ASSESSING PREVALENCE, BIOSECURITY MEASURES AND LOST CARCASS-VALUE ASSOCIATED WITH PORCINE CYSTICERCOSIS ALONG PORK VALUE CHAIN IN WESTERN KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I, Marie - Françoise Mwabonimana, hereby declare that this thesis is my original work and has not been presented previously for the award of a degree here at Egerton University or any other University.

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Recommendation

This thesis has been submitted for examination with our approval as University supervisors.

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DEDICATION

This work is dedicated to the Almighty God for his glory and mercy that gave me strength to complete my study, to my loving husband, Jean Marie Sindibona and lovely children Daniella Mwari Muhoza Patience, Fidele Dushime and Abigael Mugisha Amanda, who gave me every encouragement needed to get me where I am today, and made me understand that hard work never kills. Thank you for your patience, my high regard to you will never end.

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ABSTRACT

Porcine cysticercosis (PC) infection is a zoonotic disease of public health concern globally, caused by *Taenia solium* larvae. The prevalence of PC infection is highest where domestic pigs scavenge for food in poor sanitary conditions. Western Kenya, especially peri urban areas, have a high concentration of domestic pigs reared under the scavenging system, which likely expose pigs and humans to PC infections resulting in huge economic losses. The objectives of this study were to determine PC prevalence, PC management practices and loss in carcass value associated with PC infection along the pork value chain in Busia and Kakamega Counties of Western Kenya. Data was obtained on random sample of 162 farms with 400 pigs in cross-sectional survey of randomly selected villages. PC infection was based on *T. solium* cysts presence and Ag-ELISA test. The mean prevalence of *T. solium* cysts within the scavenging pig' population sample was 3.8 at the farms and 5.3% at the slaughter slabs while PC infection prevalence from meat inspection was 1.8%. Management practices at farm did not target controlling PC because majority of farmers reared pigs in free range scavenging (69.1%) though use of pit latrines (72.8%) was high but majority were not aware (82.7%) of the link between pig management system and PC, not aware (75.9%) of *T. solium* parasite and not aware (78.4%) of risk factors in the transmission of PC infection. The butchers associated pork from slaughter slabs (76.9%) and home slaughters (73.1%) with high risk. Consumers were in strong agreement that pork in the market is safe (86%), pork from the slaughter slabs is safer than pork from the farms (92%) and that pork from butcheries is safer than pork from the eateries (82%). PC infection in the sample villages was associated with an estimated annual loss of Kes 547,969.29 (US$ 5,478.70) worth of carcasses from meat inspection and would be Kes 1,613,465.10 (US$ 16,134.7) if carcasses were condemned on results of Ag-ELISA testing surveillance. While results provide evidence of PC infection being prevalent in Western Kenya and low awareness among farmers of management strategies for PC control and prevention, consumers perceive pork in the market as safe. The prevalence levels and low farmer awareness warrants enforcing mandatory pig confinement and effective use of latrines, effective meat inspection at local slaughter slabs and strengthening public education to create awareness on transmission risk factors and their control and prevention. Further studies should identify different *Taenia* species in cysticercoids pigs in Western Kenya to inform life cycles patterns for appropriate management intervention.

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LIST OF ABBREVIATIONS AND ACRONYMS

Ab	Antibody
Ag	Antigen
Ap	Apparent prevalence
CESAAM	Centre of Excellence in Sustainable Agriculture and Agribusiness Management
CDC	Center for Disease Control and Prevention
DALYS	Disability Adjusted Life Years
DVS	Directorate of Veterinary Services
ELISA	Enzyme-linked immunosorbent assay
DRC	Democratic Republic of the Congo
EITB	Enzyme-linked immune-electro transfer blot
ELISA	Enzyme-linked immunosorbent assay
ESA	Eastern and Southern Africa
EU	Egerton University
FAO	Food and Agriculture Organization
FBO	Food Borne Diseases
GALVmed	The Global Alliance for Livestock Veterinary Medicine
HACCP	Hazard analysis and critical control points
HP10 Ag-ELISA	HP10 antigen detection enzyme-linked immunosorbent assay
ILRI	International Livestock Research Institute
INFOSAN	International Food Safety Authorities Network
KNA	Kenya News Agency
KNBS	Kenya National Bureau of Statistics
NACOSTI	National Commission for Science, Technology and Innovation
NTDs	Neglected Tropical Diseases
NCC	Neurocysticecosis
OIE	World Organization for Animal Health
OR	Odds Ratios
PC	Porcine Cysticercosis
SAS	Statistical Analysis System

Sp	Specificity
Spp.	Species
TDR	Special Program for Research and Training in Tropical Diseases
Tp	True prevalence
USDA	United States Department of Agriculture
WHO	World Health Organization
VIL	Veterinary Investigation Laboratory

CHAPTER ONE
INTRODUCTION

1.1 Background information

Porcine cysticercosis (PC) infection is a neglected zoonotic disease of global public health concern in pigs and human. The disease affects millions of people living in poverty riddled areas of Africa (Braae et al., 2015), Asia (Iweka & Ikeh, 2009) and Latin America (Cantey et al., 2014; Coyle et al., 2009). It is a food borne parasitic disease caused by the pork tapeworm *Taenia solium* larvae which also causes taeniasis in humans (Arora & Arora, 2012; Coral-Almeida et al., 2015; Adenuga et al., 2018) and constitute an important public health concern associated with human epilepsy (Food and Agriculture Organization/World Health Organization) [FAO/WHO], 2014; Karamon & Cencek, 2014; Mahanty & Garcia, 2010; Robertson et al., 2013;). It is estimated that 30 % of all acquired epilepsy cases in Sub-Saharan Africa (Assana et al., 2013) and in Latin America (Bruno et al., 2013) are attributable to PC infections. In India, Singh et al. (2017) reported that 2.1 million persons suffered from neurocysticercosis associated with active epilepsy. Taeniasis/cysticercosis represents an important public health and economic burden in endemic countries (Lightowlers et al., 2016; Matos et al., 2011; Mkupasi et al., 2011; Ndimubanzi et al., 2010; Rottbeck et al., 2013).

The Food and Agriculture Organization and World Health Organization classify PC as one of the widely neglected tropical diseases that is currently re-emerging (Waiswa et al., 2009; (Food and Agriculture Organization) [FAO], 2014; (World Health Organization) [WHO], 2017) with infections linked to poverty among pig farmers, free roaming pig production system, poor sanitary conditions and destitute waste management practices (WHO, 2015). The PC infections cause huge economic losses through massive discarding of infected pork carcass deemed unfit for consumption (Trevisan et al., 2016) which for pig producers especially smallholder farmers are is a barrier in accessing formal markets (Coral-Almeida et al., 2015; Waiswa et al., 2009). The value of pigs and pork positive for PC infections may reduce by by up to half (Trevisan et al., 2015). This represents a reduction in income for smallholder farmers, which in addition jeopardize food safety and security. These are developmental issues relevant to transforming livelihoods of poor farmers. The World Health Organization has responded to public health concerns about PC infections by committing to rolling out policies and measures to control and eradicate PC infections by 2020 (WHO, 2015).

Poor pig management practices, and inadequate meat inspection and preparation procedures may sustain the life cycle of *T. solium,* making it more endemic and prevalent in both humans and pigs (Akoko et al., 2019; Moyano, 2014). Several epidemiological studies show that keeping pigs under free-range production system increases the risk of the infection *in* pigs (Assana et al., 2010; Braee et al., 2015b). Therefore, effort should be focused on managing of sanitary conditions, free range husbandry and absence or inadequate meat inspection which generally sustain the parasite ‘s life cycle (Weka et al., 2009). Breaking the life cycle of *T. solium* will be possible with systematic inspection of slaughter pigs and the official postmortem inspection at slaughter (Gracey et al., 1968).

In Kenya, PC infection is prevalent in Western Kenya Counties of Busia and Kakamega where 40.6% of the pigs are affected and the seroprevalence from the cysticercoids pigs of 4.5% has been reported (Kagira et al., 2010). This high prevalence can be attributed to subsistence pig production system in which pigs freely scavenge for food in poor sanitary conditions, especially in peri-urban slums (Ng-Nguyen et al., 2018; WHO, 2015). The subsistence and scavenging pig production are characterized by lack of adequate sanitation and safe drinking water (Rottbeck et al., 2013) while a large proportion of pigs are managed without housing (73%). This is evidence of pig production under poor sanitary environment which easily predisposes them to infections by *T. solium*.

Pork consumers in Western Kenya are likely to be exposed to PC infection due to the high prevalence (Githigia et al., 2007; Kagira et al., 2010; Mutua et al., 2007) observed. The PC infection prevalence in smallholder pig farms reflects weak or untargeted control management practices in the pork value chain, low awareness among stakeholders and wrong attitudes and perceptions about the risks of PC infection. Studies on PC in smallholder systems focus on prevalence and risk factors but often ignore to adopt one health concept, despite recognizing that it is a parasitic zoonotic disease. This necessitates further epidemiological studies to inform planning targeted control strategies because PC infection prevalence can stifle growth of the pork sub-sector through barrier to accessing formal markets, cause of economic loss to farmers and traders arising from condemned carcasses, and link to epilepsy cases in humans.

1.2 Statement of the Problem

In the two Counties of Busia and Kakamega in Western Kenya, prevalence of porcine cysticercosis infection is up to 5.4% and empirical evidence associates high risk of *Taenia solium* infection with pork consumption (Thomas et al., 2016). This risk could increase further to affect more people as pig population continues to rise, evidenced by increased adoption. Yet pigs are managed under scavenging poor sanitary environment such as dumping sites, pork inspection is poor, infection surveillance is weak while producers, traders and consumer hold wrong attitudes towards PC transmission and association with epilepsy in humans. The situation portends human health risk and could render pig production unsustainable in Western Kenya. There is the need therefore to continually monitor prevalence, management practices and account for associated production losses to inform implementation of effective biosecurity measures in the pork value chain which would protect consumers and secure pig production and trade for livelihoods of smallholder farmers and traders.

1.3 Objectives of the Study

1.3.1 General Objective

To contribute to sustainable pork value chain free from risk of Porcine Cysticercosis infection with improved management practices and minimal economic losses.

1.3.2 Specific Objectives

i. To determine the prevalence of porcine cysticercosis at production and slaughter points in Busia and Kakamega Counties.

ii. To determine the management practices for control of porcine cysticercosis infections at production and slaughter points in Busia and Kakamega Counties.

iii. To determine awareness, attitudes and perceptions on safety practices among farmers, butchers and pork consumers in Busia and Kakamega Counties.

iv. To determine the loss in carcass value associated with porcine cysticercosis infections at the slaughter slabs in Busia and Kakamega Counties.

1.4 Research questions

i. What is the prevalence of porcine cysticercosis infection at the production and slaughter slabs in Busia and Kakamega Counties?

ii. What management practices are carried out at the production and slaughter slabs to control porcine cysticercosis infection in Busia and Kakamega Counties?

iii. What is the level of awareness, attitudes and perceptions on safety practices among farmers, butchers and pork consumers in Busia and Kakamega Counties?

iv. What is the monetary loss in carcass value from porcine cysticercosis infection at the slaughter slabs in Busia and Kakamega Counties?

1.5 Justification of the study

Pork is the fastest growing (325%) livestock production after poultry (300%) in Kenya (Behnke & Mthami, 2011). Busia and Kakamega are pig producing Counties in Western Kenya with a typical scavenging system which predisposes pigs to cysticercosis and taeniasis to humans. Studies on prevalence of porcine cysticercosis infection suggested that porcine cysticercosis infection can be traced to contaminated environment and presence of a tapeworm carrier at the production level. Porcine cysticercosis zoonosis possesses human health risk as well as economic losses for the pork industry due to carcass disposal. Enforcing inspections under high prevalence could mean rejection of entire or part of carcasses or resulting in huge economic losses from reduced carcass value. Studies have been done on the prevalence mostly by meat inspection but work on management systems is scanty. Empirical evidence to inform targeted management interventions is, however, unavailable.

Weak pork inspection structures and home slaughter allows some carcasses to reach consumers without being inspected, hence spreading the disease to humans. Improved knowledge of the status of porcine cysticercosis infection, management practices, and production loss from empirical evidence can inform interventions to reduce disease prevalence, improve pork safety and increase income from pig production and trade.

This study, therefore, fills the knowledge gap by estimating the prevalence and loss in carcass value associated with porcine cysticercosis and identify effective biosecurity measures needed to reduce the infection. It also identifies priority education needs to improve awareness, change attitude and practices at the levels of production, trading and consumption of pork to increase income.

This information could be valuable in understanding the risk to public health and economic ramifications on smallholder pig farmers, assessment of areas of interventions, identification and implementation of effective control strategies designed for porcine cysticercosis infection eradication in pigs.

1.6 Scope and Limitations

The study was confined to Busia and Kakamega Counties located in Western Kenya. This study was first focused on blood collection from pigs at the farm and slaughter slabs followed by meat inspection records for all pigs slaughtered during the period of study. Secondly, gathering information on biosecurity measures practiced and level of awareness, attitudes and perceptions on safety practices related to the transmission of the porcine cysticercosis infection, pork quality, safety, and safe consumption of pork.

To achieve the goal of this study, the actual prevalence of porcine cysticercosis among scavenging pigs in Western Kenya was determined, the management practices at the farm, and slaughter slabs were assessed. The awareness, attitudes and perceptions on safety practices for risk of porcine cysticercosis infection among farmers, butcher and consumers were then determined.

The problem encountered during this research wasthat of obtaining information on carcass condemnations because slaughter slabs records had no meat inspection reporting cases of cysticercosis in pigs. One of the objectives of this study was to determine the loss in carcass value associated with porcine cysticercosis infections at the slaughter slabs using retrospective data, but it had limitations where no cases of cysticercosis in pigs were reported through meat inspection. The study was limited to villages known for concentration of pig producing households, pig slaughter slabs, pork butchery and pork consumers.

1.7 Ethical consideration

Before the start of this research, the proposal of this study was submitted to and approved by the National Commission for Sciences, Technology and Innovation (NACOSTI), Kenya for ethical clearance, permit No: NACOSTI/P/19/80633/27786 (Appendix 2). Details of the impact and benefits of the study were explained to DVOs in Busia and Kakamega Counties, the key community leaders and participants in the study area.

1.8 Definition of terms

Biosecurity: In its common usage, biosecurity refers to the protection of health through avoidance of disease. It is therefore the implementation of hygiene and sanitary measures that can stop the introduction of a disease into a farm and or contain its spread within and between farms (Brennan & Christley, 2012; Gunn et al., 2008; Wilson, 2014). Valeeva et al. (2011) defined biosecurity as a universal concept of direct significance to the sustainability of agriculture, environmental protection, including biodiversity, and food safety. In relation to food safety, Biosecurity is an integrated and strategic method used in the management and analysis of major risks to human animal and the associated risks for the environment. This was established based on recognition of the critical relationships between sectors and the potential for hazards to move in and between sectors, with system-wide consequences (INFOSAN, 2010; Mandal, 2019).

Bio-exclusion (or external biosecurity): This is a biosecurity measure implemented which involves preventing the introduction of new pathogens (diseases) within a population/pig unit from outside source (Levis & Baker, 2011). It useful in the limitation of the level of animal ‘s exposure to pathogen below there should level for infection.

Bio-containment (or internal biosecurity): This is the series of management practices that prevent the spread of disease agents between animal populations on a farm or the management practices designed to prevent the infectious agent from leaving the farm. It is also a very important process of protecting the food supply for consumers by reducing the consequences of diseases which includes immunization and quarantine ((Food and Agriculture Organization/World Organization for Animal Health) [FAO/OIE], 2010F).

Cysticercosis: This is the tissue infection with larvae stage of the *taenia solium* pork tapeworm acquired from ingesting eggs excreted by a person who has an internal tapeworm.

Cysticercus: A larval tapeworm at a stage in which the scolex is inverted in a sac, typically found encysted in the muscle tissue of the host.

Disease: Refers to any subjective or objective departure, from physiological or psychological well-being.

Disease burden: The impact of a health problem in a population which can be measured by financial cost, mortality, morbidity, or other indicators.

Disease surveillance: This is the monitoring of a disease to establish patterns of its progression. This refers to the continuing scrutiny of all aspects of occurrence and spread of a disease that is pertinent to effective control.

Food-borne diseases: These are defined as diseases which follow the ingestion of toxins, bacteria, and cells produced by microorganisms present in food (Okonko et al., 2010).

Food safety: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect (Mandal, 2019).

Food secure/security: A situation that exists when all people can have physically, socially and economically access to sufficient, nutritious and safe food that meets their food preferences and dietary needs for a healthy and active life (Ministry of Agriculture, Livestock, Fisheries and Irrigation, Kenya).

Gender: Refers to qualities or characteristics that society ascribes to each sex after they have learned to be women and men. Within and between cultures, people perceived gender differently but with same consideration as the determination of power and resources for females and males (FAO, 2012).

Infection: This is the invasion of an organism ‘s body tissues-causing agents, their multiplication, and the reaction of host tissues to the infection ‘s agents and the toxins they produce. In case of cysticercosis, infection is the evidence of preceding ingestion of *T. solium* ova which result in aborted development or presence of viable or degenerated or dead *T. solium* cysts wherever in the body irrespective of the positive antibody response. Include a positive serology for antibodies or antigen calcifications in brain, muscle, viable or degenerating parasites.

Livestock: Refers to animals such ascattle, sheep etc. that arekeptortradedas asourceofincomeand way of capital accumulation and savings, a source of protein, an index of social wealth and an outward sign of wealth (Moyo et al., 2010).

Meat quality: This is normally defined by the compositional quality (lean to fat ratio) and the palatability factors such as visual appearance, smell, firmness, juiciness, tenderness, and flavour.

Meat inspection: This is the principal method for ensuring the safety of meat. The purpose of meat inspection is to provide safe and wholesome meat for human consumption.

Neurocysticercosis (NCC in humans): This is the evidence of *T. solium* infectiom of the brain with or without symptoms which occurs when an immature larval stage of the parasite has migrated to the brain. In the developing word, this is considered as the most common parasitic infection of the nervous system in human and the most frequent and preventable cause of epilepsy (Del Bruto et al., 2001).

Neglected zoonotic diseases (NZDs): Diseases caused by a vector or carring species and which are transmitted between animal and human hosts. They are prevalent in many developing countries of Africa, South and Central America, and Asia. Some examples are: anthrax, bovine tuberculosis, brucellosis, cysticercosis, and echinococcosis rabies. Neglected zoonotic diseases have both direct and indirect effects on human health and they are sickening and killig livestock (Molyneux et al., 2011).

Onchospere: This is the larval form of a tapeworm once it has been ingested by an intermediate host animal (Ridley, 2011).

One Health (OH): One Health recognizes that the health of humans is connected to the health of animals and the environment with the goal to encourage the collaborative efforts of multiple disciplines and sectors, working locally, nationally, regionally and globally, to achieve optimal health for humans and animals, and the environment (Mazet et al., 2009; Nabarro & Wannous, 2014).

Parasite: Refers to an organism living in, with, or on another organism.

Porcine cysticercosis (PC): Is important food borne parasitic disease.

Prevalence: In statistics, prevalence is a concept referring to the number of cases of a disease present a particular population at a given time.

A statistical concept referring to the number of cases of a disease that are present in a particular population at a given time.

Risk: In epidemiology, a risk is a kind of measure: it is the number of new cases of a disease or other health event occurring within a given time period. It indicates the likelihood of developing the disease in the exposed group relative to those who are not exposed (Blumenthal et al., 2001).

Sensitivity: is the ability of a test to correctly classify an individual which test positive as ′diseased and it constitutes the proportion of true positives. This equates to the laboratory definition where it means the ability of an analytical method to detect very small amounts of the analyte such as an antibosy or antigen. Therefore, a test considered as highly sensitive from a laboratory perspective is also likely to be sensitive from an epidemiological perpective (Parikh et al., 2008).

Specificity: is the ability of a test to correctly classify an individual as disease-free and it is a proportion of animals without the diseases considered as proportion of true negatives. This equates to the laboratory definition where it means the ability of the test to react only when the particular analyte is present and not react to the presence of other compounds. Thus, a test highly specific from a laboratory perspective is also likely to be specific from an epidemiological perspective (Parikhet al., 2008).

Seroprevalence: is usually a defined population testing positive for antibodies to *T. solium* cysts and less commonly positive for cestode antigen in serum.

Taeniasis: The intestinal infection with adult tapeworm.

Tapeworm: A parasitic flatworm or cestodes. Live tapeworm larvae (coenuri) are sometimes ingested by consuming undercooked food. Once inside the digestive tract, a larva can grow into a very large adult tapeworm and cause a disease.

Value chain: A set of inter-connected activities, individuals or businesses that transport and transform a raw material from the original producer to the final consumer (Porter, 1985). From input supplies, the actors in the supply chain is comprised by producers, processors, importers and exporters who are engaged in various activities required to bring a product from its conception to its consumption. Therefore, the value chain can be described as an interaction between the supply and demand chains (Kula et al., 2006).

Zoonosis: A zoonosis is defined by the WHO as any disease or infection that is naturally transmissible from vertebrate animals to humans but can be perpetuated solely in nonhuman host animals‖ (FAO, 2020; Mandal, 2019; Maudlin et al., 2009; WHO, 2015).

CHAPTER TWO

LITERATURE REVIEW

This chapter emphasizes on general review of porcine cysticercosis infection and its prevalence with highlight on the status in Africa. The predisposing risk factors of PC, pork meat quality and safety, the production losses from PC and the conceptual model for PC infection assessment are provided.

2.1. Importance and Distribution of Porcine Cysticercosis

The Porcine cysticercosis (PC) infection is a commonly neglected serious tropical zoonotic disease, which is prevalent in many developing countries (Fleury et al., 2013; Mwape et al., 2013) with high effect on public health and agriculture and has caused significant economic losses worldwide such as seizures and death in pigs and humans (Dixon et al., 2020; Gonzalez et al., 2016; Nkwengulila, 2014). The disease has remained largely neglected in West Africa but eradicable and easy to control (Melki et al., 2018; Willingham et al., 2010). *T. solium* parasite has been documented to be a high public health burden of ill health in humans (Carabin et al., 2011; Garcia et al., 2014). Owing to conditions related to poverty, such as poor management practices, inadequate sanitation and absence or lack of meat inspection and control, cysticercosis remains a veterinary problem and an important public health in endemic low-income and non-endemic countries in the world (Figure 1), where the reasons for its persistence have not been addressed effectively (Torgerson et al., 2015; Wardrop et al., 2016; Willingham et al., 2010).

