **90**(1-4):111-134.

Mdegela, R.H., Laurence, K., Jacob, P. and Nonga, H.E. (2011). Occurrences of thermophilic *Campylobacter* in pigs slaughtered at Morogoro slaughter slabs, Tanzania. *Trop Anim Health Prod.*, **43**(1):83-87. doi: 10.1007/s11250-010-9657-4.

Mellau, B.L., Nonga, H.E. and Karimuribo, E.D. (2011). Slaughter stock survey of carcasses and organ/offal condemnations in Arusha region Northern Tanzania. *Trop. Anim. Health Prod.* **43**(4): 857-864/. Doi:1007/sl 1250-010-9773-1.

Mensah, P. Mwamakamba, L., Karuiki, S., Fonkoua, M.C. and Aidara-Kane, A. (2012b). Strengthening food disease surveillance in WHO African Region: An essential need for disease control and food safety assurance. *African Journal of Food, Agriculture, Nutrition and Development*. On line Scholarly Reviewed Journal **12**(4): 6337-6348.

Mensah, P. Mwamakamba, L., Mohammed, C., and Nsue-Milang, D. (2012a). Public health and food safety in WHO African Region. *African Journal of Food, Agriculture, Nutrition and Development*. On line Scholarly Reviewed Journal **12**(4): 6317-6335.

Mitani, H., Talbert, A. and Fukunaga, M. (2004). New World relapsing fever *Borrelia* found in *Ornithodoros porcinus* ticks in central Tanzania. *Microbiol Immunol.*, **48**(7):501-505.

Mitema, E.S. (2009). Improvement management of drugs, hormones and pesticides in Africa. *Onderstepoort Journal of Veterinary Research*, **76**: 155-159.

Mkupasi, E.M., Ngowi. H.A. and Nonga, H.E. (2011). Prevalence of extra-intestinal porcine helminth infections and assessment of sanitary conditions of pig slaughter slabs in Dar es Salaam city, Tanzania. *Trop Anim Health Prod.* **43**(2):417-423. doi: 10.1007/s11250-010-9708-x.

Muhanguzi, D. Lutwama, V. and Mwiine, F. (2012). Factors influencing pig production in central Uganda. *Vet World*, **5(6)**: 346-351. Doi 5455/vetworld.2012.346-351.

Muwonge, A., Johansen, T.B., Vigdis, E., Godfroid, J., Olea-Popelka, F., Biffa, D., Skjerve, E. and Djønne, B. (2012). *Mycobacterium bovis* infections in slaughter pigs in Mubende district, Uganda: a public health concern. *BMC Vet Res*. **8**:168 doi: 10.1186/1746-6148-8-168

Muwonge, A., Kankya, C., Godfroid, J., Djønne, B., Opuda-Asibo, J., Biffa, D., Ayanaw, T., Munyeme, M. and Skjerve, E. (2009). Prevalence and associated risk factors of mycobacterial infections in slaughter pigs from Mubende district in Uganda. *Trop Anim Health Prod.*, **42(5)**:905-913. doi: 10.1007/s11250-009-9506-5. Epub 2009 Dec 12

Muwonge, A., Kankya, C., Johansen, T.B., Djønne, B., Godfroid, J., Biffa, D., Edvardsen, V., and Skjerve, E. (2012). Non-tuberculous mycobacteria isolated from slaughter pigs in Mubende district, Uganda. *BMC Vet Res*. **8**:52. doi: 10.1186/1746-6148-8-52.

Nasinyama, G.W., McEwen, S.A., Walter-Toews, D., Gyles C.L., Wilson, J., Opuda-Asibo, J. and Poppe, C. (1998). Prevalence, characteristics, and distribution of non-typhoidal *Salmonella* in diarrhea children and slaughter animals in Kampala district, Uganda. *Proceedings of the 4<sup>th</sup> World Congress of Foodborne Infections and Intoxications, Berlin, 7-12<sup>th</sup> June 1998*, 433-444.

Newell, E., Vyungimana, F., Geerts, S., Van Kerckhoven, I., Tsang, V.C. and Engels, D. (1997). Prevalence of cysticercosis in epileptics and members of their families in Burundi. *Trans R Soc Trop Med Hyg.*, **91(4)**:389-391.

Nganga, C.J., Karanja, D.N. and Mutune, M.N. (2008). The prevalence of gastrointestinal helminth infections in pigs in Kenya. *Trop Anim Health Prod.* **40(5)**:331-334.

Ng'ayo, M.O., Njiru, Z.K., Kenya, E.U., Muluvi, G.M., Osir, E.O. and Masiga, D.K. (2005). Detection of trypanosomes in small ruminants and pigs in western Kenya: important reservoirs in the epidemiology of sleeping sickness?. *Kinetoplastid Biol Dis.* 4:5.