A study in South East Asia by Cook et al. (2019) confirmed the association of *T. solium* infection with lower relative levels of socio-economic development in endemic areas. *Taenia solium* cysticercosis can also cause neurocysticercosis, a fatal infection of the central nervous system (Beam et al., 2018; Wandra et al., 2015) and sometimes death (de Lange et al., 2019; Kula et al., 2006). Cysticercosis is also a serious constraint for the nutritional and economic well-being of smallholder farming communities in many countries of Africa (Ngowi et al., 2019), Latin America and Asia as it reduces the market value of pigs and renders pork unsafe to eat (World Organization for Animal Health/Special Program for Research and Training in Tropical Diseases) [WHO/TDR], 2012).

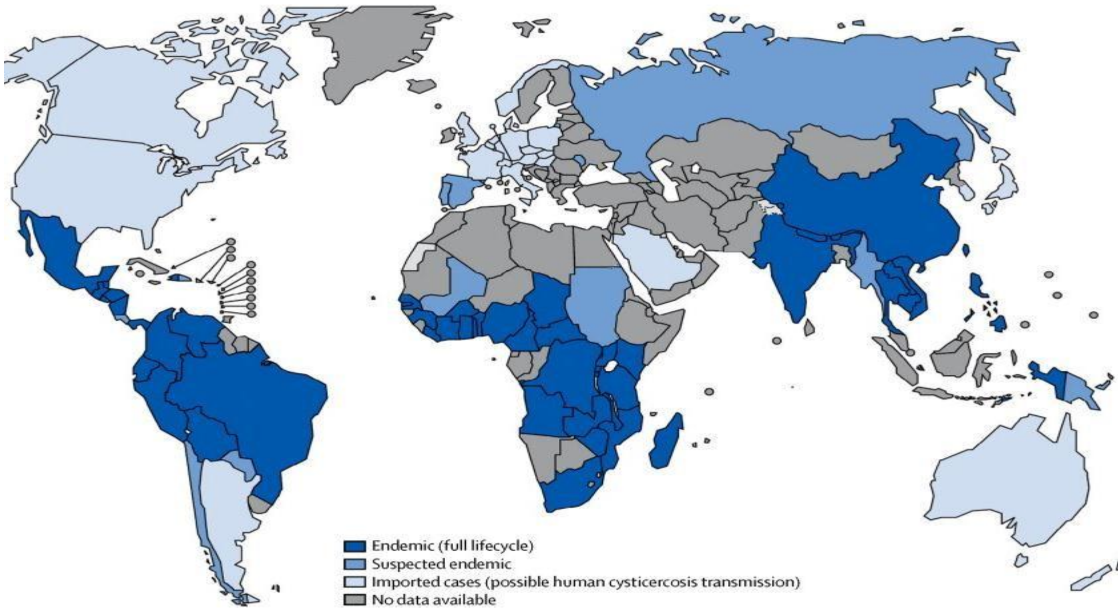

Figure 1: Global Distribution of Taeniasis and T. solium cysticercosis.

Source: WHO, 2015 **(**http://atlasofscience.org/wp-content/uploads/2015/11).

Taeniasis and cysticercosis occur worldwide (White *et al.,* 2018). Their occurrence is associated with certain cultural practices such as eating raw or undercooked pork, poor socioeconomic conditions and lack of knowledge on the mode of transmission of the parasite (Singh et al., 2013). The endemicity of *T. solium* porcine infections in the rural areas of developing countries (Moyano et al., 2014) has been associated with general poverty (Wandra et al., 2015), free ranging of pigs and outdoor defecation by humans where pigs can have access to environment with raw or improperly treated sewage effluent to irrigate vegetables and pastures where pigs feed (Jayashi et al., 2012; Krecek et al., 2012; Mwanyali et al., 2013). The zoonotic tapeworm *T. solium* has a two-host life cycle, the indirect one with humans as the definitive host, and pigs as a normal intermediate host harbouring the larval cysticerci (Donadeu et al., 2017). Cysticercosis in pigs results from the ingestion of *T. solium* eggs directly by faecal-oral route, or environments contaminated with human faeces whereas humans are infected through undercooked pork or improperly washed vegetables from contaminated environments (Floury et al., 2013; Singh et al., 2010).

2.2 Epidemiology of Porcine Cysticercosis

In epidemiology, prevalence is a comparison between the numbers of diseased animals with the total number of animals studied and is usually expressed as a percentage **(**Kenneth, 2012). Prevalence is the proportion of a population found to be affected by a disease. Compared to East African endemic countries, the overall estimated prevalence 's from 14 non-East African community endemic countries (Table 1) include Ghana (18.8%), Cameroun (19.5%), Mozambique (10.0%) and Egypt (30.0%). An average of 1.3 - 45.3% cases of cysticercosis in human beings were reported using Ab-ELISA (Antibody detection); 4.6 - 11.9% were detected using Ag-ELISA (Antigen detection); 6.9 - 16.7% using EITB and 23.2 to 54.6% were documented using CT scan reported for some countries such as Zambia, Burkina Faso, DRC, Burundi, Tanzania, Egypt, Ghana, Nigeria, Mozambique and Uganda (Shonyela et al., 2018).

Cysticercosis in many countries of Africa was mainly attributed to the free-roaming pig production system, debased sanitary and hygienic conditions in rural areas as well as poor waste management practices. The contact between infective human faecal matter and pigs is imperative for the successful propagation of the parasite lifecycle (Figure 2). Once ingested, the eggs develop into the larval forms in pig intestine, which can reach to the blood stream and eventually form cysts (porcine cysticercosis). *T. solium* infection can also be transmitted from human-to human or from pig-to-human. This could be achieved through consumption of under-cooked pork by human beings or pigs drinking water contaminated by fecal matter (indirect) (Del Brutto, 2014; Flisser et al., 2011; Flisser & Gyorkos, 2007; Hidalgo, 2007; Kungu et al., 2017; WHO, 2016). Humans can also serve as intermediate hosts and develop the cystic form by accidental ingestion of *T. solium* eggs (Gonzalez et al., 2003; Lescano et al., 2007; Quet et al., 2010).

Table 1: Prevalence of Porcine Cysticercosis in Africa.

Countries	Prevalence
West Africa	
Burkina faso	36.05%
Gambia	4.80%
Ghana	18.80%
Nigeria	27.80%
Senegal	13.20%
Central Africa	
Cameroun	19.50%
South Africa	
Mozambique	10.00%
Zambia	24.32%
Zimbabwe	28.60%
Southern Africa	
South Africa	50.20%
Madagascar	21.30%
Angola	6.80%
North Africa	
Egypt	30.00%
Chad	25.70%
East Africa	
Burundi	25.70%
Kenya	22.90%
Rwanda	20.00%
Tanzania	22.50%
Uganda	18.00%
Democratic Republic of Congo	39.60%

Source: Shonyela et al. (2018)

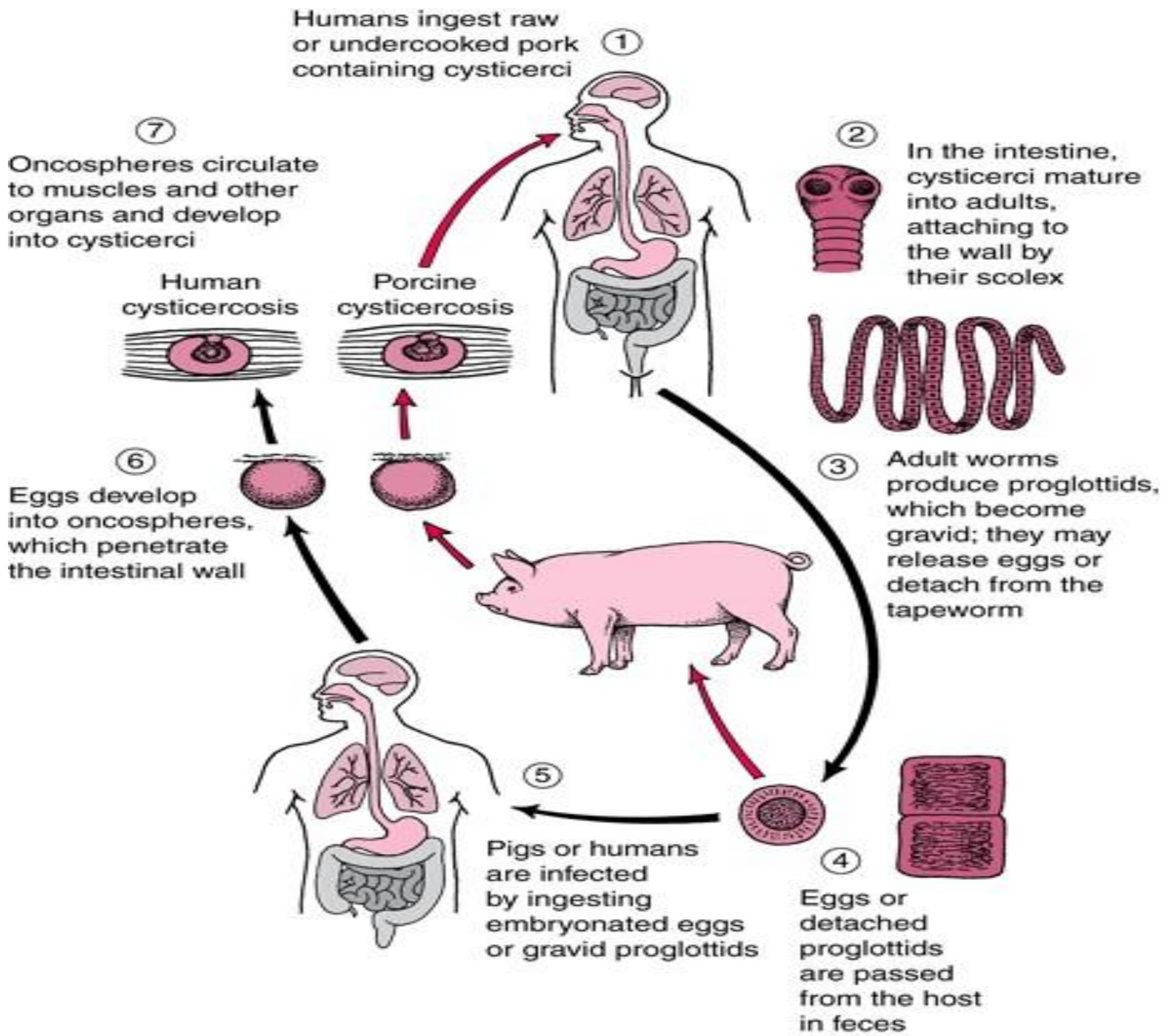

Figure 2: Life cycle of Taenia solium

Source: Pearson (2016) (http://www.msdmanuals.com/professional/infectious-diseases/cestodestapeworms/taenia-solium-pork-tapeworm-infection-and-cysticercosis).

2.3 Diagnosis of Porcine Cysticercosis Infection

Animals affected are detected using various methods including lingual examination of live pigs; visual inspection of carcass at the slaughter slabs and serological testing. The diagnosis for *T. solium* cysticercosis in porcine has also been done by the DNA detection (Waema et al., 2020).

Immunology (Immunochemistry and PCR) (Eom et al., 2011; Jeon et al., 2009) and serological methods which are ELISA techniques (Ag-ELISA, Ab-ELISA) using blood samples of infected pigs for antibodies or parasites antigens detection has been developed to confirm the disease in pigs (De Aluja et al., 2012; Guyatt et al., 2016; (World Organization for Animal Health) [OIE], 2008). OIE, (2008) acknowledge a larger sensitivity of immuno-diagnostic techniques as compared to the diagnosis in live animals and the carcass dissection. The lingual examination appears to be inexpensive and easier for PC detection in field work but it is effective for highly infected pigs and has low sensitivity. It is used by meat safety checkers to detect palpable cysts in infected pigs as an indication of the disease (Chembensofu et al., 2017). The post-mortem inspection of the carcass has been reported as the best suited for meat inspection at the slaughter slabs (Goussanou et al., 2013) but this technique has been found to be less sensitive for moderately infected pigs (Dorny et al., 2004). The serological methods (ELISA techniques) typically show exposure to PC infection and active infections (Willingham, 2006). More recently diagnosis using molecular diagnostic technique (Guyatt et al., 2016; Karamon et al., 2013; Mayta et al., 2008; Sreedevi et al., 2012) and microscopic diagnostic methods (coprology) (Idika et al., 2017) has been reported for both cysticercosis and taeniasis. Hence, Johansen et al. (2017) found that PC has been misdiagnosed or under-diagnosed due to the fact that there are no applicable, cheap, sensitive and specific diagnostic tools for this disease. The diagnostic, control methods and the endemicity of *Taenia solium* are fairly well understood (Samorek-Pierog & Cencek, 2018).

Prevalence may be specified as apparent prevalence (Ap) or true prevalence (Tp) (Lewis & Torgeson, 2012). The Ap is defined as the proportion of the pig population that tests positive using a diagnostic method, and Tp is the proportion of truly infected pigs in that population (Greiner & Gardner, 2000; Thrusfield, 2013). Sensitivity (SE) of a diagnostic test can be computed as the proportion of infected animals that the test detects as positive (Berkvens et al., 2006; Dorny et al., 2004). Specificity (SP) has been defined as the ability of a test to correctly classify an individual as disease-free (Parikh et al., 2008). The sensitivity of post-mortem inspection procedures is the probability of identifying bodies or parts thereof that contain grosslydetectable abnormalities likely to contain risks. It is recommended to establish their contribution to achieving overall public health goals (Code of hygienic practice for meat, 2005).

The World Health Organization (WHO) classifies PC as a neglected and re-emerging tropical disease (WHO, 2017). Shonyela et al. (2018) reported that the prevalence of PC in endemic African counties varies from 19.5% to 40% and it varies widely with the diagnostic methods used. The three methods commonly used in epidemiological survey are tongue examination, meat inspection and Ag-ELISA (Goussanouet al., 2014). Table 1 presents results from a review of 68 studies for 20 endemic countries between 2001 and 2017. Determination of prevalence by tongue inspection was 9.4% (Boa et al., 2006; Guyatt et al., 2016; Silva et al., 2012); 15% by postmortem examination (Kagira et al., 2010; Phiri et al., 2006; Prasad et al., 2006;), 24.7% by Enzyme-linked Immuno electro transfer Blot (EITB) technique and 29.7% by ELISA B158/B60 (Komba et al., 2013).

Salient literature on PC prevalence suggests that the majority of studies (Bustos et al., 2012; Mwanyali et al., 2013; Mwape et al., 2013; Praet et al., 2013; Ramahefarisoa et al., 2010; Winkler et al., 2008; Winkler et al., 2009) in sub-Saharan Africa used Ag-ELISA and tongue inspection methods to detect PC whilst in East Africa many studies used seroprevalence as they considered it to be very sensitive (85-90%) and specific (92-96%) (Braee et al., 2014; Donadeu et al., 2017; Kungu et al., 2017; Nkouawa et al., 2017;Pondja et al., 2015).

Studies on pig production in Zambia, Madagascar, West Cameroon, Tanzania, Kenya, South Africa and Mozambique reported Ag-ELISA sensitivity between 76.3% and 86.7% with specificity ranging between 84.1% and 98.9% (Komba et al., 2013; Krecek et al., 2008; Porphyre et al., 2015; Pouedet et al., 2002; Trevisan et al., 2017). Porcine cysticercosis infection in pigs is usually without noticeable signs apart from diarrhoea and myositis (Gonzalez et al., 2003). On the other hand, symptoms in human beings depend on the location, number of cysts and degeneration stage of the cysticerci in the host.

In some cases, anorexia, loss of weight, abdominal pain and digestive upsets have been documented (Garcia et al., 2014; Webb & White, 2016; White, 2000). Cysts in the brain may lead to neurocysticercosis characterized by headache, epilepsy, paralysis and even death (Boa et al., 2006; Carabin et al., 2011; Nsadha, 2013).

2.3.1 Meat inspection

Meat inspection has been considered important worldwide from the food safety perspective (Luukkanen et al., 2015), performed to ensure that meat is clean and free from unwanted matter for human protection. Abattoirs are often very unhygienic and sources of cross contamination of foodstuffs destined for human consumption. This necessitates designing and implementing biosecurity plans to reduce and eliminate risk of disease transmission along the value chain, from farm to fork (Ocaido et al., 2013). Therefore, the ante-mortem inspection of animals and meat inspection are critical to ensure that only healthy animals and healthy meat enters the human food chain (FAO/OIE/World bank, 2011). In pigs, clinical signs are not well defined and this makes the ante mortem diagnosis based on clinical signs impossible (Sreedevi, 2013) and can only be visible at the stage of nervous symptoms exhibition characterized by the presence of cysticerci in the eye and brain of pig (Prasad et al., 2006). Nonetheless, it has been found to be more readily available and less costly than Ag-ELISA testing (Guyatt et al., 2016). Furthermore, the assessment of the prevalence from the tongue cyst-positive constitutes a potentially rapid epidemiological tool for high risk areas of cysticercosis (Guyatt et al., 2016). Several studies have been done on tongue inspection (de Aluja et al., 2008; Morales et al., 2008; Ngowi et al., 2009; Wohlgemut et al., 2010) and meat inspection to diagnose PC (Cruz et al., 1989; Gweba et al., 2010). Meat inspection has been reported as the main diagnostic procedure used in the diagnosis of metastodes of *T. solium* in the carcass. It is performed after the animals are slaughtered with the main purpose of identification and eliminating infected animals from the food chain. The provision of the routine meat inspection is made within official meat hygiene regulations following the predilected sites. It is done using visual inspection, palpation followed by incision of the various organs including masseter muscles, heart, gracilis muscles and diaphragm. Oesophagus, lungs, liver, stomach, spleen, kidney and subcutaneous fat are visually inspected for the presence of cysts (Faleke & Ogundipe, 2004). The incisions include parallel incisions into external and internal masseter muscles, a longitudinal incision along the length of the tongue, incision into the heart septum and three incisions into the triceps muscle (Boa et al., 2002; Kakoty et al., 2017). Cai et al. (2006) observed that the routine meat inspection is a useful method when animals are heavily infected whereas in Zambia, Dorny et al. (2004) reported that meat inspection has high specificity, but low sensitivity 38.7% in case of light infestations.

2.3.2 Sero-prevalence of porcine cysticercosis

The seroprevalence of porcine cysticercosis is reportedto vary from one region to another (Ngowi et al., 2004). Serological methods have been reported to be helpful in parasite identification in endemic areas and monitoring of the control strategies in place (Gavidia et al., 2013; Mohan et al., 2013; O ‘Neal et al., 2014). Enzyme-linked immunosorbent assay (ELISA) is preferred because it is highly sensitive and specific and its application for circulating parasite antigens detection may present some diagnostic advantages since it demonstrates not only exposure but also active infections (Willingham, 2006). The assay is genus specific and therefore does not allow the differentiation between infections of the three different *Taenia* species commonly found in pigs (*T. solium, T. hydatigena* and *T. asiatica*) and it is a qualitative determination of viable metacestodes (cysticerci) of *Taenia spp*. in human and porcine serum samples but not appropriate in pig with low infection (Dorny et al., 2004). The Antigen (Ag) ELISA has been reported to have a sensitivity of 85% (Garcia et al., 2000) and a specificity of 94.7% (Dorny et al., 2004) and 84.1% (Krecek et al., 2008).

2.4 Biosecurity Measures for Porcine Cysticercosis Infection

The concept of biosecurity is a strategic and integrated approach that alludes to implementation of hygiene and sanitary measures that can stop the introduction of a disease into a farm and/or contain its spread (Valeeva et al., 2011). It is a universal theory of direct importance to the sustainability of agriculture, and wide-ranging aspects of public health and protection of the environment, including biological diversity.

Biosecurity covers the introduction of animal and plant diseases and pests, the introduction and release of living modified organism and their products, and the introduction and management of invasive alien species. It covers also the zoonoses and food safety. The aforementioned is therefore an indispensable part of risk management for pig producers. In pig farming, external and internal biosecurity measures can be distinguished within the herd (Alawneh et al., 2014). These are important biosecurity measures applied in maintaining animal health by preventing the transmission of diseases at farm level, contributing to public health and improving livelihood of pig farmers (Laanen et al., 2013; Manuja et al., 2014).

They also reduce the use of antimicrobials (Backhans et al., 2015; Postma et al., 2016). This application of farm biosecurity associated to hygiene management has been observed to influence positively on food safety (Andres & Davies, 2015). The poor implementation of biosecurity measures is therefore an exposure for pigs to the risk of PC (Assana et al., 2010). Estimating the extent of the risks of PC and its consequences on pig farming requires well maintained and updated pig production and management records. However, veterinary reports, farm records and other important statistics on pig farming are usually inaccurate or completely missing in various households and slaughter slabs. This poor level of biosecurity measures will require an intervention by the government's officials in establishing the guidelines with focus on the farmer's capacity building in pig farming and biosecurity practices in the pig sector.

The transmission of the *T. Solium* is related to behavioural and environmental factors such as inadequate sanitation and hygiene, poor pig management and consumption of infected pork (Chenais et al., 2017; Fretin et al., 2013; Kylie et al., 2017; Ngowi et al., 2013). The introduction of strategies for control of the parasite aim at interrupting the various points in the life cycle with focus on both human and porcine hosts to ensure the safety of pork production (Floury et al., 2013). The application of biosecurity measures with pigs reared on free range system has been reported very difficult and almost impossible but commonly practiced in large herd with modern facilities (Bellini et al., 2016; Delsart et al., 2020; Kouam et al., 2020; Wormington, et al., 2019).

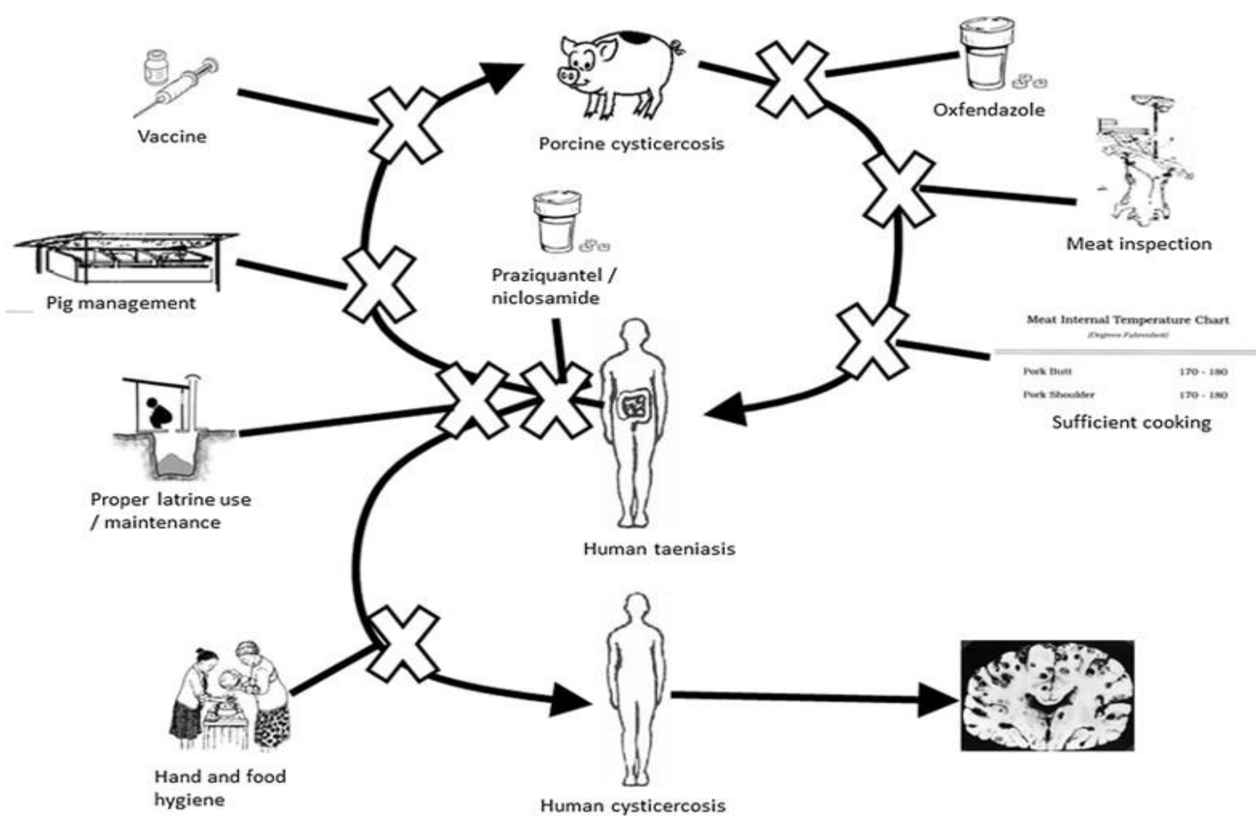

Figure 3: Interventions for control in the life cycle of *T. solium*. X indicates the areas of life cycle interruption

Source: Devleesschauwer et al. (2014).

2.4.1 Biosecurity measures for porcine cysticercosis infection at farm level

The role of biosecurity in disease prevention and the increase of productivity at the farm level has been demonstrated by Kouam & Moussala. (2018) and reported as the cheapest way of diseases control in the herds. At farm level, the prevalence of various diseases is associated with the level of biosecurity applied as by different production systems (Pandolfi et al., 2018). From the consideration of the biosecurity practices in the pig industry, poor animal husbandry practices, absence of measures to restrict entry into the farms and the non-organized movement of animals has been qualified as challenges in many developing countries (FAO, 2012). But the observation of routine farm biosecurity constitutes a priority solution in the minimization of risk in diseases spread. The good health of animal has been reported to be contributing factor to the reduction of the disease prevalence which leads to an improved human health (Allievi et al., 2015). In pig farms, knowing that the pig itself constitutes the main risk, biosecurity is considered as a combination of all measures taken to reduce the risk of any disease introduction and their spread. This mean to reduce the probability of diseases to occur following that zero risk is not easy to achieve (FAO, 2010).

The risks for *T. solium* porcine infections in the rural areas identified include free ranging of pigs and outdoor lack of toilets where pigs can have access to human faeces, use of raw or improperly treated sewage effluent to irrigate vegetables and pastures where pigs feed; and involvement of human *T. solium* carriers in pig care (Komba et al., 2013; Zirintunda & Ekou, 2015). In pig farming, the emergence or re-emergence of *Taenia sp.* larvae infection is generally predisposed by the pig rearing, poor sanitation and poor hygiene conditions during slaughter without adequate meat inspection enforcement (Gabriël et al., 2015, Ngowi et al., 2017). The interaction between the pathogens present on farms and others factors such as the housing, feed and management practices has been reported to be the contributing factors on the occurrence of a disease (Clark et al., 2019; Perry et al., 2013).

The total confinement of pigs (Mbuthia et al., 2015) makes possible the application of biosecurity measures (Bellini et al., 2016). This has been recommended by Nantima et al. (2015b) as a component of proper biosecurity in good pig management. Considering the disease aspect, the extensive system has been reported to differ from intensive system where the management practices and disease control are easily applied. Therefore, animals are saved from diseases and consumer 's food safety guaranteed (Niemi et al., 2016). The intensification of livestock production is therefore feasible with a long-term application of One Health aiming on the mitigation of the health risks at the crossing point between animals and humans in different environments (Nabarro & Wannous, 2014). A case-control study on feed stuff and poor latrines revealed that feeding potato peels to pigs increased the risk of infection for pigs kept in elevated pens and on poorly maintained floors compared to pigs on a cemented floor (Braae et al., 2015).

2.4.2 Biosecurity measures for porcine cysticercosis infection at the slaughter points

Slaughterhouses are important stage for bio-containment in the pork value chain where risks of PC to consumers can be reduced with effective pork inspection (FAO, 2012; Saegerman et al., 2012). During processing which begins with the arrival of animals at the abattoir, contamination can occur pre- and post-slaughter and the potential sources of contamination include other animals, water, contaminated surfaces, personnel, and poor technique. Considering as a source of infection or pollution, the disposal of condemned carcass or meat require a careful control and the Hazard Analysis Critical Control Point (HACCP) system has been developed to ensure the safety of the final product. Therefore, the ante-mortem inspection of animals and meat inspection are critical to ensure that only healthy animals and healthy meat enters the human food chain (FAO/OIE/World bank, 2011).

Taenia solium cysticercosis is a meat-borne parasitic disease with public health risk to producers, processors and consumers within the pork value chain. Therefore, enforcing control along the pork value chain is of public health importance (Porphyre et al., 2015). From the one health approach, disease control at livestock value chain level contributes to poverty alleviation, disease burden reduction and livelihoods improvement especially in the developing world (WHO, 2009b). Abattoirs are often very unhygienic and sources of cross contamination of foodstuffs destined for human consumption. This necessitates designing and implementing biosecurity plan to reduce and eliminate risk of disease transmission along the value chain, from farm to fork (Ocaido et al., 2013).

The leverage areas for addressing associated sustainability concern outcomes illustrated with the Casual Loop Diagram (CLD) (Figure 4) are the educational training on the pig management systems, *Taenia solium* cysticercosis and its transmission which need to be reinforced (R) and the effective biosecurity measures witch need to be balanced (B) and implemented correctly in the pork value chain. The reduced of PC prevalence will therefore contribute to the pork safety for consumers and increased income from pig production and trade.

Prevention, control and possible elimination of *Taenia solium* require a one health approach (Rossi et al., 2016; Samorek-Pieróg & Censek, 2018) which facilitates closer collaboration between human and animal health. This approach was developed from one medicine in 1960s by Schwabe, (1984) to illustrate the similarity of human and Veterinary medicine (Calistri et al., 2013; Hitziger et al., 2018). This has contributed towards amalgamating the veterinary, human health and the environmental sectors for public and animal health improvement (Dean et al., 2013; Narrod et al., 2012; Zinsstag et al., 2009).

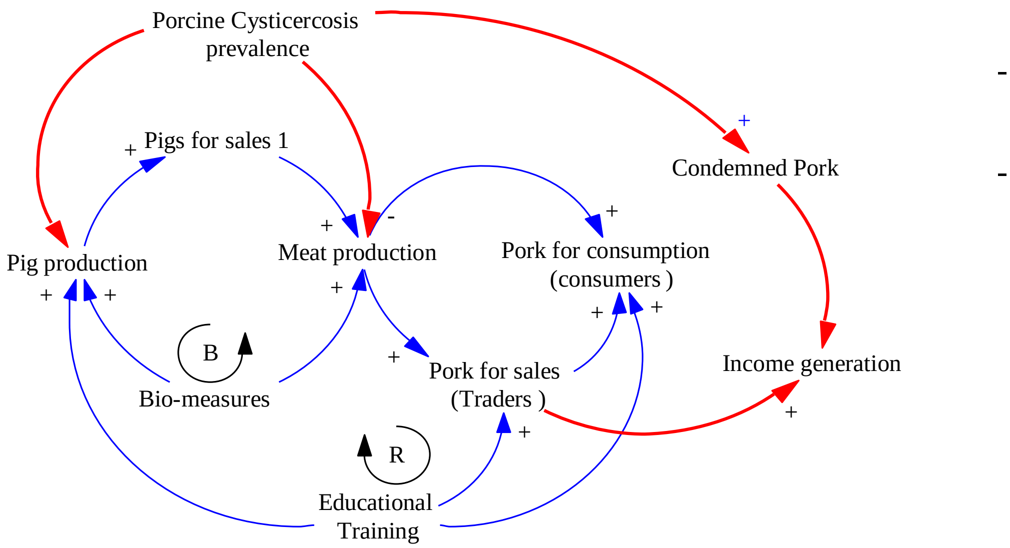

Figure 4: Casual Loop Diagram (CLD) of biosecurity measures and control of porcine cysticercosis (Author proposed strategies).

Therefore, several interventions for taeniasis and cysticercosis control has been suggested by the World Health Organization such as preventive chemotherapy; improved health education (Johansen et al., 2017); improved sanitation; improved pig husbandry; improved meat inspection and processing; vaccination of pigs; treatment of pigs and diagnosis and treatment of taeniasis cases in humans (WHO, 2014). Moreover, it has been found possible to interrupt the parasite‘s lifecycle by the combination of the effective vaccines application against porcine cysticercosis infection (Gilman et al., 2012; Lightowlers, 2013; Sánchez-Torres et al., 2019) and mass chemotherapy through the implementation of anthelmintic treatment interventions in both the human and porcine populations for cysticercosis and taeniasis respectively in endemic areas (Ash et al., 2017; Okello et al., 2016). The success in the eradication of porcine cysticercosis may involve the treatment of taeniasis in humans followed by the health education (Ngowi et al., 2011). Oxfendazole has been suggested to be the most effective anthelmintic (Moreno et al., 2012) against muscle cysts with little orno side-effects (Johansen et al., 2017) and has been reported to induce protection against reinfection with *T. solium* for at least three months (Pondja et al., 2012).

The improvement of the pig husbandry through pig confinement is a contributing factor to the reduction of PC risk, even other diseases (Gabriël et al., 2015). Studies elsewhere demonstrate that health education constitute an important element in the control of PC in endemic areas (Carabin et al., 2018; Ertel et al., 2017; Hobbs et al., 2019; Mwidunda, 2015; Ngowi et al., 2011). This can be associated with the implementation of good sanitation and hygiene when planning for long-term control strategies (Pruss-Ustun et al., 2014; Thys et al., 2016). The introduction of strategies aimed at controlling *Taenia solium* seek to interrupt the parasite at various points in its life cycle in both human and porcine hosts to ensure safety of pork production (Floury et al., 2013; Thomas et al., 2016). Effective control of the parasite therefore requires knowledge of both its public health and economic ramifications (Lightowlers et al., 2016).

Furthermore, it is important to understand the pattern of infections which entails: widespread human treatment to curb further spread of PC infections, combination of animal vaccination with health education (De Aluja et al., 2008; Lightowlers, 2013) and extensive animal vaccination as a preventive strategy. Moreover, there‘s need to introduce and enforce stringent laws, along with severe punishment which may promote behavioral change in pig management, better meat inspection procedures that promote food safety (Thomas et al., 2019), adequate meat handling and hygiene (Kyvsgaard et al., 2007), and appropriate human waste disposal (Chawhan et al., 2015) together with the mandatory pig confinement in areas of high PC infection in a bid to control spread of porcine cysticercosis (Mkupasi et al., 2017).

Vaccination in the control of porcine cysticercosis has been recognized as an important approach in preventing *Taenia solium* transmission and a potential and attractive method for controlling *T. solium* transmission (Cai et al., 2008; Lightowlers, 2010). Reference is made on the landscape analysis on control of *Taenia solium*, in which Chemoprophylaxis in pigs had been widely suggested as a control strategy (Assana et al., 2013; (Cysticercosis Working Group in Eastern and Southern Africa) [CGWESA], 2009; Fleury et al., 2013; Lightowlers, 2013; Lightowlers, 2010; Rosales-Mendoza et al., 2012).

Several experiments have been performed with success and several vaccines developed, of which two have progressed the furthest and have shown a high degree of potential for use in control of porcine cysticercosis infection (Flisser et al., 2004; Lightwolers, 2006). In animals, neglected zoonotic diseases are generally asymptomatic or and may sometimes show few symptoms. This become a challenge to farmers in the use and choice of the vaccines to be used even thinking that these neglected zoonotic diseases, *Taenia solium* cysticercosis included may lead to the reduction of the productivity and reduction mortality with public health risk as some of them even though are zoonotic (King et al., 2011) and require a regular surveillance (Jacobson, 2010).

Studies reported the use of TSOL18 (Weka et al., 2019), TSOL45, and S3Pvac, vaccines used in the vaccination of cysticercosis in pigs which showed positive effect. The vaccination has been recommended to be done in very young piglets for it to be effective in infection reduction. Unfortunately, this could not eliminate the larval forms of the parasite, *T. solium* (Sciutto et al., 2007; Lightowlers, 2010). GALVmed is working on protecting livestock and improvement of human lives by promoting the vaccine. Antiparasitic medications are available and a vaccine of*Taenia solium* is being developed (The Global Alliance for Livestock Veterinary Medicine) [GALVmed], 2017).

2.5 Public Health Education

Public health education creates an opportunity to gain local co-operation and hence increased effectiveness and sustainability of an intervention strategy. It should focus on local perceptions, knowledge and practices related to the disease as outlined by Gonzalez et al. (2006). Sankhyan et al. (2015) stated that the transmission of porcine cysticercosis infection was reported possible by eating cabbages rather by pork consumption and poor personal hygiene. Therefore, the success in the control and eradication require incorporation of the educational interventions about porcine cysticercosis infestation. Public health education could lead to a reduction of the risk of infection in humans (Ngowi et al., 2008). It can be used alone or in combination with other strategies.

Ngowi et al. (2011) demonstrated that the protection of consumers from cysticercoids pork can be possible through the improvement of the knowledge about, attitudes towards and practices of the control of *Taenia solium* which has been successfully attained through introduction of health education. Control programs are needed to manage this endemic disease in the short and medium term (WHO, 2010; WHO, 2013). Improvement in sanitary conditions and modernization of pig production has been recognized as effective control measures for cysticercosis (Garcia et al., 2006).

The implementation and success will require the involvement of a multilevel and multi-disciplinary approach due to the complex epidemiology of *Taenia solium.* This will demand full collaboration from public workers, medical, Veterinarians and the communities working in a synergistic approach (Rossi et al., 2016; Samorek-Pieróg & Censek, 2018). Laxity of any of the actors will fail any control program (Kyvsgaard & Murrell, 2005; Murrell & Pawlowski, 2005). In China, two health education programs using mass media, personal communication and workshops for doctors successfully contributed in the reduction of the prevalence of taeniasis from 0.045% to 0.002% in Henan Province from 1994-1996 and from 1.73% to 0.59% in Shangong Province (Wu et al., 2012).

From 2002 to 2005, a health education program aimed at the control of *T. solium* was implemented in Tanzania utilizing a PRECEDE-PROCEED approach and was evaluated as a randomized control trial (Ngowi et al., 2008; Ngowi et al., 2009). In Mexico, the same approach reported a reduction of seroprevalence from 5.2% to 1.2% for PC by Ag-ELISA after one year of intervention (Sarti et al., 1997). A long-time health education research using mass education on good public health and improved pig husbandry practices for a long time was done (Ngowi et al., 2008) in Mbulu district of Tanzania and proved to be effective in the reduction of cysticercosis infections.

As a result, the awareness of *T. Solium* transmission and prevention was increased by more than 40% by rural farmers, the consumption of infected pork reduced by 20 %, and the incidence rate of porcine cysticercosis decreased by about 43% (Ngowi et al., 2008). In another study using a combination of workshops and one-to-one interviews and training of smallholder farmers, the one-to-one interviews contributed a lot in the increase of knowledge about *T. solium* transmission and epilepsy from 32% to 51% at visit 2 and 62% at visit 3 (Wohlgemut et al., 2010). Public health education has been shown to be highly effective since it creates awareness in people on the impact of cysticercosis in human and pigs and the possibility of eliminating it. However, it has to be implemented by knowledgeable people (Flisser et al., 2001).

The economic impact of *T. solium* infection in pig farming is epitomized by production losses and lost trade opportunities as infected meat might be discarded or decrease in value. Studies conducted in Uganda, Tanzania, Zambia and Nepal revealed 86-100% of pig traders who rejected pork with cysts and this situation lead to both nutritional and financial losses (GALVmed, 2017). Successful reduction of the disease will require the collaboration from both medical public health and veterinary services to determine foci of the disease and devise control strategies (FAO, 2014; Johansen et al., 2014). The home slaughter also has been suggested as a potential component of intervention and control programmes in equipping all the people involved with a better understanding of the risks associated with animal farming and human behavioral practices through the reinforcement of extension services (EdiaAsuke et al., 2014; Mutua et al., 2011; Thys et al., 2016). Gweba et al. (2010) has recommended the serological and epidemiological survey to be the required data for the effective and successful porcine cysticercosis control.

2.6 Awareness, Attitudes and Perceptions about Risks for Porcine Cysticercosis Infection

The public health education used alone or in combination with other strategies can inform effectiveness and sustainable reduction of the risk of infection in humans (Ngowi et al., 2008; Sorvillo et al., 2011). Creating public awareness is an important component of one of the health approaches involving human, veterinary, environmental and social sectors. This has been reported to be beneficial to workers, producers and consumers (Garcia et al., 2016). For most of the time African women have been neglected in the pig husbandry. Ngowi et al. (2011) considered women as essential constituent and recommended that they be integrated in the prevention and control programmes for *Taenia solium* infections. In Zambia, various tools have been used to promote the awareness of *T. solium* parasite, its transmission and change of the attitude vis-à-vis the risk of contamination (Gabriël et al., 2018; Lauridsen et al., 2017).

This is due to the complex epidemiology of *Taenia solium* and for societal and political acceptance, commitment and engagement (CWGESA, 2009; GALVmed, 2017; Kungu et al., 2017; Wu et al., 2012). Public health education can be effective because people are sensitized on the prevalence of human taeniasis and porcine cysticercosis, and methods that could possibly help to eradicate these diseases (Madzimure et al., 2012). This together with the high level of consumer 's knowledge about farming (Alonso et al., 2020) will also contribute to developing pig production systems (Carter et al., 2013; Riedel et al., 2012).

2.7 Pig Production Systems

2.7.1 Roles of pig production

In the developing world, livestock remain very important and are a livelihood asset for smallholder farmers and marginalized people (Bill & Melinda Gates Foundation, 2012; Donadeu et al., 2019). Livestock species play economic and socio-cultural roles for rural households acting in different production systems and in different value chains by contributing to improve income and wellbeing of the family (Kristjanson et al., 2010). The social role of livestock is well understood from the gender aspect in livestock production (Bettencourt et al., 2014). In Africa, Latin American and Asia, livestock supports the livings of poor livestock keepers (FAO, 2011; Köhler-Rollefson, 2012), traders and labourers (Abdulhameed et al., 2018; FAO, 2019; Mwendia et al., 2018).

In a large number of countries in sub-Saharian Africa, the modest figures for pig production do not reveal the status of the contributions that pigs make to food security and household regular cash income (Mbuthia et al., 2015; Roesel et al., 2019). This is despite pig production being characterized by smallholder farmers with generally no more than one to five crossbred pigs, compared with the potential that pig production has on improving livelihoods of the majority of pig-rearing households (Deca et al., 2007; FAO, 2012; Huynh et al, 2006; Madzimure et al., 2012; Mutua et al., 2011) and provide an affordable source of high quality protein for human consumption in the region (Chiduwa et al., 2008; Kristjanson et al., 2004; Randolph et al., 2007; Yeshambel & Bimrew, 2014). The income from pig sales meets essential household and farming expenses, and provides some financial independence for women, in rural areas (Chauhan et al., 2016; Kagira et al., 2010; Ouma et al., 2015; Tekle et al., 2013). The process to the achievement of gender equality, increasing of the household productivity and the improvement of the household health and nutrition is possible through women empowerment (Galiè et al., 2019; World Bank, 2012). Pig farming has been reported to be important for farmer 's poverty alleviation and have been known to contribute up to 50% of the total income of the family in Laos and Asia (Costard et al., 2009; Phengsavanh et al., 2010).

Pork consumption has been increasing in the developing countries (Delgado, 2003). In keeping with this trend, in Western Kenya, pig keeping has become a popular small-holder activity for low-income families. The majority of the farmers (98%) in Kenya kept pigs for income generation (Dietze, 2011) as it has been also reported by Abah et al. (2019), Efrem et al. (2017) and Nath et al. (2013) in Nigeria, Ethiopia and India, respectively. In Brasilia (Mirinda, 2011) and Nagaland/India (Patr et al., 2014), the pig is raised for income generation and as source of pork for home consumption. A study by Kagira et al. (2010) showed that very few of them were for home consumption because the majority of farmers in Kenya have access to other sources of protein.