Ngowi, H.A., Carabin, H., Kassuku, A.A., Mlozi, M.R., Mlangwa, J.E. and Willingham III, A.L. (2008). A health-education intervention trial to reduce porcine cysticercosis in Mbulu District, Tanzania. *Prev Vet Med.* **85(1-2)**:52-67. doi: 10.1016/j.prevetmed.2007.12.014.

Ngowi, H.A., Kassuku, A.A., Maeda, G.E., Boa, M.E. and Willingham, A.L. (2004a). A slaughter slab survey for extra-intestinal porcine helminth infections in northern Tanzania. *Anim Health Prod.*; **36(4)**:3353-40.

Ngowi, H.A., Kassuku, A.A., Maeda, G.E., Boa, M.E., Carabin, H. and Willingham III A.L. (2004b) Risk factors for the prevalence of porcine cysticercosis in Mbulu District, Tanzania. *Vet Parasitol.* **120(4)**:275-283.

- Ngowi, H.A., Kassuku. A.A., Carabin, H., Mlangwa, J.E., Mlozi M.R., Mbilinyi, B.P. and Willingham III A.L. (2010). Spatial clustering of porcine cysticercosis in Mbulu district, northern Tanzania. *PLoS Negl Trop Dis*. **4(4)**:e652. doi: 10.1371/journal.pntd.0000652.
- Nissen, S., Al-Jubury, A., Hansen, T.V., Olsen, A., Christensen, H., Thamsborg, S.M. and Nejsum, P. (2012). Genetic analysis of *Trichuris suis* and *Trichuris trichiura* recovered from humans and pigs in a sympatric setting in Uganda. *Vet Parasitol.*, **188(1-2)**:68-77. doi: 10.1016/j.vetpar.2012.03.004. Epub 2012 Mar 20.
- Nissen, S., Poulsen, I.H., Nejsum, P., Olsen, A., Roepstorff, A., Rubaire-Akiiki, C. and Thamsborg, S.M. (2011). Prevalence of gastrointestinal nematodes in growing pigs in Kabale District in Uganda. *Trop Anim Health Prod*. **43(3)**:567-572. doi: 10.1007/s11250-010-9732-x. Epub 2010 Nov 19
- Nsadha, I., Mutambo, Nkwole, A., Lubega, G. W., Nasinyama, G. W., Ojok, L. and Waiswa, C. (2012). Spatial distribution of human epilepsy, porcine cysticercosis and taeniosis in the Lake Kyoga Basin in Uganda. *Africa Journal of Animal and Biomedical Sciences* **7(1)**: 123-127.
- Nsadha, Z., Saimo, M., Waiswa, C., Nabwire, I.M., Nkwole, A., Sikasunge, C.S., Willingham III, A.L., Mutagwanya, R., Lubega, G.W. and Ojok, L. (2011). Trans- boundary porcine cysticercosis: a possibility on Uganda's borders. *Africa Journal of Animal and Biomedical Sciences* **6(1)**: 67-71.
- Nsadha. Z, Saimo .M, Waiswa. C, Maingi, Ojok L, Willingham III.A.L, Mutagwanya.R. and Nyakarahuka.L, (2010). Risk factors and lingual prevalence of porcine cysticercosis in Lake Kyoga Basin in Uganda. *Africa Journal Of Animal and Biomedical Sciences*, **5(3)**: 43–50.
- Nsengiyumva, G., Druet-Cabanac, M., Ramanankandrasana, B., Bouteille, B., Nsizabira, L. and Preux, P.M. (2003). Cysticercosis as a major risk factor for epilepsy in Burundi, East Africa. *Epilepsia*.**44(7)**:950-955.
- Nzisabira L, Nsengiyumva G, Bouteille B, Ndayiragije A, Niyongabo T, Bigirimana V, Dumas M and Aubry P (1992). Cysticercosis in the province of Kayanza (Burundi)]. *Bull Soc Pathol Exot*. **85(5)**:374-377.
- Oloya, J., Opuda-Asibo, J., Kazwala, R., Demelash, A.B., Skjerve, E., Lund, A., Johansen, T.B., Djønne, B. (2008). *Mycobacteria* causing human cervical lymphadenitis in pastoral communities in the Karamoja region of Uganda. *Epidemiol Infect*. **136(5)**:636–643.
- Oloya, J., Kazwala, R., Lund, A., Opuda-Asibo, J., Demelash, A.B., Skjerve, E., Johansen, T.B., and Djønne, B. (2007). Characterization of mycobacteria isolated from slaughtered cattle in pastoral regions of Uganda. *BMC Vet Res.*,**7**:95.
- Omolo, M.O., Hassanali, A., Mpiana, S., Esterhuizen. J., Lindh. J., Lehane, M.J., Solano, P., Rayaisse, J.B., Vale, G.A., Torr S.J. and Tirados, I. (2009). Prospects for developing odour baits

to control *Glossina fuscipes* species., the major vector of human African trypanosomiasis. *PLoS Negl. Trop. Dis.*, **3(5)**:e435. doi: 10.1371/journal.pntd.0000435. Epub 2009 May 12.