Pig production in Kenya stands at 354,600 (FAO Statistical Databases [FAOSTAT], 2014) and PC affects 40.6% of this population and this greatly affects the economy. A population of 66.8% and 53.0% in Busia and Kakamega Counties, respectively live below the poverty line, respectively (Kenya National Bureau of Statistics) [KNBS], 2019; (United Nations Development Program) [UNDP], 2008) and yet they undertake pig production. The smallholder pig system in Kenya operate under 3 different systems namely the traditional free-range, small-scale and intensive large-scale commercial farms which are mainly found in Nairobi, Rift valley and Kiambu (Kirima et al., 2017).

2.7.2 Pig production systems

Pig production systems, in most of the countries have been developed from the simplest to large-scale market-oriented enterprises. Based on the herd - size, the goals of the production and management practices, three mains systems exist, namely free-range system, small-scale confined pig production and large-scale confined pig production. The free-range system is the most common system practiced in urban and rural areas of developing countries (Bettencourt et al., 2015). This system is characterized by free roaming in the household and surrounding area, scavenging and feeding in the street, from neighbouring land or forests around villages, or from garbage dumps. The pigs reared in the free-range system require minimal inputs and low investment of labour, with no or limited money invested in concentrated feed or vaccines (FAO, 2010).

Pig farming systems in rural Kenya, especially in Western parts are traditional in which pigs are in scavenging system or at most confined at night and/or seasonally to protect crops (Mbuthia et al., 2015). The system uses local breeds of pigs or their crosses, with between 2 and 10 pigs per farm (FAO, 2012; Kagira et al., 2010; (Kenya Meat Commission) [KMC], (2014) that is hardy and undemanding in terms of nutrition and management (Lekule et al., 2003; Mutua et al., 2012).

In this system health risks are numerous and productivity is low due to low off take, lack of supplementary feeding, lack of proper housing, low reproductive rates, minimal health care and high mortality rate (Deca et al., 2007; Niraula et al., 2015; Nsoso et al., 2006; Praet et al., 2009). However, poor implementation of biosecurity measures exposes pigs to risk of PC disease. Estimating the extent of the risk and consequences requires good records but the reported statistics is often inaccurate.

On the other hand, large-scale commercial farms can be distinguished with intensive and outdoor pig production (FAO, 2010). The commercial pig production using local breeds or even improved breeds of pigs has often demonstrated unsustainable and unprofitable owing to high input costs that include feed and infrastructure, housing and low market prices to justify the investment (Chabo et al., 2000). It has been reported apart from low productivity and as countries modernize, the traditional pig farming systems have disadvantages. Pigs can become a cause of conflict being destructive when crops and gardens are damaged; among free-ranging pigs, heavy losses may be experienced when access to modern roads with fast traffic (Ganaba et al., 2011). In large-scale outdoor pig production, animals are mainly outdoors and confined by fencing; there is therefore less need for investiment in mortar facilities and brick

According to Mutua (2010), the potential for pig husbandry in Western Kenya has been under-utilized in their aspect of livelihoods improvement and rural poverty reduction. In Busia County, pig production accounts for 41% of livestock in smallholderfarming (Cate et al., 2011; Mutua et al., 2010b). Although pigs are relatively easy to keep and prolific (Petrus et al., 2011; Vicente et al., 2010) and thus easy to improve (Lekule, 2003; Mutua et al., 2010a), they are also prone to infection from *T. solium*. The farmers additionally obtain outputs such as manure that is used as fertilizers and/or biogas (methane) production (FAO, 2003; Thomas et al., 2016;http://www.infonet-biovision.org/AnimalHealth/manure).

The system is found in developing and transition countries where pigs are confined to a shelter made with local materials to more modern housing. The pigs are completely dependent on their keeper for feed, and receive agricultural by-products, prepared feed, leaves, tree branches or crop residues (FAO, 2010). In East Africa, the small-scale pig production has been reported to contribute to the improvement of smallholder farm families 'welfare and reduce farmer 's poverty (Dewey et al., 2011; Kristjanson et al., 2014; Ouma et al., 2015).

Global human population and meat consumption have increased by a factor of 2.4 and 4.7, respectively (Fernandes et al., 2019). Growth in the pig population in Kenya and heads slaughtered has been observed since 2011 and in 2014 Kenya had an average of 350,000 pigs. In 2012, 12,950 tonnes of pig meat was produced indicating a deficit in production. The per capita consumption of meat in Kenya is led by bovine meat at 12.2 kg, mutton/goat at 2.2 kg, and poultry at 0.6 kg. The annual global meat consumption per head is increasing and expected to reach 72 kg until 2050 (Miele, 2016). Pork consumption is at 0.4 kg, against Uganda 's 3.4 kg and South Africa 's 6.8 kg (FAOSTATS, 2014).

Pig production is done by approximately 7000 producers that are either small-scale commercial farms, medium scale commercial farms and large integrated commercial farms. The small-scale farmers, estimated to be 5000, make up about 70% of pig producers in Kenya (FAO, 2012). Small scale farmers are characterized by 5-100 pigs raised in a traditional free-range systems and are spread in Central, Rift Valley, Eastern, North Rift, Kisumu and parts of Western Kenya (Bergevoet & van Engelen, 2014).

2.7.3 Pork value chain

The Kenyan pig industry is much more structured with the pork value chain ensuring quality and meeting government policy and consumer demand (FAO, 2011). The majority (70%) of pig farmers are small-scale producers who supply pigs to local butchers whereas live pigs are traded on farm. However, large and medium scale pig farmers have their own licensed slaughter slabs which are always inspected by the Department of Veterinary Services (DVS) (Mutua et al., 2011). The smallholder pork producers face challenges of knowledge gap in the best practice both in pig husbandry and farm management. Due to this gap, the rural population is exposed to porcine cysticercosis as a zoonotic food borne disease. The complex epidemiology of *Taenia solium*, multi-disciplinary involvement and multilevel approach will be required in the success of the disease reduction and possibly the break of the cestode life cycle (Maurice, 2014).

Considering the pork marketing, live pigs are sold at the farm gate, slaughtered pigs at the abattoirs, pork at the butcheries and processed products at specialized pork eateries (Levy et al.,2013). Eateries in Thika sell 80% of pork roasted and 20% as undifferentiated pork cuts, at an average of USD 4.67 per kg. In Western Kenya, the most important challenge faced by the pig production sector is the lack of appropriate pig slaughterhouses (Levy, 2014), and similarly in Botswana (Moreki & Mphinyane, 2011; Motsho & Moreki, 2012) and Zimbabwe (Mutambara, 2013).

Consumers have been qualified as key stakeholders within the food chain worldwide (Kjærnes & Lavik, 2007). The improvement of the livestock value chains is made possible through good hygiene and good management (Roberts et al., 2009). Therefore, the attitude of consumers regarding the occurrence of the disease is the evidence of the sustainability of the livestock industry (Niemi et al., 2020).

Livestock production is key in the social and economic sustainability of developing and developed countries and it supplies substantial draft power in smallholder operations that make up the majority of international food production. Many changes have been observed by the FAO, (2019) in the livestock sector over the last fifty years despite of the increased demand of food from animals in the fast growing of the economy in the world. From the perspective of the pig production development in Kenya, pig and poultry meat has been progressively accepted as white meat and this has pushed considerably the level of its consumption (Bett et al., 2012; Bettencourt et al., 2015; FAO, 2012). Opposite to that, the United States Department of Agriculture has classified it as red meat and it plays an important role in people ‘s daily diet as they can provide very good source of protein, Vitamin B12, iron and selenium (Yenealem et al., 2020).

It constitutes also a good source of Vitamin C, niacin, phosphorus and zinc (USDA, 2018; Xiong et al., 2014). All over the industrialized world, protein is necessary for human growth and meat is one of the most nutritive sources of protein consumedby humans (Grigg, 1995; Rao et al., 2009). Even though meat is generally perceived as a high value product in resource-poor communities (Melki et al., 2018), a number of public health issues which have had adverse effects on the production, trade and consumption of meat have been globally reported. Meat has been reported to be very delicate foods to spoilage (Bersisa et al., 2019; Birhanu et al., 2017). The meat is likely to be contaminated from production to it consumption and once contaminated, meat become a source of food-borne diseases and may lead to death (WHO, 2007). The risk of animal zoonoses appear to be the biggest cause of public concern with meat (FAO, 2020) for which the production plays a role in food security for households and income generation for the country. Therefore, the management of the safety of meat is crucial in public health protection by ensuring the access to the market and bolsters the economy of Kenya (Kariuki et al., 2013).

Parasites have remained the most harmful pork borne hazards in the human life worldwide (Davies, 2011). Attention to parasite infection rate in domesticated animal, pigs included has therefore been increased (Inpankaew et al., 2015; Schär et al., 2014). From the one health concept, an integrated agenda has been made aimed at observing and improving health issues with consideration of human, animal, and environmental factors (WHO/TDR, 2012; Schureret al., 2016). Some parasites are only transmitted to humans through contaminated food (Torgerson et al., 2015). However, tapeworms may infect human through food or direct contact with animals like it is for *Taenia solium* in pigs (Saw et al., 2015).

In developing countries, studies have shown that generally many abattoirs and slaughter slabs are poorly constructed, and have poor slaughter and meat inspection facilities characterized mainly by poor hygienic and substandard conditions (Ghimire et al., 2013; Mdegelaet al., 2010; Melki et al., 2018; Mkupasi et al., 2011). Butchers can highly contribute to meat borne diseases and illness prevention (Khanal & Poudel, 2017; Ngasala et al., 2015).

The handling of meat at butchery level requires formal training on butchering practices and licensing (Chepkemoi et al., 2015). This could contribute to a reduction in contamination at butchery level as the knowledge plays a key role in the prevention and control of diseases (Aburi, 2012; Khelkar et al., 2015). Taking into account sale of pork in informal markets has been characterized by human health risks, strict measures should also be enforced on slaughterhouse workers and consumers in collaboration with producers with the focus on risk reduction (Fahrion et al., 2014; Gizaw, 2019).

Food systems cover an entire range of activities and actors in the production, processing, marketing, consumption, and disposal of food, including the inputs needed and outputs generated at each stage. Food safety hazards are increasingly being appreciated worldwide as a major public health problem, with important and widespread socioeconomic consequences for human welfare and economic performance (Jaffee et al., 2019). In both developed and developing countries, food-borne diseases are a common but more common in the latter because of poor food handling and sanitation practices (Chepkemoi et al., 2015), inadequate food safety laws, and lack of education among food handlers (Haile Selassie et al., 2013).

The WHO, (2015) reported that contaminated meat is one of the major causes of the global burden of food borne diseases for which eating contaminated food has been killing 420,000 every year with almost 1 in 10 people becoming sick. Furthermore, Food Borne Diseases (FBD) led to two different categories of costs. Firstly, they are associated with the public health impacts of unsafe food, productivity losses from ill-health and premature death, including the cost of medical care. Secondly, there areeconomic and social impacts of food safety failures on consumers, businesses and the economy as a whole (Jaffee et al., 2019).

The harm caused by the disease such as the loss of productivity and several types of responses which can include the medical treatment and food recalls has been identified as potential economic costs associated with FBD (McLinden et al., 2014). Pork quality has a tremendous impact on the eating experience, and nothing is more important to farmers than providing a safe, wholesome product. The pork industry continues to seek for ways to improve pork safety and quality, production performance, animal welfare and the environment (Wayne, 2019). The public health protection is dependent on the participation of all actors in the livestock value chain (Ngasala et al., 2015; Nyokabi et al., 2018) since the livestock value chains act as important pathways for zoonosis (FAO, 2011).

The biosecurity measures could reduce the negative impacts of zoonoses (FAO, 2008), thereby ensuring the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health are ensured (Frampton, 2010). In East Africa and Kenya in particular, human and animal health sectors have been involved in the diseases surveillance but more work needs to be done in the integration between these sectors regarding the disease under-reporting and inefficiencies (Falzon et al., 2019).

In 2017 the peri-urban areas in Kenya, an increase in pork eateries has been observed in addition to meat processing plant which pushed up the pig sales for 7.8% up where pigs slaughtered went up from 360,100 pigs up to 388,200 pigs (Ambrey, 2019; KNBS, 2019). To ensure food safety along the entire food chain, WHO is working in close collaboration with the World Organization for Animal Health (OIE), FAO and other international organizations (WHO, 2019). Effective cooking of pork lowered the risk of exposure to infection with *Taenia Solium* infected pork. It is therefore advisable to cook the meat at 145-160°F (63–71°C) (Meester et al., 2019; Rachel, 2019). The pork industry in Kenya and Africa has continued to expand (FAO, 2012). In Europe, the pig supply chains constitute an essential component in the food sector with 23.1 billion kg of pork produced on average per year (Eurostat, 2018). Kenya ‘s pig industry is differentiated into specialized business units consisting of feed millers, producers, abattoirs, retaillers and processors. Smallholders pork producers face challenges of knowledge gap in the best practice in farms management and husbandry as businesses. The slaughter slabs have limited infrastructure and technology for pork handling; they lack cold storage infrastructure and rely on wood fuel to heat water for slaughter operations (FAO, 2012). Meat quality and safety are directly linked to public health and welfare. There are therefore highly relevant issues for the meat industry worldwide (Biswas & Mandal, 2020). Currently, consumers prefer food products with superior quality because the quality and safety have become the main factor for the food industry. But generally, consumers are at risk of death due to unsafe food consumption with billions of them being at high risk of acquiring food-borne diseases (WHO, 2015). In the developing countries, food borne diseases are mainly a consequence of a lack of inadequate sanitation where by the food safety laws are weak and the regulatory organizations are weak (Abdullahi et al., 2016; FAO/WHO, 2004). When considering the food safety on a farm-to-table approach, Mwamakamba et al. (2012) reported that food borne diseases are caused by factors which appeared at different points along the whole process. Therefore, the management of food quality will be required from the production, preparation to the consumption stage. The consumer, being the last checker, has to be able to ensure the safety of the food produced its consumption (Mwamakamba et al., 2012). This requires an examination and evaluation of the characteristics of food products in the processes of the food industry (Di Wu & Da-Wen Sun., 2013).

Consumers around the world have different ideas about food safety compared to experts (Verbeke et al., 2010), however they have the right to believe that the foods they purchase and consume are of high quality and safe (FAO, 2019). In the food supply chain, the consumer ‘s level of trust depends on safety and quality associated with the production, marketing and consumption (Taylor et al., 2012). Therefore, there is a need to introduce prevention and control programmes which will contribute to the reduction of infection risk caused by meat-borne diseases to consumers (Melki et al., 2018). In addition to safeguarding the well-being of consumers, food safety as the foundation of a nutritious diet is also crucial to enable agricultural producers to gain access to markets. This in turn contributes to economic development and poverty alleviation (FAO, 2019; WHO/FAO, 2010). The upgrade of the pig value chain all over the world require small farms organization into groups for good practices applications, development of a quality assurance system feasible under smallholder conditions, strengthening of their capacity for appropriate market information in smallholder ‘s producers and the improvement of the cost and quality competitiveness (Nga et al., 2015; Niraula et al., 2015; Powell et al., 2011). The detection of infection during a pre-purchase examination by pig traders who are aware of the disease may often lead to a refuse to buy a suspect pig. Farms and whole communities may become stigmatized when they are known to sell infected pigs and/or pork contaminated with cysts (WHO/TDR, 2012). Porcine cysticercosis infection has already been reported in Teso South of Busia County among heavy pork consumer communities (Kenya News Agency) [KNA], 2018).

CHAPTER THREE

PREVALENCE OF PORCINE CYSTICERCOSIS AMONG SCAVENGING PIGS IN WESTERN KENYA

Abstract

Porcine cysticercosis (PC) infection is a global neglected and re-emerging tropical disease, posing public health risk in endemic area. Smallholder farmers in Western Kenya continue to practice scavenging pig production. This study determined the prevalence of PC infection at the farms and slaughter slabs in a cross-sectional survey in two Counties (Busia and Kakamega) of Western Kenya. Two hundred and eighty-seven (287) heparinized blood samples were collected at the farm from 162 households in 9 villages and 113 pigs from 5 slaughter slabs. The prevalence of PC was detected through meat inspection at slaughter slabs, and the prevalence of *Taenia solium* antigen determined by using the ApDia AgELISA test at the farms and slaughter slabs. At meat inspection, the PC prevalence was 1.8%, while prevalence of *Taenia Species* cysts detected with Ag-ELISA test was 3.8% at the farms, and 5.3 % at the slaughter slabs. The Ag-ELISA test had sensitivity of 100% (95% CI: 19.79– 100.00) and specificity of 96.4% (95% CI: 90.49– 98.84). The PC prevalence levels observed among scavenging pigs in Western Kenya should be a cause of public health risk concern. This observation warrant enforcing mandatory pig confinement and use of latrines at the farms and meat inspection at local slaughter slabs. Further studies are recommended to identify different *Taenia* species in cysticercoids pigs in the region, which this study could not differentiate.

Keywords: Pig, *Taenia spp.*, meat inspection, ELISA test, Slaughter slabs, Smallholder farmers.

3.1 Introduction

Porcine Cysticercosis (PC) is a zoonotic, neglected food-borne disease of global public health concern and trade implications. The disease manifests itself as seizures and death in pigs and humans (Wardrop et al., 2016). Cysticercosis in pigs is transmitted by two species of tapeworms: *Taenia solium,* the zoonotic and *T. hydatigena,* and the non-zoonotic with the latter being rare in Africa (Gomez-Puerta et al., 2019; Nguyen et al., 2016). The zoonotic tapeworm *T. solium* has a two host life cycles; the indirect cycle with humans as the definitive hosts, and in pigs as a normal intermediate host harboring the larval cysticerci (Donadeu et al., 2017). Cysticercosis in pigs results from ingesting *T. solium* eggs directly by fecal-oral route, or from environments contaminated with human harboring adult *T. solium* (Fleury *et al*., 2013). Human transmission of *T. solium* is typically through consumption of under-cooked pork or water containing fecal matter (indirect) (Kungu et al., 2017). The World Health Organization (WHO) classifies PC as a neglected and re-emerging tropical disease (WHO, 2017). The prevalence of PC in endemic African counties is variable, and up to 40% prevalence has been observed (Shonyela et al., 2018).

Prevalence of PC can vary with the diagnostic methods used (Shonyela et al., 2018). For instance, prevalence estimated through tongue inspection is lower (9.4%) relative to prevalence estimated through postmortem examination (15%), while Enzyme-linked Immuno electro transfer Blot (EITB) technique and ELISA B158/B60 diagnosis is much higher (24.7 to 29.7%). This difference is due to the test sensitivity and specificity or the probability of having a positive or negative result. This emphasizes the necessity to complement screening (meat inspection) with diagnostic confirmatory tests (Ag-ELISA) that have high sensitivity and specificity in PC detection. The Enzyme Linked Immunosorbent Assay (ELISA) test is a useful quantifiable, precise and sensitive clinical diagnostic used widely in the detection of various infectious diseases. Considered as a gold standard method, it was used to indicate the presence or absence of porcine cysticercosis infection in pigs because it could detect both exposure and active infections which the meat inspection could not detect (Crowther, 2001). This study was undertaken to determine the prevalence of PC at the farm level and slaughter slabs in Busia and Kakamega Counties of Western Kenya, a region with prominent scavenging pig production systems in the country and considered endemic region for PC.

3.2 Material and Methods

3.2.1 Area of study

The study was conducted in Busia and Kakamega Counties of Western Kenya (Figure 5). These Counties were purposely selected because they have high scavenging pig population. The current pig population was unknown in the two Counties, but last the census indicated that Busia had 21,315 while Kakamega has 6,198 pigs (KNBS, 2009).

The study was conducted in 5 slaughter slabs namely Musambaruwa, Matayos, Malinya, Khahega and Shinyalu in Busia and Kakamega Counties. Scavenging pigs are a livelihood asset in these Counties with the majority of residents being subsistence smallholder farmers (Kenya National Bureau of Statistics, 2013). The following livestock are reared in the two Counties: cattle (Zebu, dairy), hair sheep and rabbits, goats, pigs, poultry (layers, broilers, indigenous chicken, ducks, turkeys, geese and pigeons.

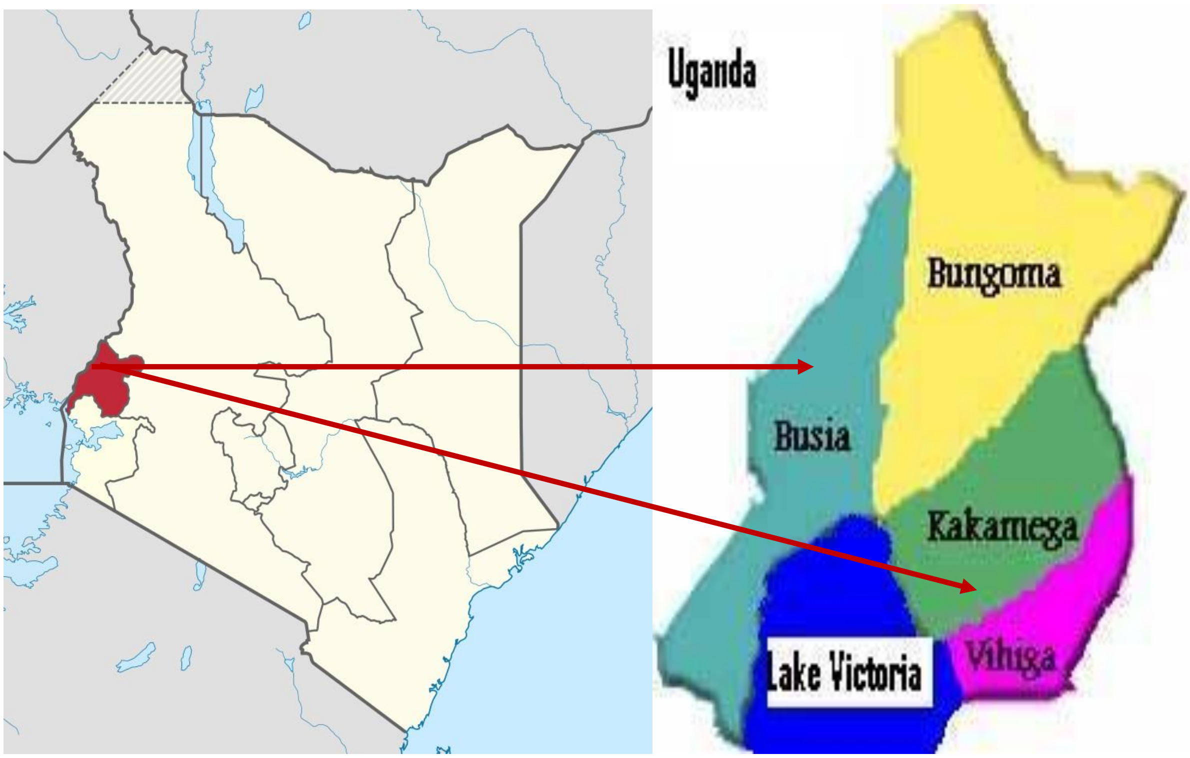

Figure 5: Map of Kenya indicating Western Kenya (Red color). The red arrows indicate Busia and Kakamega Counties

Source: Kenya National Bureau of Statistics (2019).

Busia County is located at the extreme western region of the country and borders three other Counties including Bungoma to the North, Kakamega to the East, and Siaya to the south west. Part of Lake Victoria is in the County on the South East and borders with Uganda to the west. It lies between latitude 0º and 0º 45 north and longitude 34º 25 east (Source: Kenya National

Bureau of Statistics, 2013). Busia County covers an area of 1,628.4 km^2 (628.7 sq. mi) and an estimated population of 893,681 and density of 550/km^2 (1,400/sq. mi) with 7 sub-counties and 35 wards (Source: County Commissioner 's Office, Busia, 2013). This County receives an annual rainfall of between 760 and 2000 mm. Fifty per cent of the rain falls in the long rain season with its peak between late March and late May, while 25 per cent falls during the short rains between August and October. From December to February, we have the dry season while the temperatures for the whole Country are almost homogenous. The mean minimum temperature ranges between 14 and 22^{o}C while the annual mean maximum temperatures ranges between 26 and 30 ^{o}C (Kenya National Bureau of Statistics, 2010).

Kakamega County is located in the Western Kenya and borders Bungoma and Trans Nzoia Counties to the north, Nandi and Uasin Gishu Counties to the east, Vihiga County to the south and Siaya County to the west. The County has an estimated population of 1,867,579 and density of 682/km^2. It covers an area of 3,033.8 km^2 (1,171.4 sq, mi). Kakamega, second after Nairobi, has a largest rural population and is divided into twelve sub counties, six wards, one hundred and eighty-seven Village Units and four hundred community administrative areas. Above the sea level, the altitude ranges from 1,240 metres to 2,000 metres while the southern part of the county is made up of rugged granites rising in places to 1.950 metres and is hilly. In Kakamega, there are two main ecological zones namely; the Upper Medium (UM) and the Lower Medium (LM) which covers a major portion of the southern part of the county and the Centrak and Northern parts of it, repectively. The county has a very conducive climate for crop and animal production while the annual rainfall is ranging from 1280.1mm to 2214.1 mm per year with the rainfall pattern evenly distributed all year around December and February receiving light rains while March and July receiving heavy rains. The county has an average humidity of 67 percent with the temperatures ranging from 18^{o}C to 29^{o}C. The hottest months are January, February and March, with other months having relatively similar temperatures while July and August have relatively cold spells. Compared to the current increased in temperature, the maximum and minimum temperatures for the day and night time, respectively, have been on a warming trend throughout Kenya since the early 1960s. The Upper Medium covers the Central and Northern parts of the county. The second ecological zone, the Lower Medium (LM), covers a major portion of the southern part of the county.

3.2.2 Sample size determination

The pig sample size of 400 pigs was determined using a formula for finite population with a known pig population size (Yamane (1967):

$$n = \frac{N}{1 + N(e)^2}$$

Where

n is the corrected sample size needed; N is the pig population size and e is 0.05 is the allowable margin of error set at 0.05.

Let's assume that the population of pigs for Busia district (21, 315, 00 pigs) and Kakamega East Sub-County (6, 198, 00 pigs).

N= 21, 315, 00 pigs + 6, 198, 00 pigs = 27, 513, 00 pigs

At 5 % MoE, the sample size would be:

$$n = \frac{27,513,00}{(1 + 27,513,00(0.05 * 0.05))}$$

= 399.99 ~ 400 pigs

3.2.3 Procedure

A cross-sectional survey was conducted in nine villages in Busia and Kakamega Counties which were identified by the local veterinary office as having the highest numbers of pig producing farmers and pig slaughter slabs. At farm level, pig producing households were randomly selected using simple random sampling procedure. The cross sectional survey was facilitated by field veterinary and public health officers knowledgeable about pig production distribution in the area. A total of 162 pig producing households with 400 pigs were subsequently sampled, 287 pigs from farm level and 113 pigs from slaughter slab as summarized in Table 2.

Table 2: Sampling level.

Sampling	Busia	Kakamega	Total
Farms	102	60	162
Pig at the farms	200	87	287
Pigs at the slaughter slabs	84	29	113
Pork carcass at the slaughter slabs	84	29	113

All pig slaughter slabs (5) in the two Counties were sampled where blood samples from slaughtered pigs were collected. Sampling was a multi-stage procedure with blood samples from all pigs on the farm if flock size was less than five, otherwise a maximum of 5 pigs excluding those younger than three months; lactating and pregnant sows were subjected to the test. Additionally, blood samples from pigs scheduled for slaughter and daily meat records from slaughtered pigs were obtained from slaughter slabs concomitantly. Piglets younger than three months were excluded because the cysts take about two months to develop after ingestion of the eggs. Pregnant and lactating sows being in physiological stages are vulnerable to stress and were therefore excluded. At the slaughter slabs, blood samples were taken from all pigs slaughtered in the duration of the data collection.

The prevalence of PC was determined at farm level using Ag-ELISA test and at slaughter slabs using both meat inspection and Ag-ELISA test. Blood samples collected from 287 live pigs on 162 farms and from 113 live pigs and their pork carcasses from 5 slaughter slabs was handled with cool box and transported to the laboratory quickly. To ensure the quality of the sample collected, the serum was separated from clot as soon as possible and transferred to a clean storage tube to avoid hemolysis which could lead to false results. To make the procedure succefull and get quality results, various precautions were followed such as avoiding repeated freezing and thawing of samples, interruption during the assay, transfer of each sample using a separate disposable tip to prevent the cross-contamination.

Meat inspection

The meat inspection as screening test was performed at 5 local slaughter slabs in the two study Counties following the standard procedure (Harenda et al., 2000). Daily records for meat inspection were collected also from slaughter slabs. Results of day-to-day meat inspection were recorded for the pigs slaughtered during the study period (Appendix 1).

Blood sample collection and laboratory analysis

Five milliliters of whole blood were collected using vacutainer 10 ml syringes from the external ear vein or the jugular vein of pigs and stored in a cool box at 4 - 8 °C to prevent hemolysis during transportation to the laboratories. Samples from Busia Country were transported to the International Livestock Research Institute (ILRI) laboratory in Busia, while samples from Kakamega County were transported to the Veterinary Investigation Laboratory (VIL) in Kakamega. In both laboratories, blood samples were sedimented by centrifugation at 3000 rpm for 5 minutes at 20°C to obtain cleaner sera from pigs at farm and slaughter slabs levels in which circulating antigen were detected for viable parasites diagnosis at Egerton University. The serum was then dispensed into 2 milliliter labeled Eppendorf tubes and stored at 4 °C. The serum samples were submitted to molecular laboratory in Animal Science Department at Egerton University, Njoro, Kenya, for freezing and preservation in a cool box at 4 - 8 °C for later Antigen (Ag) ELISA tests. The serum samples were analyzed using the ApDia Cysticercosis Antigen (Ag) ELISA test (REF 650501), an Enzyme Immunoassay for the qualitative determination of viable cysts of *Taeniaspp.* (Deckers et al., 2010).

After blood samples (Appendix 1) collection and serum obtained, a 150 µl of serum samples were pre-treated using 150 µl 0f a 5% trichloroacetic acid (TCA) to break the antigen-antibody complexes following the instructions from the manufacturer ‘s manual (ApDia, Belgium). Microtiter plates were coated with with B158C11A10 monoclonal antibodies. A 100 µl of the pre-treated samples/controls was added to each well and the samples were determining in duplo. It was then mixed immediately by vortexing. It was then mixed immediately by vortexing followed by incubation for 5 to 20 minutes at room temperature, mixed again by vortexing, and then centrifuges the tubes for 5 to 9 minutes at 12000g. After centrifugation, the mixture was neutralized by adding 150 µl of the supernatant into Eppendorf tubes with the same volume of a 0.156M carbonate/bicarbonate neutralized buffered solution which was then mixed by vortexing to the B158C11A10 monoclonal antibody-coated wells. The preparations were then allowed to incubate for 15 minutes at 20^oC while shaking at 700-800 rpm. Unbound serum proteins were removed from microtiterstrips by a washing procedure with 300 µL of concentrated phosphate buffered washing solution which contains 0.05 % Proclin 300, apply 5 times by changing washing solutions for each cycle. Finally, the microtiterstrips was empty and the excess fluid was removed by blotting the inverted strips on absorber paper. A100 µl of peroxidase conjugated monoclonal B60H8A4 antibodies which contains antimicrobial agents and an inert red dye was added to the wells then trips were seal securely with a microplate sealer. The preparations were again allowed to incubate for 15 minutes at 20^oC while shaking at 700-800 rpm, followed the removal of the unbound conjugate by washing the microtiterstrips 5 times with 300 µL ofconcentrated phosphate buffered Washing Solution. A100 µl of chromogen solution was added to each well, containing H_2O_2 (hydrogen peroxide) and tetramethylbenzidin, followed by incubation for 15 minutes at room temperature in absence of light. A 50 µl of 0.5M H_2SO_4, the stopping solution were added to each well). The reactions were established with a blue color develops in proportion to the amount of immune complex bound to the wells of the strips. The optical densities were read at 450 nm with reference wavelength 600-650 nm in a microplate reader within 15 minutes after stopping (ApDia, Belgium).

Ethical consideration

This research was authorized for implementation by the National Commission for Sciences, Technology and Innovation (NACOSTI), Permit No: NACOSTI/P/19/80633/27786. At the county level, consent was obtained from the County Director of Veterinary Services (CDVS) and community leaders and participants in the study area.

3.2.4 Data analysis

The prevalence was computed from the daily meat inspection records at slaughter level considering the total number of animals slaughtered during the period of the data collection. The meat inspection was performed with the objective of looking for the presence of the cysts in the carcass/organs as unfit for consumption and absence of the cysts as fit for consumption. Results of meat inspection were gathered and recorded on daily basis for the pigs slaughtered during the period of data collection.

The sensitivity and specificity of the diagnosis tests were computed using the two-by-two contingency table (Table 3). The True prevalence as a proportion of all animals tested as truly positive or actually infected at slaughter slabs level was therefore calculated.

Table 3: Sensitivity and specificity.

Diagnosis of prevalence		Tongue inspection	
		Positive (Infected)	Negative (Uninfected)
Ag-ELISA	Positive	a) = true positives	(b) = false positives
	Negative	(c) = false negatives	(d) = true negatives
	Total	a+c	b+d

All observed data were recorded, entered in Microsoft Excel (2007) and exported to the Statistical Analysis System 9.2 (SAS, 2008). Results on positive PC cases from visual meat inspection and from antigen ELISA test were analyzed for epidemiological measures using FREQ procedure of SAS (2008).

The prevalence was computed from the serological tests and ELISA positive cases at the farm and slaughter slab sampling, using the formula of Pfeiffer (2013):

$Op = TD^{+}/n \times 100$

Where:

Op = Observed Prevalence of disease, TD^{+} = Total diseased positive pigs, n = Total pigs 'sample. The sensitivity was computed as: Sen= (TP/(TP+FN)) where, Sen= sensitivity, TP= True Positive, and FN= False Negative. The specificity was then calculated as: Spec = (TN/ (TN+FP)) where, Spec = Specificity, TN= True Negative and FP=False Positive.

Bayer ‘s theorem was applied to compute the likelihood that carcasses testing positive indeed had PC infection. The probability of a pig having the disease at the slaughter slabs level, given a positive result was then calculated as: P (A/X) = P(X/A) *P (A)/ (P(X/A) *P (A) + (P(X/~A) *P (~A).

Where:

P (A) = The probability of having pigs with *Taenia* cyst; P(X/A) = The probability of having true positives pigs and (P(X/~A) = The probability of having false positives pigs. The priori prevalence of PC in Western Kenya was assumed to be 5.3% (Thomas, 2013).

3.3 Results

3.3.1 Sample pig herd characteristics

Out of the 400-pig sample population, serum samples collected were 287 at the farms and 113 at the slaughter slabs. Of the slaughtered pigs, 74.3% (84/113) were in Busia and 25.7% (29/113) in Kakamega from a total of 162 households. A larger number of the slaughtered pigs were boars (66.7%) but at the farms, gilts (65.2%) were more than the boars (34.8%). Most of the sampled pigs (61.1%) were reared under the scavenging system, while some (38.9 %) were tethered during the day and released in the night.

3.3.2 Prevalence of porcine cysticercosis

Table 4 shows that the prevalence of PC detected with Ag-ELISA test was 3.8% (95% CI 1.61 – 6.05%) at the farm and 5.3% (95% CI 1.18 – 9.44) at the slaughter slabs. The PC prevalence detected using Ag-ELISA was 2.1 to 2.9 times higher than that detected from meat inspections (1.8%: 95% CI 0.66 – 4.20).

Table 4: The PC prevalence of Ag-ELISA and meat inspection at farm and slaughter slabs levels.

Sampling level	Tests	Number of Pigs	Test results	
			Positive (%)	Negative (%)
Farms	Ag-ELISA	287	3.8	96.2
Slaughter slabs	Meat inspection	113	1.8	98.2
	Ag-ELISA	113	5.3	94.7

3.3.3 Sensitivity and specificity of the Ag-ELISA test

The Ag-ELISA test had sensitivity of 100% (95% CI: 19.79– 100.00) and specificity of 96.4% (95% CI: 90.49 – 98.84). The reliability of Ag-ELISA test was expressed by the true positive (66.7%, 95% CI: 5.999 – 75.8921) and false positive (39.2%, 95% CI: 24.1079 – 94.001) (Figure 6).

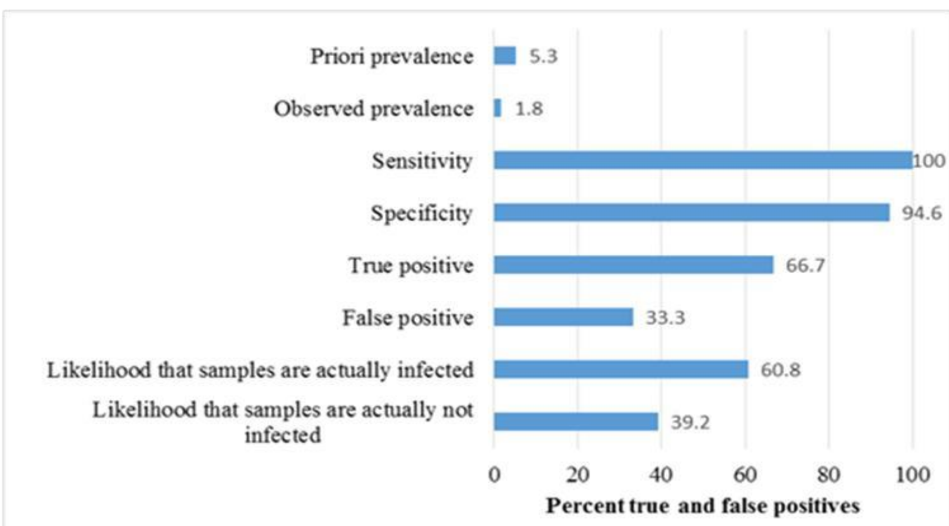

Figure 6: Percent true and false positives for porcine cysticercosis.

3.4 Discussion

This paper discusses the prevalence of Porcine Cysticercosis determined from a cross-sectional survey of pigs managed under scavenging system and subsistence livelihood in two Counties in Western Kenya. The scavenging system is a banned system in pig production and present a high risk of PC infection in some countries. The observed PC prevalence from Ag-ELISA test at the farms (3.8%); at the slaughter slabs (5.3%) and County (6.9% in Kakamega and 4.8% in Busia) was much lower than the levels observed within other Counties in Kenya and in endemic African countries. Eshitera et al. (2012) estimated 32.8% PC prevalence in Homa bay County. However, this county has a lower pig population compared to Busia and Kakamega (KNBS, 2009). The PC prevalence in Homa bay County is within the range of 19.5 to 40% reported in other East African countries as well other African countries such as Ghana, Cameroun, Egypt and Mozambique (Shonyela et al., 2018) and South East Asia (Khaing et al., 2015). The mean PC prevalence detected on meat inspection were higher compared to those reported in India (0.3% - 0.88%) by Satyaprakash et al. (2018) and Vaidya et al. (2018), but lower than those (4.4%) reported in Nairobi, Kenya and South Western Nigeria (Adesokan et al., 2019; Akoko et al., 2019). These results suggest that public health risk of porcine cysticercosis was relatively low in western Kenya.

Although public health risk may be low in Western Kenya, Porcine Cysticercosis is classified an emerging disease and globally targeted for total eradication, especially where pigs are produced under scavenging systems as it is the case in rural villages of Western Kenya. In Brazil, similar PC prevalence levels (5.3%) as those observed in Western Kenya was deemed high (Emilio et al., 2017) considering the global goal commitment to eradicate the disease by 2020. Considering that a large majority of the pigs were managed under scavenging conditions with low sanitary practices, public health risk of PC infections should be of concern in the region to warrant enforcing mandatory pig confinement, proper use of latrines at the farms, meat inspection at local slaughter slabs, and strengthened diagnostic surveillance. Implementation of risk-based surveillance at meat inspection would check against the potential for high economic losses, increased public health risks and pork trade in Western Kenya. This is important because prevalence of Porcine Cysticercosis infection in Western Kenya can be traced to contaminated environment and presence of a tapeworm carrier at the production level (Shonyela et al., 2018; Thomas, 2013).

The observed PC prevalence in Western Kenya is within prevalence range (4.5 to 6.2%) observed in the same region between 2005 and 2013 (Thomas, 2013). This may be moderate prevalence compared to those exceeding 10% reported by WHO/FAO/OIE (2005) as highly endemic. Therefore, these results would suggest the presence of an endemic *Taenia species* infection in Western Kenya, probably sustained with predominant scavenging pig production under poor sanitary practices characterized by poor human fecal waste disposal. Proper use of latrines was limited in the area (27.2%). The poor pig management practices and inadequate meat inspection procedures sustains the life-cycle of *Taenia spps* consequently sustaining endemic conditions and prevalent in both humans and pigs

However, this study could not differentiate between infections of different *Taenia* species in cysticercoids pigs as Ag-ELISA is genus specific and not species specific (*T. solium, T. hydatigena, T. asiatica*) (Devleesschauwer et al., 2014). Further studies could pursue identification of different *Taenia* species in cysticercoids pigs in the region to better inform targeted interventions.

The sensitivity in this study was higher (100%) than 87% reported elsewhere (Krecek et al., 2011) and compared to the standard sensitivity and specificity of 80-90% while the positive and negative likelihood ratios 4-9 and 0.1-0.3 (Mitchell & Lucey, 2011). With the observed prevalence (1.8%), specificity **(**96.4%%), sensitivity (100%), true and false positives (33.3%, 66.7% respectively), carcasses that tested positive had 60.8% chance of being truly PC infected. Conversely, the probability that samples testing positive being actually not PC infected was 39.2%. These results confirm findings by Fredriksson-Ahomaa (2014) who stipulated that meat inspection should not be solely used because it leads to the underestimation of the disease prevalence in an endemic area.

Considered the Ag-ELISA as a gold standard method, it was used to indicate the presence or absence of porcine cysticercosis infection in pigs because it could detect both exposure and active infections which the meat inspection could not detect (Crowther, 2001; Thiha & Fatimah, 2015). This therefore suggests that Ag-ELISA test should be used as a screening test, followed by meat inspection to confirm the infection at slaughter slabs.

3.5 Conclusion and recommendation

Although it may be concluded that PC prevalence is relatively low in the Counties studied, public health risk intervention is warranted, considering that PC is a globally-neglected and re-emerging tropical disease. The intervention should involve enforcing mandatory pig confinement, use of latrines in the farms, meat inspection at local slaughter slabs and performing Ag-ELISA test of the parasite. Further studies are needed to identify the species of *Taenia* responsible for PC.

CHAPTER FOUR

PORCINE CYSTICERCOSIS CONTROL IN WESTERN KENYA: THE INTERLINK OF MANAGEMENT PRACTICES IN PIG FARMS AND MEAT INSPECTION PRACTICE AT SLAUGHTER SLABS

Abstract

The control of biosecurity is the one of the most challenges faced by smallholder pig farmers who rear in free range system, as it is the case in Busia and Kakamega Counties of Western Kenya. The probability of exposure in the free range farms is very high, though it is needed in the disease prevention. This study determined the management practices for controllong Porcine cysticercosis on pig and in porks at farms and slaughter slabs in the two Counties. A total of 162 pig rearing households at farm level, 26 butchers and 26 slaughter slab workers at the slaughter slabs level were interviewed using a structured questionnaire. Data was analyzed using SAS, the "Statistical Analysis System" programme. Results indicated that the frequently used management practices ($p<0.05$) at farm level were rearing pigs under free range (69.1 %), latrine ownership by household (87.7%) and use of pit latrines (72.8%) in household. At slaughter level, results of the butcher (76.9%) and workers from the slaughter slabs (62.5%) shown that meat inspection was not practiced adequately ($p<0.05$) in the two areas of study. The results suggest that pigs slaughtered for human consumption were not adequately inspected and therefore the study recommends for implementation of effective pig management practices at farm level and pork meat inspection at slaughter slabs to prevent PC infections and assure food safety along the pork value chain.