Pezo, D. and Rösel, K. (2012) . Preliminary survey findings on slaughter hygiene at Wambizzi abattoir Kampala, Uganda, at the workshop held on 16 August 2012.  
<http://safefoodfairfood.wordpress.com/category/countries/uganda>

Phiri, I.K., Ngowi, H., Afonso, S., Matenga, E., Boa, M., Mukaratirwa, S., Githigia, S., Saimo, M., Sikasunge, C., Maingi, N., Lubega, G.W., Kassuku, A., Michael, L., Siziya, S., Krecek, R.C., Noormahomed, E., Vilhena, M., Dorny, P. and Willingham, A.L. (2003). The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. *Acta Trop.*, **87(1)**:13-23.

Sikasunge, C.S., Johansen, M.V., Willingham, A.L. 3rd, Leifsson, P.S. and Phiri, I.K. (2008). *Taenia solium* porcine cysticercosis: viability of cysticerci and persistency of antibodies and cysticercal antigens after treatment with oxfendazole. *Vet Parasitol.* **158(1-2)**:57-66. doi: 10.1016/j.vetpar.2008.08.014.

Tabuchi, N., Kataoka-Ushijima, Y., Talbert, A., Mitani, H. and Fukunaga, M. (2008). Absence of transovarial transmission of *Borrelia duttonii*, a tick-borne relapsing fever agent, by the vector tick *Ornithodoros moubata*. *Vector Borne Zoonotic Dis.* **8(5)**:607-613. doi: 10.1089/vbz.2007.0279.

Tejler, E. (2012). Outbreaks of African Swine fever in domestic pigs in Gulu District, Uganda. Swedish University of Agricultural Sciences, Uppsalla, 30pp. <http://epsilon.slu.se>.

Thomas, L.F, de Glanville, W.A., Cook, E.A. and Fèvre, E.M. (2013). The spatial ecology of free-ranging domestic pigs (*Sus scrofa*) in western Kenya. *BMC Vet Res.*, **9(1)**:46.

Turkson, P.K., Lindqvist, K.J and Kapperud, G. (1988). Isolation of *Campylobacter* species. and *Yersinia enterocolitica* from domestic animals and human patients in Kenya. *APMIS*, **96(2)**:141-146.

UBOS (2009). Livestock Census. Uganda Bureau of Statistics, Kampala, Uganda.

von Wissmann, B., Machila, N., Picozzi, K., Fèvre, E.M., deC Bronsvoort, B. M., Handel, I.G. and Welburn, C.S. (2011). Factors Associated with Acquisition of Human Infective and Animal Infective Trypanosome Infections in Domestic Livestock in Western Kenya. *PLoS Negl Trop Dis.* **5(1)**: e941. doi: 10.1371/journal.pntd.0000941.

Wabacha, J.K., Gitau, G.K., Nduhiu, J.M., Thaiya A.G., Mbithi, P.M. and Munyua, S.J. (1998). An outbreak of urticarial form of swine erysipelas in a medium-scale pigery in Kiambu District, Kenya. *J S Afr Vet Assoc.*, **69(2)**:61-63.

Waiswa, C. (2008). African animal and human trypanosomiasis in South Eastern Uganda: animal reservoirs, vector competence and characterisation of *Trypanosoma brucei* isolates. PhD thesis Makerere University. <http://dspace.mak.ac.ug/handle/123456789/230>.

Waiswa, C., Fèvre, E.M., Nsadhha, Z., Sikasunge, C.S. and Willingham, A.L. (2009). Porcine cysticercosis in southeast Uganda: seroprevalence in Kamuli and Kaliro districts. *J Parasitol Res.* pii: 375493. doi: 10.1155/2009/37549.

Waiswa, C., Olaho-Mukani, W. and Katunguka-Rwakishaya, E. (2003). Domestic animals as reservoirs for sleeping sickness in three endemic foci in south-eastern Uganda. *Ann. Trop. Med. Parasitol.* **97**(2):149-155.

Wendo, C. 2002. Blue pork scare still persists. New vision 25<sup>th</sup> May, 2002. <http://allafrica.com/stories/200205270892.html>

WHO (2003) Food safety and nutrition food law guide lines

WHO (2007). Food safety and Health : a strategy for WHO African region . Fifty seventh session, Brazzaville, Republic of Congo, 21-31<sup>st</sup> August, 2007. Regional WHO office for Africa.

Wohlgemut, J., Dewey, C., Levy, M. and Mutua, F. (2010). Evaluating the efficacy of teaching methods regarding prevention of human epilepsy caused by *Taenia solium* neurocysticercosis in Western Kenya. *Am. J. Trop. Med. Hyg.* **82**(4):634-42. doi: 10.4269/ajtmh.2010.09-0404.