Keywords: *Swine, Taenia Solium, Biosecurity, Farmers, Pork*

4.1 Introduction

Porcine cysticercosis is an infection of pigs with high effect on agriculture and public health (Dahourou et al., 2018; Thomas et al., 2016) and which is prevalent in many developing countries (Mwape et al., 2013). The disease is caused by *Taenia solium*which also causes cysticercosis in pigs, seizures and death in pigs (Donadeu et al., 2016; Gonzales et al., 2016) and epilepsy in humans (Garcia et al., 2014; Nash & Garcia, 2011). The zoonotic tapeworm *T. solium has* a two-host life cycle with the indirect one in humans as the definitive host harboring the mature tapeworm in the small intestine and causing taeniasis. The life cycle which cause porcine cysticercosis has pigs as normal intermediate host harboring the larva cysticerci with encysts in the muscles and the brain (Donadeu et al., 2017). The transmission of *T. solium* is related to behavioural, socioeconomic and environmental factors (Kylie et al., 2017; Wardrop et al., 2015). This was confirmed in as study in Western Kenya by Dermauw et al. (2018) who reported that the inadequacy in sanitation, meat inspection and cooking habits as contributing factors for *T. solium spp.* transmission. The requisite for the successful propagation of the parasite's lifecycle is attributed to the contact with infected human faecal waste by pigs (Ngowi et al., 2013).

In pig farming, external and internal biosecurity measures are critical tools in the prevention of diseases transmission, improvement of livelioods of pig farmers and contribution to the public health (Laanen et al., 2013). Biosecurity encompasses bio-exclusion, bio-containment, and bio-management. The three practices are distinct, but often blended with sets of actions and overlapping components. Most often, pig producers focus on bio-exclusion and bio-management while neglecting bio-containment which is the prevention of the spread of disease agents to neighbors or even long-distance transfer. In bio-exclusion, the external biosecurity involves preventing the introduction of new pathogens/diseases from outside source within a pig unit while bio-management refers to control economically important infectious diseases that are already present in the farm population using a combined effort (Levis & Baker, 2011).

The observation of routine farm biosecurity constitutes a priority solution in the minimization of risk in diseases spread (FAO/OIE/World Bank, 2010). A part from the welfare issues, it has been documented that the total confinement of pigs may also create other management problems such as the aggressiveness and biting (Bellini et al., 2016; Lara E. de la Casa, 2017; Mbuthia et al., 2015). The feasibility of the intensification of livestock production require long-term application of the One Health approach (Mazet et al., 2009) focusing on the mitigation of the health risks at the interfaces between animals and humans in different ecosystems (Nabarro & Wannous, 2014). Studies elsewhere have reported that the safe slaughter of pigs and monitoring of rejected carcasses found to be infected at farm level contributed to the interruption of the parasite life cycle (Shonyela et al., 2017). Poor implementation of biosecurity measures exposes pigs to the risk of PC disease (Bellini et al., 2016; Mbuthia et al., 2015).

A well maintained and updated pig production and management records are the requisite in estimating the extent of the risks of PC and its consequences to pig farming. However, the farm records, veterinary reports and other important statistics on pig farming are usually absent completely missing in various households and slaughter slabs or inaccurate. This study was carried out to determine the management practices frequently used by pigs rearing farmers and the level of implementation of meat inspection at various alaughter slabs in Busia and Kakamega Counties of Western Kenya.

4.2 Materials and Methods

4.2.1 Study site and questionnaire

This study was conducted in Busia and Kakamega Counties of Western Kenya, from August to September 2018. The Western Kenya borders Uganda and covers an area of 8.361 km^2 (2,867.3 sq. miles) and a population density of 590/km^2 (1,500/sq.mi) (Census 2019). Busia and Kakamega Counties are two of the forty-seven (47) Counties of Kenya (Figure 7) where 9 villages with high concentration of free scavenging pigs were selected for data collection. Those villages were Mundika, Bugengi, Nango'ma, Lwanya, and Murende in Busia County, and Shikulu, Shivagala, Lunenele for Idakho cental and Mukongolo for Idakho North in Kakamega County. From an estimated population of 5,021.843 in Western Kenya, the human population at risk of taeniasis is 893,681 and 1,867,579, respectively in Busia and Kakamega (KNBS, 2019).

The climate is mainly tropical and varie due to altitude with the minimum temperatures ranging from 14^oC to 18^oC and maximum of 30^oC to 36^oC during the year. In April, the whole region experiences heaviest rainfull while the lowest is in January and the long rains is at its peak between late March and late May.

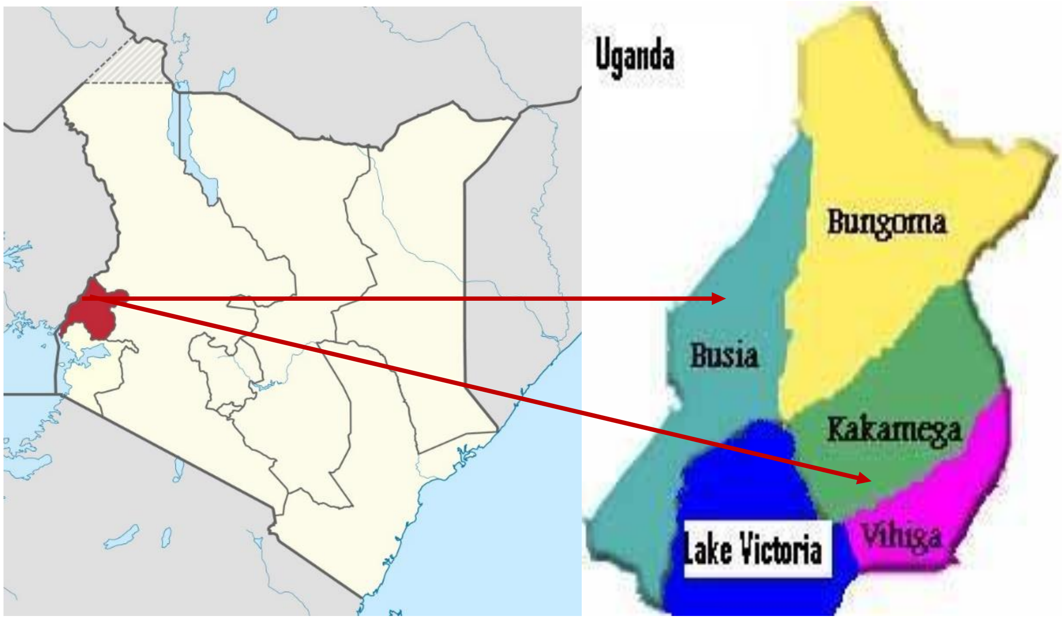

Figure 7: Map of Kenya indicate Western Kenya)Red color). The red arrows indicate Busia and Kakamega Counties

Source: KNBS (2019).

4.2.2 Data collection

Data collection strived for quality and integrity of data capture from the respondents. A structured questionnaire (Appendix 1) used was pre tested to improve relevance and was administered by trained enumerators fluent in the local languages and Kiswahili, though many of the respondents could speak and understand English language. Information on biosecurity measures influencing porcine cysticercosis (PC) infection and implemented at the production level and slaughter slabs in Busia and Kakamega Counties were collected.

Qualitative data on management practices influencing the disease were collected using the structured questionnaires through interview (Appendix 1). During the intervieuw, the structured questionnaires were translated in the local languages and the National language for some participants. A structured questionnaire on management practices used in the pig farming at the farmer level was administered to 162 pig-rearings smallholder households, on the frequently used management practices. They were composed by 102 (63.75%) pig-rearing smallholders from Busia County and 60 (36.25%) from Kakamega County.

A separate questionnaire on meat inspection implementation at the slaughter slabs level was administered to 26 licensed butchers who brought their pigs at the slaughter slabs during the period of the data collection and 26 slaughter slabs workers to collect information on the level of implementation of meat inspection. All slaughter slabs (Khayega, Shinyalu, and Malinya from Kakamega county; Musambaruwa and Matayos from Busia county) in the selected clusters were sampled. Variables defining management practices and meat inspection implementation were collected using the binary response from farmers and slaughter slabs. Respondents would indicate whether they had frequently (yes) or had not frequently practiced (no) against a set of nine measures of management practices, namely, free-range pig keeping, use of outdoor defecation by humans, presence of latrine by the household, using of pit latrines by the household, sourcing water outside the farm, sourcing feed outside the farm, routine deworming, routine vaccination, presence of a fenced farm, and meat inspection (Table 5).

Table 5: Management practices, Type of Questions and Responses.

Management practices	Type of Questions	Responses
Free range pig keeping	Are your pigs kept outdoors?	Yes/No
Use of outdoor defecation	Are outdoor bushes used for defecation?	Yes/No
Presence of latrine at household	Does the household own a pit latrine?	Yes/No
Use of pit latrine by household	Does the household member use the pit latrine?	Yes/No
Sourcing water outside the farm	Whether farmers Sourcing water outside the farm or not?	Yes/No
Sourcing feed outside the farm	Whether farmers Sourcing feed outside the farm or not?	Yes/No
Routine de-worming	Are often your pigs dewormed?	Yes/No
Routine vaccination	Whether farmer vaccinated pigs or not?	Yes/No
Presence of a fenced farm	Whether farm had a fenced pig pen or not?	Yes/No
Meat inspection	Whether meat was inspected at the Slaughter slabs in Busia/Kakamega or not?	Yes/No

4.2.3 Data analysis

Qualitative data on management practices from pig rearing households, butchers approached at the slaughter slabs and slaughter slab workers was entered into Microsoft Excel (2007) and exported to SAS version 9.1.3 (SAS, 2006) for analysis. Descriptive statistics was used to summarize respondents ‘demographic characteristics and management practices (James et al., 2013).

4.3 Results

4.3.1 Demographic characteristic of farmers and butchers by Counties

A total of 214 respondents comprising of 162 pig rearing households, 26 butchers and 26 slaughters slabs workers were interviewed at farm and slaughter slab points in Busia and Kakamega Counties of Western Kenya. Out of the 162 pig rearing households interviewed, majority, 37.7%, 26.5% and 10.5% were youthful farmers whose age groups varied between 21-30, 31-40 and 11-20, respectively (Table 6). One quarter (25.5%) of the households interviewed were over 41-50 years old, and 53.1 % belonged to the female gender, while 41.7 % had no formal school education. Majority (77.2%) of farmers in Busia and Kakamega Counties had kept pigs for a period of 6 -10 years while 22.8% had kept them for an average period of 28-35 years (Table 6).

Table 6: Farmer's demographic characteristic within Busia and Kakamega Counties (n=162).

Characteristics	Categories	Frequency	Percent
Age *(years)*	[11–20]	41	25.3
	[21– 30]	61	37.7
	[31–40]	43	25.5
	[41–50]	17	10.5
Gender	Male	76	46.9
	Female	86	53.1
Education level	None	67	41.4
	Primary	41	25.3
	Secondary	46	28.4
	College/University	8	4.9
Farmer occupation	Farming	153	94.4
	Public employee	4	2.5
	Private employee	5	3.1
Farmers 'pig production Experience (*years*)	[1–10]	125	77.2
	[21 – 20]	31	19.1
	[21 – 30]	4	2.5
	[31 – 40]	1	0.6
	[41 – 50]	1	0.6

n = Number of butchers interviewed

For butchers, results in Table 7 indicate that out of the 26 respondents interviewed, majority, 53.9% were between 11-20 years old, 92.3% of them were male gender and 57.7% had secondary school education. Majority (46.2%) of butchers in Busia and Kakamega Counties had sold pigs for a period of 6 -10 years.

Table 7: Butchers' demographic characteristic within Busia and Kakamega Counties (n=26).

Characteristics	Categories	Frequency	Percent
Age *(years)*	[11–20]	14	53.9
	[21– 30]	5	19.2
	[31–40]	5	19.2
	[41–50]	2	7.7
Gender	Male	24	92.3
	Female	2	7.7
Education level	None	0	0.0
	Primary	9	34.6
	Secondary	15	57.7
	College/University	2	7.7
Selling 'pig Experience (*years*)	[1–10]	12	46.2
	[21 – 20]	9	34.6
	[21 – 30]	5	19.2
	[31 – 40]	0	0.0
	[41 – 50]	0	0.0

n = Number of butchers interviewed

4.3.2 Pig farming management practices preventing PC infection at the production level

The results (Table 8) shown that in Busia and Kakamega, more of the farmers frequently practiced ($p<0.05$) free ranging pig rearing system (69.1%), have latrines (87.6%) and use latrines (72.8%). However, more farmers did not frequently ($p<0.05$) use of outdoor defecation (66.7%), fencing the farm (77.8%), routine deworming (70.4%), sourcing water (92.0%) or sourcing feed (87.0%) outside the farm and vaccination (69.7%).

Table 8: Management practices implemented at farm level within Busia and Kakamega Counties (n=162).

Management practices	Practice frequently	Count	Percent	OR	*P-value*
Free range pig keeping	Yes	112	69.1	2.24	<.0001
	No	50	30.9		
Use of outdoor defecation by humans	Yes	54	33.3	0.5	<.0001
	No	108	66.7		
Presence of latrine at household	Yes	142	87.6	7.1	<.0001
	No	20	12.4		
Use of latrine by household	Yes	118	72.8	2.68	<.0001
	No	44	27.2		
Sourcing water outside the farm	Yes	13	8	0.09	<.0001
	No	149	92		
Sourcing feeds outside the farm	Yes	21	13	0.15	<.0001
	No	141	87		
Routine de-worming	Yes	48	29.6	0.42	<.0001
	No	114	70.4		
Routine vaccination	Yes	49	30.3	0.43	<.0001
	No	113	69.9		
Presence of fenced Farm	Yes	36	22.2	0.29	<.0001
	No	126	77.8		

n = number of farmers interviewed; no (0) implies Not frequently, the management practice was not frequently practiced by the household while Yes (1) implied frequently, the management practice was frequently practiced.

4.3.3 Management practice promoting PC infection at the slauther slabs point

The results from Table 9 indicate the attitudes of butchers and slaughter slabs workers concerning the level of implementation of meat inspection as a management practice at slaughter slabs in the two Counties (Busia and Kakamega). While more of the slaughter slabs workers

(61.5%) and butchers (76.7%) attested that the meat inspection is frequently ($p<0.05$) done, and 38.1% and 23.1% of them, respectively did not attest that.

Table 9: Assessment of meat inspection implementation by respondents in the two Counties.

Respondents	Meat inspection	Frequency	Percent	OR	*P- value*
Butchers	Frequently	20	76.9	3.3	0.006
	Not frequently	6	23.1		
Slaughter slabs Workers	Frequently	16	61.5	1.6	0.2393
	Not frequently	10	38.5		

4.4 Discussion

This paper investigated factors favouring porcine cysticercosis in Busia and Kakamega Countries through the determination of the implementation of pig farming management practices and meat inspection at farm and slaughter slabs levels. The demographic descriptors reveal that out of the 162 farmer population intervieuwed, 37.7 % were aged between 21 and 30 years old, 53.1 % were of the female gender, 41.4 % had no formal school education and 77.2 % had kept pigs for a period of 6 to 10 years of experience (Table 6). These findings were similar to those by Kagira et al. (2010) and Mutua et al. (2010a) who reported that the female gender dominated owning and rearing pigs in the rural areas of Western Kenya and other African countries (Ikwap et al., 2014; Karimuribo et al., 2011; Sibongiseni et al., 2016). The findings agree with a report by Ampaire & Totchschild (2010) who argued that in Africa, women are traditionally empowered to own and rear pigs as opposed to cattle.

Results of this study also shows that out of 162 pig rearing households' farmers interviewed, majority, 37.7 %, 26.5 % and 10.5 % were youthful people whose age groups varied between 21-30, 31-40 and 41-50, respectively and 53.1 % belonged to the female gender (Table 6). These findings differed from early reports on pig's farmer age ranges of 12-88 and 45-60 years in Homa bay and Embu Counties of Kenya (CARE International Kenya, 2017; Eshitera et al., 2012; Kithinji et al., 2017). They also reported that 86.4 and 92.6 % pig farmers in Uganda and

Kenya (Embu County) respectively were male. This variation could be attributed to the socio-cultural differences in Busia and Kakamega Counties, the two areas of this study.

Pigs reared in the two Counties were predominantly under free range system at the farm level with 69.1 % of respondents (Table 8). Ownership and use of structurally dilapidated, unhygienic latrines for human waste disposal formed the main bio-exclusion, bio-containment, and bio-management practices with a prevalence ‘s of up to 87.7 and 72.8 % in the surveyed farms. Studies elsewhere, has established a significant positive relationship between inappropriate use of latrines and PC prevalence, (Eshitera et al., 2012; Sikasunge et al., 2007). It has been documented that the risk of acquiring *T. solium* infection which lead to the endemicity of the zoonotic porcine cysticercosis, is elevated when pigs are kept under free range system (WHO, 2015). Results in this study not only concur with this fact but also corroborated the information that pigs kept under free range pig production system, compounded by poor utilization or lack of latrines could have been the main contributing factors for the spread and endemicity of PC in the two Countries at farm level.

In this study 76.9 % and 61.5 % of butchers and slaughters slabs workers reported that meat inspection was frequently implemented at slaughter slbs (Table 9). It was observed that meat inspection practice was occasionally ignored in some slaughter slabs when in seasons of high demand and was not thoroughly performed in the sense that infected animals could be slaughtered and uninspected pork easily found its way in to the human food chain.

These observations concur with those od Gabriel et al. (2016), who reported inadequate meat inspection as as contributory factor to the spread of the infection by *Taenia solium* which could lead to the emergence or re-emergence of cysticercosis in pig farming systems. These results suggest that inadequate meat inspection is a critical factor influencing the spread of this disease in Busia and Kakamega Counties at the slaughter slabs level.

4.5 Conclusions

The free-range pig production system characterized by no fencing and scavenging, and inappropriate use of latrines were the critical poor used management that propagated and propelled PC infection at farm level in Busia and Kakamega Counties. As factor of biosecurity at slaughter slabs, the meat inspection practice was not adequate in the two counties of Western Kenya. These results suggested that there is need for implementation of effective biosecurity measures to prevent PC infection and ensure food safety and quality along the pork value chain in Western Kenya. In their mandate to the reinforcement of the regulations by inspiring farmers through sensitization trainings and strengthening the meat inspection in Western Kenya, will require collaboration with policymakers.

CHAPTER FIVE

PORCINE CYSTICERCOSIS RISKS: AWARENESS, ATTITUDES AND PERCEPTIONS ON SAFETY PRACTICES AMONG FARMERS, BUTCHERS AND CONSUMERS IN WESTERN KENYA

Abstract

In Africa, the demand for pork is increasing following the high need for animal protein in the household's diets. But the safety and quality of pork remain a universal concern that needs intervention to assure consumers protection from Porcine Cysticercosis (PC) contamination. This study determines the awareness, attitudes and perceptions on safety risks associated with PC among farmers, butchers and consumers in Western Kenya. Data were obtained using structured questionnaires in cross-sectional survey interviews with 162 farmers, 26 butchers and 92 consumers from Busia and Kakamega Counties. The data were in binary response and were analyzed using Chi - square test to detect differences in the frequency distributions. Results show that only two in ten farmers had knowledge of *Taenia solium* parasite (24.1% vs. 75.9%), risk factors in PC transmission (21.6% vs. 78.4%) and could associate pig management system with PC (17.3% vs. 82.7%). A larger proportion ($p<0.01$) of the butchers perceived pork from slaughter slabs (76.9% vs. 23.1%) and home slaughters (73.1% vs. 26.9%) as presenting high risks and pork from the butcheries (69.2% vs. 30.8%) as presenting no risks, but were not ($p>0.05$) in total agreement as to whether pork from the eateries (61.5% vs. 38.5%) was safe. Among the consumers, a larger proportion strongly agreed ($p<0.05$) that pork in the market was generally safe (85.9 % vs. 14.1%), pork from the slaughter slabs is safer than pork from the farms (92.2% vs. 7.8%) and pork from butcheries was safer than pork from the eateries (81.5% vs. 18.5%). However, more consumers strongly disagreed ($p<0.05$) that pork from the eateries exposed them to cysticercosis (64.1% vs. 35.9%) while they were not ($p>0.05$) in total agreement as to whether undercooked pork is more likely to transmit cysticercosis. In the study area, the awareness of pig management and risk factors for PC transmission was low among farmers. Butchers and consumers perceived pork safety differently along the value chain. The study recommended

strengthening public education about PC risks and pork safety among all actors in the pork value chain in Western Kenya.

Keywords: *Pork; quality; safety; T. solium; porcine cysticercosis; value chain actors*

5.1 Introduction

The pork industry in Kenya is growing and is differentiated into specialized business units along the value chain, consisting of feed millers, producers, abattoirs, processors and retailers. The pork value chain is organized in a way that live pigs are sold at the farm gate, slaughtered pigs at the abattoirs, pork sold at the butcheries and processed products sold at specialized pork eateries (Levy et al., 2013). In Western Kenya, smallholders dominate pork production but lack access to functionally good pig slaughterhouses to enhance pork safety for consumers (Levy, 2014). Improving pork safety and quality is important for consumers because in the food supply chain, the consumer level of trust depends on safety and quality associated with the product marketed (Taylor et al., 2012).

Rapid growth in pork consumption should contribute (Bett et al., 2012; FAO, 2012) to improved food security and nutrition because pork is rich in protein, Vitamin B12, iron and selenium, Vitamin C, niacin, phosphorus and zinc (USDA, 2018). However, consumption of pork may expose consumers (Davies, 2011) to hazards and risk of Porcine Cysticercosis (PC) *Taenia solium* in pigs, associated with PC, may infest people through food following ingestion of the parasite larval cysts in undercooked and contaminated pork (Saw et al., 2015). Focus on the prevention, control and reduction of the hazard and risk to PC is thus a public health objective (Inpankaew et al., 2015; Schär et al., 2014). The public health objective promotes one health concept‖ for PC eradication (Schurer et al., 2016; Torgerson et al., 2015; WHO/TDR, 2012).

Integrating public health education with control strategies could promote effective and sustainable reduction of the risk of PC infestation in humans (O'neal et al., 2012, Thys et al., 2016). Creating public awareness is an important component of one health approach‖ involving human, veterinary, environmental and social sectors. Integrated into One health concept ‘is public health education in combination with other control strategies for effective and sustainable eradication of the risk of PC infestation in humans (Ngowi et al., 2008; Sorvillo et al., 2011). Knowledge of awareness, attitudes and perceptions of safety practices among farmers, animal health workers, butchery-owners and consumers in addressing risks of PC infestation is important for the control of *Taenia solium* (GALVmed, 2017; Kungu et al., 2017). This study examined the extent of awareness, attitudes and perceptions on safety practices among farmers, butchery-owners and consumers in Western Kenya on the risk factors for PC.

5.2 Materials and Methods

5.2.1 Study area

This study was conducted in two of the forty-seven (47) Counties of Kenya namely Busia and Kakamega Counties located in the Western Kenya where nine (9) villages were considered for it high concentration of free scavenging pigs and 5 slaughter slabs (Appendix 3, 3.1.2). The Western region covers an area of 8.361 km^2 (92,867.3 sq. miles) and borders Uganda. It has an estimated population of 5,021,843 as by the Census 2019. It has a density of 590/km^2 (1,500/sq. miles). In Busia and Kakamega, scavenging pigs constitute a livelihood asset with the majority of the population being subsistence smallholder farmers (KNBS, 2013). The livestock reared in the two Counties is composed of Zebu and dairy cattle, local and dairy goats, hair sheep, pigs, poultry, rabbits and bee keeping. In Western region, the climate is generally tropical and vary by County due to altitude. With the minimum temperatures ranging from 14^{o}C to 18^{o}C and the maximum of 30^{o}C to 36^{o}C throughout the year, the whole region experiences heaviest rainfall in April and lowest in January, with the long rains at its peak between late March and late May. In Busia and Kakamega, the human population at risk of taeniasis is represented by 893,681 and 1,867,579 people, repectively (KNBS,2019).

Busia County is located at the extreme region of the country in Western Kenya. This County borders Bungoma county to north, Kakamega County to the east and Siaya County to the south west. Its also borders with Uganda to the west and has a part of Lake Victoria in the South East of it. It lies between latitude 0º and 0º 45 north and longitude 34º 25 east (Source: Kenya National Bureau of Statistics, 2013). Busia County covers an area of 1,628.4 km^2 (628.7 sq. mi). It has an estimated population of 893,681 and density of 550/km^2 (1,400/sq. mi) with 7 sub-counties and 35 wards (Source: County Commissioner ‘s Office, Busia, 2013). This County receives an annual rainfall of between 760 and 2000 mm and has the dry season from December to February. Fifty per cent of the rain falls in the long rain season which is at its peak between late March and late May, while 25 per cent falls during the short rains between August and October. The annual mean maximum temperatures range between 26 and 30°C while the mean minimum temperature range between 14 and 22°C. The temperatures for the whole Country are almost homogenous (Kenya National Bureau of Statistics, 2010).

Kakamega County is situated in the Western part of Kenya and borders Bungoma and Trans Nzoia Counties to the North, Vihiga County to the South, Nandi and Uasin Gishu Counties to the East and Siaya County to the West. The County covers an area of 3,033.8 km^2 (1,171.4 sq. mi) and an estimated population of 1,867,579 with a density of 682/km^2. It is the second populous county after Nairobi with the largest rural population which is adminstratively divided into twelve sub counties, sixty wards, one hundred and eighty-seven Village Units and four hundred Community Administrative Areas. The altitude ranges from 1,240 meters to 2,000 metres above sea level. The southern part of the county is made up of rugged granites rising in places to 1,950 metres above sea level and is hilly. The climate is very conducive for many activities including crop and animal production. There are two main ecological zone namely, the Lower Medium (LM) which covers a major portion of the southern part of the county and the Upper Medium (UM) which covers the Central and Northern parts of the county. The annual rainfall ranges from 1280.1mm to 2214.1mm per year with the rainfall pattern evenly distributed all year round with March and July receiving heavy rains while December and February receive light rains. With an average humidity of 67 percent, the county has the temperatures ranging from 18 ^{0}C to 29 ^{0}C. January, February and March are the hottest months with other months having relatively similar temperatures except for July and August which have relatively cold spells. Since the early 1960s both minimum (night) and maximum (day) temperatures have been on a warming trend in Kenya while the current projections are indicating increases in temperature.

5.2.2 Methodology

To obtain relevant data needed to answer the study research question, a cross-sectional survey was conducted in nine rural villages in the two study Counties in the absence of quality production data, veterinary data and market data. Cross sectional survey enabled access to primary data at the farms, slaughter slabs and from traders and consumers for a value chain situational analysis. Qualitative data on awareness, attitudes and perceptions on quality and safety risks issues associated with PC among group of farmers, butchers and pork consumers in Western Kenya was collected using structured questionnaires through intervieuw (Appendix 1) and which was translated in the local languages for somes paricipants and National language during the intervieuw. Structured questionnaires (Appendix 1) were administered to 280 respondents of which 162 were farmers, 26 were butchers and 92 were consumers. Snowball sampling was adopted for the survey to reach the targeted study population. Farmers were randomly selected from local villages known for high concentration of pigs. However, all licensed butchers from 26 butcheries in Busia and Kakamega Counties were sampled with the help of slaughter slabs owners while consumers were approached at the pork butcheries. The structured questionnaires (Appendix 1) had binary responses at production, trade and consumer levels. The responses involved the demographic characteristics, management practices implemented at farms and slaughters slabs which include farmer awareness about pig management, *Taenia solium* parasite and risk transmission factors for PC. Butchers and consumers were interviewed on attitudes and perceptions on safety practices for pork in the market.

5.3 Statistical analysis

Data collected was entered in Excel database, and thereafter exported to the Statistical Analysis System version 9.1.3 (SAS, 2006). The analysis was on frequency distribution with Chi-square ($\chi 2$) test statistics to examine the relative differences in awareness, attitudes, and perceptions about safety practices.

5.4 Results

5.4.1 Demographic characteristic of the respondents

Out of the 162 farmers who participated in the intervieuw, 37.7 % were between 21 and 30 years old, 53.1 % were female by gender, 47.7 % had no formal school education and 77.2% had experience in keeping pigs for a period of 6 to 10 years (Table 6). Among the 26 butchers interviewed, 53.9 % were between 11-20 years of age, 92.3% were males, and 57.7% had attained primary level education, while 46.2% had 1-5 years of experience in pork butcher trade (Table 7).

The results (Table 10) indicate that of the 92 consumers interviewed, 48.9% were between 31-40 years of age, 83.7% were females and 46.7% had not acquired formal education.

Table 10: Consumer's demographic characteristic within Busia and Kakamega Counties (n=92).

Characteristics	Categories	Frequency	Percent
Age *(years)*	[11–20]	16	17.4
	[21– 30]	25	27.2
	[31–40]	45	48.9
	[41–50]	6	6.5
Gender	Male	15	16.3
	Female	77	83.7
Education level	None	43	46.7
	Primary	37	40.2
	Secondary	12	13.1
	College/University	0	0.0

n = Number of consumers interviewed

5.4.2 Farmer's awareness of risk of Porcine Cysticercosis

Table 11 shows the frequency distribution of farmers by their awareness about the pig management systems, *Taenia solium* parasite and the possible risks factors of its transmission. The estimated frequencies among those interviewed showed that only about two-in-ten farmers declared being aware of the link between pig management system and PC compared ($p<0.0001$) to eight-in-ten (17.3% vs. 82.7%) who declared that they were not aware. Furthermore, results revealed that two-in-ten farmers declared that they were aware of the *Taenia solium*parasite compared ($p<0.0001$) to eight-in-ten (24.1% vs. 75.9%) who claimed not being aware ($\chi2$ 43.556[a], *p*.value 0.0001). Regarding awareness about risk factors in the transmission of porcine cysticercosis, only two-in-ten farmers were aware compared ($p<0.0001$) to eight-in-ten (21.6% vs. 78.4%) who claimed not being aware.

Table 11: Frequency distribution of farmer' by their awareness of transmission factors for T. solium cysticercosis.

Awareness of:	Response	Frequency	Percent	($\chi 2$)	P-value
Knowledge about *Taenia solium* parasite				43.556	0.0001
	Aware	39	24.1		
	Not aware	123	75.9		
Knowledge about the link between pig management systems and PC				69.358	0.0001
	Aware	28	17.3		
	Not aware	134	82.7		
Knowledge about risks for PC transmission				52.247	0.0001
	Aware	35	21.6		
	Not aware	127	78.4		

5.4.3 Butchers and consumers' attitudes towards safety of pork in the market

Table 12 presents the frequency distribution of butchers 'attitudes to issues of safety of pork sold at different retail outlets along the value chain. While more ($p<0.01$) of the butchers interviewed had the perception that pork from slaughter slabs and home slaughters has high risks and pork from the butcheries has no risks, they could not ($p>0.05$) split on the safety of the pork from the eateries. For pork from slaughter slabs, about eight-in-ten of the butchers interviewed had the perception that risk was high compared to two-in-ten (76.9% vs. 23.1%) that had the perception that there are no risks. For pork from home slaughters, about seven-in-ten of the butchers interviewed had the perception that risk was high compared to three-in-ten (73.1% vs. 26.91%) that had the perception that there were no risks.

Table 12: Frequency distribution of Butchers' attitudes to safety of pork at different retail outlets.

Pork sale point	Risk perception	Frequency	Percent	Chi-Square(χ^2)	*P- value*
Home slaughter				5.5385	0.0186
	High risk	19	73.1		
	No risk	7	26.9		
Slaughter Slabs				7.5385	0.0060
	High risk	20	76.9		
	No risk	6	23.1		
Butchery				3.8462	0.0499
	High risk	8	30.8		
	No risk	18	69.2		
Eateries				1.3846	0.2393
	High risk	10	38.5		
	No risk	16	61.5		

In contrast, pork from the butcheries had about three-in-ten perceiving that risk was high compared to seven-in-ten (30.8% vs. 69.2%) that had the perception that there were no risks. Though the perception of risk being high or no risk was not statistically different ($p>0.05$) for pork from the eateries, fewer had the perception that risk is high (38.5% vs. 61.5%).

Table 13 presents the frequency distribution of consumer perception to safety of pork in the market in response to whether they strongly agreed or disagreed with the specific statements put to them. More of the consumers interviewed strongly agreed ($p<0.05$) that pork was generally safe (85.9% vs. 14.1%), that pork from the slaughter slab was safer than pork from the farm (92.4% vs. 7.6%) and that pork from butcheries is generally safer than pork from the eateries (81.5% vs. 18.5%). However, more of the consumers ($p<0.05$) interviewed strongly disagreed that pork from the eateries exposed humans to cysticercosis (64.1% vs. 35.9%). On the other hand, consumers could not split ($p>0.05$) on whether undercooked pork was more likely to transmit cysticercosis to humans and whether they always cooked pork well before eating.

Table 13: Frequency distribution of consumer perception of safety of pork in the market(n=92).

Perception	Agreement	Frequency	Percent	(χ^2)	*P- value*
Pork sold is generally safe				47.3478	0.0001
	Strongly agree	79	85.9		
	Strongly disagree	13	14.1		
I always cook well the pork before eating				3.5217	0.0606
	Strongly agree	55	59.8		
	Strongly disagree	37	40.2		
Undercooked pork is more likely to transmit cysticercosis to human				1.5652	0.2109
	Strongly agree	52	56.5		
	Strongly disagree	40	43.5		
Pork from the slaughter slab is safer than pork from farm				66.1304	0.0001
	Strongly agree	85	92.4		
	Strongly disagree	7	7.6		
Pork from butchers is generally safer than pork from the eateries				36.5652	0.0001
	Strongly agree	75	81.5		
	Strongly disagree	17	18.5		
Pork from the eateries expose human to cysticercosis				7.3478	0.0067
	Strongly agree	33	35.9		
	Strongly disagree	59	64.1		

n= number of respondents

5.5 Discussion

This study investigated awareness, attitudes and perceptions on safety practices among farmers, butchers and consumers about the risk factors for PC in Western Kenya. Results showed only two-in-ten farmers had knowledge of *Taenia solium* parasite, risk factors in PC transmission and could associate pig management system with PC. These findings differed with those of Adenuga et al. (2018) who found high level of awareness among farmers, with seven in-ten (70.5%) being aware of porcine cysticercosis and about half (47.8%) knowing about its transmission as a zoonotic disease. Mishra et al. (2007) reported high level of awareness among farmers (59.1%) but with low awareness about pork tapeworm transmission (35.0%). These Results of the present study may have differed from those others because it was carried out in the rural area of Western Kenya where pig keeping had become a popular small-holder activity for low-income families where over half (57.6%) lived in poverty. These resource-poor families engage in pig production using the traditional scavenging feeding system because of inability to invest in modern housing, commercial feeds and herd health programme. Pig production is a diversification livelihood strategy and not a major source of income streams for these farmers. About half (50%) of the farmers were without formal school education to enable them be trained by extension staff on modern pig husbandry (Kithinji et al., 2017; Nantima et al., 2015a) as compared to pig farmers in Botswana and Tanzania where 15 to 25% of farmers had secondary education (Karimuribo et al., 2011; Nsoso et al., 2006).

The results of this study concur with the findings of Sibongiseni et al. (2016) and Mwendia et al. (2018) which reported an association between poor knowledge of *T. solium* infections and poor hygiene by farmers. This practice was common in Western Kenya where farmers owned and used dilapidated, unhygienic latrines for human waste disposal. Therefore, this study suggests the need for farmers to be trained on the three variables namely, pig management systems, *T. solium*, porcine cysticercosis as important tools for control in the two areas.

Results of this study showed that the risks of pork in the market were perceived to be high at slaughter slabs and home slaughters, and no risks at the butchery and eateries. Findings elsewhere by Fahrion et al. (2014); Fogang et al. (2015) and Ocaido et al. (2013), reported that pork from informal market was riskier to human health exposing consumers to zoonotic diseases.

The findings of this study are in agreement with reports of Ngasala et al. (2015) and Gayatri et al. (2017) who reported that butchers as knowledgeable people able to protect human beings through disease prevention and control. These results suggest the need for creation of awareness of the risk of disease transmission to butchery-owners along the pork value chain in the study area.

Results revealed that the majority of consumers agree with the perceptions, all except for the eateries where consumers were less likely to agree in strong agreement about exposure to cysticercosis in the eateries. The present results confirm the findings by Kagira et al. (2010) and FAO (2012) that reported that most butchery in Western Kenya had restaurants/eateries attached where pork was sold was cooked (41%). The butcheries sold also raw pork (59%). Studies in Burkina Faso (Ngowi et al., 2017), reported that, boiling was the common traditional method for cooking pork. Boiling of pork products exposes consumers to *Taenia solium* (Cook, 2015; Thomas, 2014) due to undercooking since consumers do enjoy and prefer the juiciness of the meat (Levy et al., 2014). A study by Nguhiu et al. (2020) in Thika Sub-County of Kiambu County of Kenya, reported frying as the preferred method by consumers. The boiling method may expose humans as it cannot kill all cysts. This expresses how consumers ignored the fact that pork from the eateries could expose humans to cysticercosis due to the practice of eating undercooked pork. It is also suggesting that health education could significantly increase knowledge and awareness of the disease, and can inspire behavioral change that will reduce disease transmission through thorough cooking practices.

Consumers were not sure of the safety aspect of the meat consumed in the stall because of doubts of health inspection and meat source. Our findings confirmed those by Mutua et al. (2019) on the traceability approach for consumers along the traditional pork value chain in western Kenya. Hence, our results suggest the need for consumers to be educated on the pork eating habits as it predisposes humans to the utter risk of *T. solium* infection in the study area.

5.6 Conclusion

The study concluded that farmers from Western Kenya had little knowledge of pig management, *Taenia* parasite or its transmission. Results also indicate that butchers and consumers hold different views about where safe pork is found in the market. Therefore, public education about PC risks and pork safety is necessary among all stakeholders in the pork value chain in Western

Kenya. This should involve training pig farmers, pork meat consumers, butcheries to create awareness on transmission risk factors and strategies for the control of porcine cysticercosis. It should be possible to complement training with public education to stop consumer habits of eating undercooked pork from untraceable slaughter sources along the pork value chain, especially so in the local eateries. This predisposes humans to the risk of *T. solium* infection resulting in intestinal tapeworm when the pork eaten contains larval cysts. The stakeholders need to embrace multi-sector one health approach to break the *T. solium* life cycle. The main components of this campaign are recruitment of qualified pork inspectors and enforcement of meat inspection practices as requisite to the control of PC in Busia and Kakamega Counties.

CHAPTER SIX

LOSS IN CARCASS VALUE FROM PORCINE CYSTICERCOSIS INFECTION IN BUSIA AND KAKAMEGA COUNTIES, WESTERN KENYA

Abstract

The pig trade is commonly affected by a variety of infectious diseases. Cysticecosis is an important zoonotic parasitic disease causing a serious public health risk and significant financial losses due to pork condemnation and death in pigsworldwide. The direct monetary loss from Porcine Cysticercosis (PC) infections resulting from pork carcass condemnation at the slaughter slabs was estimated. Data was obtained from the slaughter slabs in two Counties (Busia and Kakamega) in Western Kenya. Out of 113 pigs slaughtered during the period of the study, PC detected during meat inspection was 1.8% (2/113 pigs) and during Ag-ELISA test was 5.3% (6/113 pigs). Assuming total condemnation of the carcasses positive for PC when a carcass average weight was 50 Kg selling at a price of Kes 310 per Kilogram of pork, the direct monetary loss amounted to Kes 31,527.00 (US$ 315.27) were estimated with meat inspection. With Ag-ELISA testing surveillance, the loss was estimated to Kes 92,829.50 (US$ 928.30). For the recorded 5 pigs slaughtered daily in twenty-one days working, the monetary loss projected in a year would be Kes 547,969.29 (US$ 5,478.7) with meat inspection and Kes 1,613,465.10 (US$ 16,134.70) with Ag-ELISA testing surveillance. This study concluded that PC negatively affected the Western Kenya/national economy. The study recommends reinforcing the pig value chain since the pig sector has the potential to increase incomes for farmers, butchery owners and food security for consumers. This could play a key role in augmenting income from pig production and enhance trade in the markets for pig products.

Keywords: *Taenia Sollium*, Pigs, Financial loss, Meat inspection, Ag-ELISA

6.1 Introduction

Porcine cysticercosis has been found to have high impact on public health and agriculture (Dahourou et al., 2018). The disease has already been reported in Teso South of Busia County among heavy pork consumer communities (Mutua et al., 2007). Pigs in that area are kept by farmers under free range as it requires low inputs but at the same time poses a health risk to the farmers and consumers of pork (KNA, 2018). The presence of *T. solium* in the meat reduces the market value of pigs and makes pork unsafe to eat (Trevisan et al., 2017). It also increases carcass condemnation or reduces meat prices, which leads to loss of food protein (Havelaar et al., 2015; Torgerson et al., 2015).

Livestock have contributed to enhancing the viability of the economy and supporting the livelihoods of smallholder farmers and traders worldwide (ILRI, 2002; Phiri et al., 2003). The pig farming sector has a notable economic importance in augmenting farmers 'income and implications on general public health in Kenya. In Busia and Kakamega Counties, many farmers are raising pigs as a source of household income and animal protein. Pigs are mainly kept under a scavenging system roaming in search of feed and later sold locally in the market to butchers directly or to livestock traders (Kagira et al., 2010). In the recent past pork consumption in Kenya has increased significantly but consumers face a health risk from *Taenia solium* causing porcine cysticercosis which is medically linked to epilepsy in humans (KNA, 2018). This is caused by the scarcity of veterinary services in rural areas where the majority of animals for slaughter come from (Kiswaga et al., 2014).

Porcine Cysticercosis (PC) has been considered as an important parasitic tropical zoonotic disease causing significant economic losses (Torgerson, 2013) worldwide such as seizures in pigs and even death in humans (Braae et al., 2017; Gonzales et al., 2016). In infected animals, the disease often causes no symptoms but has an important economic impact due to production losses from condemnation of infected carcasses and control measures (Goussanou et al., 2013; Pawlowski et al., 2005). The presence of cysts in the brain and spinal cord in humans lead to neurocysticercosis (CDC, 2019).

In Mexico, one of endemic countries, the estimated annual monetary loss due to porcine cysticercosis is US$43 million (Flisser et al., 2003). According to Nkwengulila (2014) and Kiswaga et al. (2016), the annual monetary loss of US$ 144,449) and US$ 46,791.56 respectively due to PC has been estimated in Tanzania; where €25million (US$ 39.2 million) has been reported in ten West and Central African countries and Euros 17, 442, 000 in Nigeria alone (Zoli et al., 2003). In Cameroon, pig production losses of €478,844 (Foyaca-Sibat et al., 2009) and in South

Africa, US$ 5 Million production losses have been recorded (Praet et al., 2009). In Eastern Cape Province of South Africa and in Mexico, losses of US$ 5.0 million and US$ 19,507,171 were estimated by Carabin et al. (2006) and Bhattarai et al. (2019), respectively. Due to scarcity of data on the loss in carcass value from porcine cysticercosis infection in Western Kenya, the objective of this study was to determine the direct monetary loss from porcine cysticercosis infection at slaughter slabs level in Busia and Kakamega Counties during the period of study.

6.2 Material and methods

6.2.1 Study area

The study was conducted in 5 slaughter slabs namely Musambaruwa, Matayos, Malinya, Khahega and shinyalu in Busia and Kakamega Counties. Scavenging pigs are a livelihood asset in these Counties with the majority of residents being subsistence smallholder farmers (Kenya National Bureau of Statistics, 2013). The livestock reared in the two Coutries are the following: Dairy and Zebu cattle, pigs, dairy and local goats, hair sheep, poultry, bee keeping and rabbits.

Busia County is located at the extreme region of the country and borders three counties namely: Bungoma to the north, Kakamega to the east and Siaya to the south west. Part of Lake Victoria is in the County on the South East and borders with Uganda to the west. It lies between latitude 0º and 0º 45 north and longitude 34º 25 east (KNBS 2013). Busia County covers an area of 1,628.4 km^2 (628.7 sq. mi), has an estimated population of 893,681 and a density of 550/km^2 (1,400/sq. mi) with 7 sub-counties and 35 wards (Source: County Commissioner 's Office, Busia, 2013). This County has the dry season from December to February and receives an annual rainfall of between 760 and 2000 mm. Fifty per cent of the rain falls in the long rain season which is at its peak between late March and late May, while 25 per cent falls during the short rains between August and October. The temperatures for the whole County are almost homogeneous. The mean minimum temperature ranges between 14 and 22ºC while the annual mean maximum temperatures range between 26 and 30ºC (KNBS, 2010).

Kakamega County is located in the Western part of Kenya and borders Vihiga County to the South, Siaya County to the West, Bungoma and Trans Nzoia Counties to the North and Nandi and Uasin Gishu Counties to the East. The County covers an area of 3,033.8 km^2 (1,171.4 sq. mi) with an estimated population of 1,867,579 and a density of 682/km^2. Kakamega has the largest rural population and is the second populous county after Nairobi. It is administratively divided into twelve sub counties, sixty wards, one hundred and eighty-seven villages and four hundred community administrative areas. The altitude ranges from 1,240 meters to 2,000 metres above sea level with the southern part being hilly and made up of rugged granites rising in places to 1,950 metres above see level. The climate is very conducive for many activities including crop and animal production. There are two main ecological zones namely; the Upper Medium (UM) and the Lower Medium (LM). The Upper Medium covers the Central and Northern parts of the county. The second ecological zone, the Lower Medium (LM), covers a major portion of the southern part of the county. The annual rainfall ranges from 1280.1 mm to 2214.1 mm per year. The rainfall pattern is evenly distributed all year round with March and July receiving heavy rains while December and February receive light rains. The temperatures range from 18^{o}C to 29^{o}C with the hottest month being January, February and March while other months except for July and August which have relatively cold spells, are having quite similar temperatures. The minimum and maximum temperatures in Kenya have been on a warming trend since the early 1960s with an average of 67 percent of humidity but currently the projections are indicating increases in temperature.

6.2.2 Methodology

A face to face interview was carried out with slaughter slab owners and butchers to collect information on the total number of pigs slaughtered per day, the unit price per Kg in the market and the average carcass yield (Appendix 1). Due to the missing data at County and slaughter level, the actual prevalence of PC at slaughter slabs level in the two Counties using meat inspection and Ag-ELISA test were considered as primary data. The determination of the direct monetary loss in carcass value from porcine cysticercosis infection was therefore calculated based on the positive cases of PC infection detected which were assumed to be further condemnation and considered as total condemnation for determination of the direct loss in carcass value during the period and which was extrapolated to one year.

6.2.3 Data analysis

Data generated was arranged and analysed in Excel 2007 spreadsheet. During the study period, a total of 113 pigs from slaughter slabs were considered for blood collection in Western Kenya. Among the 113 pigs slaughtered, 2 pigs (1.8%) were found positive through meat inspection and 6 pigs (5.3%) by Ag-ELISA test at slaughter slabs level. The average of slaughter figures per year of 1,825 pigs was calculated based on the average mean daily figure which was 5 pigs and therefore the average pork butchery price of Kes 310/Kg were considered for determination of the direct monetary loss. Most pigs were slaughtered at 7 months and the average carcass yield of 50 Kg was considered. Sensitivity analysis was conducted to assess if prevalence reduction for the two different methods had effect on changes in the monetary loss due to PC in Western Kenya. During the period of the study, from August to September 2018, one Kenya Shilling was equal to $ (United States Dollar) 0.01. Two different models were therefore considered to compute the direct annual loss.

The model below of Ejeh et al. *(*2014) was used based on positive animals as follow:

$$DEL = nW * Av.\frac{P}{Kg}$$

Where DEL is the Direct Economic Losses due to the total pork condemned, *n* is the total number of condemned pork for the period of study, *W* is the total weight of condemned pork in Kg and Av. P/Kg is the average price of condemned pork per Kg at the market in Kes. n= 6 pigs for Ag-ELISA and 2 pigs for meat inspection

W= 50kg

Av. P/Kg = Kes 310

When considering the actual prevalence rate of 5.3% and 1.8% from the confirmed PC cases by Ag-ELISA and meat inspection, respectively, the direct loss in carcass value from porcine cysticercosis infection was calculated using the model of Ogurinade & Ogurinade, (1980).

DAL= ∑AC*AP*CR

Where AC= Annual pig slaughter rate of abattoir; AP = Average price of condemned pig carcass at the market; CR = Carcass condemnation rate at the abattoir and DAL= Direct annual loss due to carcass condemnation

For the case in this study, the period/duration of study was equal to 21 days (3 weeks):

C = pig slaughter rate at slaughter slabs during the study days = 113 pigs

P = Average price of condemned pig carcass at the market = 310 Kes/Kg

CR = 5.3% Ag-ELISA and 1.8% for meat inspection

6.3 Results

Table 14 shows the computed direct monetary loss for the number of positive pig carcasses detected using Ag-ELISA and meat inspection with the assumption that positive carcasses are subjected total condemnations. The direct monetary loss was estimated at Kes 1,613,465.10 equivalent to US$ 16,134.70 for Ag-ELISA and Kes 547,969.29 equivalent to US$ 5,479.7 for meat inspection.

Table 14: Direct annual financial loss due to positive cases by Ag-ELISA and meat inspection in Western Kenya.

Diagnosis method	Total carcass condemned (n)	Total carcass weight (Kg) condemned (W)	Average price of carcass (Kes/kg)	Production loss (Kes &US$/year)	
				Kes/year	**US$/year**
Ag-ELISA test	6	50	**Kes** 310	Kes 92,829.50	US$ 928.3
Annual loss				Kes**1,613,465.1**	US$**6,134.7**
Meat inspection	2	50	**Kes** 310	Kes 31,527.00	US$ 315.3
Annual loss				Kes**547,969.29**	
US$**5,479.7**					

Exchange rate Kes 1 equivalent to US$ 0.01 (2018)

Table 15 presents the annual estimated direct loss computed based on the actual PC prevalence by Ag-ELISA test and meat inspection at slaughter slabs level. For the financial loss based on the actual prevalence, the potential annual loss associated with PC at slaughter slabs was estimated at Kes 32,269.30(US$ 322.69) with Ag-ELISA test diagnosis and Kes 10,959.39 (US$ 109.59) with meat inspection.

Table 15: Annual Financial loss due to PC based on the actual prevalences by Ag-ELISA and meat inspection in Western Kenya.

Diagnosis method	**Pig carcasses (n)**	**Price (Kes/carcass)**	**CR (%)**	**Loss (Kes)**	**Loss (**US$**)**
Ag-ELISA	113	Kes 310	0.053	Kes 1,856.59	US$ 18.57
Annual loss				**Kes 32,269.30**	**US$322.69**
Meat inspection	113	Kes 310	0.018	Kes 630.5	US$ 6.3
Annual loss				**Kes 10,959.39**	**US$ 109.59**

Exchange rate Kes 1 equivalent to US$ 0.01 (2018)

Table 16 presents the average potential annual loss computed associated with PC at slaughter slabs considering losses computed from the positives cases and actual prevalence as by the two models by Ag-ELISA test and meat inspection. The average potential loss was estimated at Kes 822,867.20 equivalent to US$ 8,228.67 for Ag-ELISA and Kes 279, 464.34 equivalent to US$ 2,794.64 for meat inspection.

Table 16: Average potential financial loss due to PC based positive cases and on the actual prevalences both by Ag-ELISA and meat inspection in Western Kenya.

Diagnosis method	**Annual loss due to positive cases**	**Annual loss based on actual prevalence**	**Average potential loss (Kes)**	**Average potential loss (US$)**
Ag-ELISA	**Kes** 1,613,465.10	**Kes** 32,269.30	**Kes** 822,867.20	**US$** 8,228.67
Meat inspection	**Kes** 547,969.29	**Kes** 10,959.39	**Kes** 279,464.34	**US$** 2,794.64

Exchange rate Kes 1 equivalent to US$ 0.01 (2018)

6.4 Discussion

The direct costs related to condemnation of parts or whole carcasses are easy to capture compared to the indirect costs as a result of animal diseases and which are more difficult to capture. However, they can be considered as significant losses in agriculture related to *Taenia solium* infection of pigs caused by cystic stages of the parasite. Another loss of profit is affecting farmers when they do not sell the pork to official markets. (Carabin et al., 2006). *T. solium* cysticercosis is a tropical neglected disease that has been found to have high impact on agriculture and public health (Dahourou et al., 2018). Data from slaughter slabs on disease status has been qualified to be helpful in the estimation of the impact of parasitic diseases for better planning in development or improvement of control strategies (Ahmadi & Meshkehkar, 2011). In Western Kenya, the most important challenge faced by the pig production sector is the lack of appropriate pig slaughterhouses (Levy et al., 2014) Similar situations have been reported in Botswana (Motsho & Moreki, 2012) and Zimbabwe (Mutambara, 2013). The number on animal condemned (n) and the average weight of pigs (W) that were slaughtered at the slaughter slabs were the two parameters which influenced the direct monetary loss calculated. Different infection rates of PC prevalence ranging from 4.5 to 32.8 % observed in the region as reported in literature (Eshitera et al., 2012; Shonyela et al., 2018; Thomas et al., 2013) were considered to reflect the changes in the monetary losses. When the number of condemned animal (n) from the prevalence rate varied, the monetary loss also changed and increased. When the prevalence by meat inspection increased from 1.8 to 11%, the loss change/increased from Kes 31,527.0equivalent to 315.3 US$ to Kes 170,500.0 equivalent to US$ 1,705.0 and when the prevalence by Ag-ELISA test increased from 5.3 to 8%, the loss changed/increased from Kes 92,829.5 equivalent to US$ 928.3 to Kes 140,120.0 equivalent to US$1,401.2 (Appendix 3, 3.4).

This study estimated an annual loss of Kes 547,969.29 equal to US$ 5,478.7 with meat inspection and Kes 1,613,465.10 equal to US$ 16,134.70 (Table 14) with Ag-ELISA test due to porcine cysticercosis in Western Kenya. These losses were lower than the losses of US$ 144,449 reported by Nkwengulila (2014) and US$ 46,791.56 by Kiswaga et al. (2016) in Tanzania. This indicates that the control method of PC at the slaughter slabs need to be reinforced in Western

Kenya. It was also lower than US$ 43 million, US$ 27,750,000 and US$ 19,360,620 reported in Mexico, West and Central African countries and Nigeria, respectively (Flisser et al., 2003; Zoli et al., 2003).

This loss was also lower than US$ 531,516.84 and US$ 5Million reported in Cameroon, South Africa, respectively (Foyaca-Sibat et al., 2009; Praet et al., 2009). Other studies by Atawalna et al. (2015); Bhattarai et al. (2019) and Trevisan et al. (2018) reported in Mexico reported high economic loss of US$ 19,507,171, US$ 18,150.37 and around US$ 22,000 in Mexico, Ghanaand Mozambique, respectively as direct annual loss due to porcine cysticercosis. Assana et al. (2019) also reported a high direct financial loss of 165 million euros (US Dollar 195,376,500) in West and Central Africa. The disease prevalence, pig value and the total number of pigs slaughtered were factors contributing to the differences in losses in different Countries. This suggested a huge economic loss for the country and income reduction for pig smallholder farmers and butchery owners in Western Kenya. This was the first study to assess the loss in carcass value in Western Kenya region. Similar studies to assess the loss in carcass value and PC should be conducted in other regions of Kenya.

6.5 Conclusion and recommendation

This study estimated the annual loss in carcass value of Kes 547,969.29 (US$ 5,478.7) with meat inspection and Kes 1,613,465.10 (US$ 16,134.70) with Ag-ELISA test associated with porcine cysticercosis infection at the slaughter slabs in Western Kenya. It is therefore recommended that strengthening the pig value chain and developing strong PC control methods is needed. This is important at since the pig sector has the potential to increase incomes for farmers, butcher-owners and food security for consumers. From the study it is also recommended that an enforcement of the meat inspection practice be done.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 General Discussion

Three issues from literature review informed this study on the prevalence, management practices and direct monetary loss associated with porcine cysticercosis (PC) infections along pork value chain in Busia and Kakamega Counties of western Kenya. One is the prevalence of PC infections being persistently relatively high (5.4%), justifying monitoring of the trends as interventions are implemented. Two is empirical evidence pointing to pork consumption being a high risk for *Taenia solium* infection (Thomas et al., 2016) yet it is a practice in the two study Counties with pig population growing, pointing to likelihood of the risk of infection increasing in the population. Three is predominance of pigs being managed under scavenging poor sanitary environment such as dumping sites, but pork inspection is poor, infection surveillance is weak while producers, traders and consumer have wrong attitudes towards PC transmission and association with epilepsy in humans (Kagira et al., 2010; Mutua et al., 2010; Nantima et al., 2015a). Empirical evidence on these issues is relevant to sustaining livelihood that poor households derive from pig production.

Results from this study revealed that porcine cysticercosis was prevalent in pigs reared under free range system. Findings elsewhere (Kavishe et al., 2017; Rottbeck et al., 2013; Thomas et al., 2016) showed that the prevalence was attributed to subsistence pig production system in which pigs freely scavenged for food in poor sanitary conditions and open spaces such as unutilized government lands, dumps sites, and undeveloped private holdings which easily predisposed them to infections by *T. solium.* Findings in this study are in agreement with findings by Moyano (2014) who reported that inadequate meat inspection and poor pig management practices sustain the life cycle of *T. solium*, making it more endemic and prevalent in both humans and pigs. These results suggested the development of clear management practices for PC infection control with consideration of economic and public health implications of PC.

The mean PC prevalence based on Ag-ELISA test was 3.8% at farm level with 4.5 and 2.3% for Busia and Kakamega, respectively (appendix 3). This finding was low compared to that reported (9.9%) in the rural areas Eastern Minas Gerais of Brazil by Acevedo-Nieto et al. (2017). At slaughter slabs level, the prevalence based on Ag-ELISA test was 5.3% with 4.8 and 6.9% for Busia and Kakamega, respectively. These prevalences had been compared to others reported elsewhere in endemic countries and found to be low (Ganaba et al., 2011; Khaing et al., 2015; Pondja et al., 2010; Shonyela et al., 2018; Sithole et al., 2019). Furthermore, this seroprevalence using Ag-ELISA reported in Busia and Kakamega was attributed to lower infection rates in sampled pigs that was lower than the PC seroprevalence of 8.59% reported in Kathmandu Valley of Nepal (India) by Chaulagain et al. (2017), 9.9% in Brazil by Acevedo-Nieto et al. (2017) and 26% in Tanzania by Lipendele et al. (2015). Findings from this study however, contrast with findings by Secka et al. (2010) who reported PC prevalence with 6.4 and 8.9% for Gambia and Senegal respectively using Ag-ELISA. These results indicated that the incidence of porcine cysticercosis in an endemic area may be influenced or affected by the generalized appropriate use of toilets and latrines.

Results of the PC prevalence at meat inspection revealed a low public health risk of porcine cysticercosis in Western Kenya when compared to findings by Arriola et al. (2014) in Peru and Nguhiu et al. (2017) in Nairobi, Kenya, respectively. But there was a need of interventions after the disease had persisted for a long time and the system had never been improved. These results suggested that there were inadequate meat inspection procedures and wanting public health mechanisms.

The prevalence findings in this study suggested the presence of an endemic infection in Western Kenya where pigs were predominantly reared under free range system, aggravated by poor human faecal waste disposal. This indicated that pork consumers in Western Kenya were likely to be exposed to PC infection due to the fact that the disease had persisted for eight years. This persistence of prevalence of PC was in line with finding by Braee et al. (2014) in Tanzania who reported a fluctuation in prevalence in three consecutive years, 15% (2012), 24% (2013) and 20% (2014). A similar scenario of fluctuation had been reported by Pondja et al. (2015) in Mozambique where 5.6%, 33.3% and 66.7% were found for the first, second and third sampling rounds, respectively. A study in India and Romania reported 4.23% and 6.4% of prevalence in an area where porcine cysticercosis persisted to constrain the pork production improvement

(Chawhan et al., 2015; Oleleu et al., 2016). This suggests the need of support from the county government to smallholder farmers, to address the challenges hindering the development of the pig industry. Results from this study showed that Ag-ELISA was more sensitive than meat inspection in conformity with the study of Dermauw (2016) which showed that serological test provided better sensitivity than meat inspection. This therefore suggested that Ag-ELISA test should be used as a screening test followed by meat inspection to confirm the infection at slaughter. But this has been shown to be costly and require appropriate tool, access to the laboratory and expertise. It cannot be affordable to each one. In developing countries, diagnostic clinical laboratories are characterized by poor resources and are located with sometimes defective electrical supply and water supply. It has been reported that in rural areas of some countries, those laboratories lack skilled technical staffs (McNerney, 2015; Peeling et al., 2011).

In Kenya, like in Southeast Asia, pigs represent an important source of food and income for smallholder farmers (Barennes et al., 2008; Khaing et al., 2015), when in Europe, the pig supply chains constitute a key component of the food sector (Eurostat, 2018). Study by Motsa 'A et al. (2018) and Bienvenu et al. (2014) confirmed the positive impact of the pig production by smallholder rural farmers in Cameroun and in the Democratic Republic of Congo respectively. Results describe farmers and butcher's demographic characteristics, management practices frequently implemented at farm and the level of meat inspection implementation at slaughter slab levels in Western Kenya.

In the study area, gender balance was not emphasized whereby female headed households (53.1%) were more involved in pig farming compared to male headed household (46.9%). These results confirmed the idea that in Africa, by tradition women are allowed to own pigs and not cattle as reported by Tuyizere (2007). In Burkina Faso, a study by Ngowi et al. (2017) reported that, pig production remained particularly the main activity for women. This concurred also with the report from a study done in Uganda where 58% (Uganda Bureau of Statistics) [UBS], 2008-2010) of people involved in subsistence production were women meaning that African women supply food to their families and need to be empowered. This is also in agreement with the findings by Tatwangire, (2013) among small scale pig farmers Uganda. Other studies by Chuduwa et al. (2008) in Zimbabwe, Halimani et al. (2012) in South Africa, Nsoso et al. (2006) in Botswana and Petrus et al. (2011) in Namibia, also reported that in rural areas more females were rearing pigs. A study by Ngowi et al. (2009) in the rural areas of Tanzania showed that 61% of females reared pigs.

These results however, contradict the findings by Nantima et al. (2015) who reported that many pig keeping households in Uganda and Kenya were predominantly male headed (86.4%). The study also contradicts findings by Nwanta et al. (2011) and Kouam & Moussala (2018) who reported that 89% and 76.29% of pig farmers in Nigeria and Cameroun, respectively were male. This could be attributed to the cultural differences in the areas of study. Among the Embu County communities, the male gender are the ones who are involved in the husbandry of bigger livestock (pigs included) while women and youth in the smaller livestock (chicken and rabbits) (CARE International Kenya) [CARE], 2017). A study in West Papua by Iyai (2001) reported also that in smallholder pig keeping, gender played a prominent role with men playing the more prominent (>50%) than women, acting as farmer manager. Defang et al. (2014) reported that the lower participation of female farmers in raising pigs as compared to male could be as a result of drudgery, physically over-demanding work as well as capital-intensive nature of investment required by pig production, which discourages women. These results suggested the integration of the gender mainstreaming in the pig sector by the Government through pig farmers' sensitization to the adoption of the women empowering in Western Kenya.

The routine farm bio-security measures are an important constituent in minimizing and controlling spread of diseases. Several epidemiological studies confirmed that in many endemic countries where pigs are reared in the free-ranging system, the risk by the infection to porcine cysticercosis is always high (Emilio et al., 2017; Ganaba et al., 2011; Tatwangire, 2013). This has been confirmed in Cameroon where a hyperendemicity of the disease has been reported with high prevalence of 24.6% using Ag-ELISA (Assana et al., 2010). Our findings revealed that in Busia and Kakamega Counties, farmers had pit latrines (waste disposal pits) constructed near the pig’s pens but not effectively and appropriately used. These findings confirmed reports by Gweba et al. (2010); Yohana et al. (2013) and Maganira et al. (2018) who reported a human to-pig transmission of PC through household waste, water and sources of pig feeds. It confirms also findings by Prüss-Ustün et al. (2014) who reported that the effective use of pit latrines contributes to decrease of the *Taenia solium spp* spread in the endemic area. The findings from this study also showed that there is a problem in terms of ownership and utilization of latrine by households where farmers having latrines were many (87.6%), and only 72.8% of them were using them. This could be a contributing factor to the persistence of porcine cysticercosis in an endemic area like Western Kenya. This attitude was confirmed by Pay et al. (2016) who reported 72.2% of farmers also having pit latrines with 25% of them continue to use the open defecation. This differs from study by Assana et al. (2010) and Maridadi et al. (2011) who reported 42.7% and 50% of smallholder's farmers without pit latrines in Cameroon and Tanzania, respectively. These results suggested a minimal or lack of supervision or general lack of knowledge on proper means of disposing various types of human waste by farmers/community. Results from this study confirmed the findings by Kungu et al. 2015, Ng-Nguyen et al. 2018 and Yohana et al. (2013), who reported that the unhygienic conditions, pig free range practice and the poor pit latrines utilization promote the existence and persistence of porcine cysticercosis as they contribute to maintenance of the life cycle of *Taenia solium*. Therefore, this study demonstrated that meat inspection practice contributes to the safety of the pork when effectively practiced. This is in agreement with the findings by Mkupasi et al. (2017) who reported inadequate meat inspection as risk factor for PC transmission. These results suggested adoption of intensification in the pig farming for effective implementation of the biosecurity measures and effective practice of meat inspection with integration of all stakeholders in the pig value chain in Kenya.

The assessment of the awareness, attitudes and perceptions on safety practices among farmers, butchery owners and consumers about the risk factors for PC in Western Kenya were carried out. Related studies in Western Kenya (Mwendia et al., 2018) revealed that diseases and farmers' lack of technical knowledge on animal husbandry contributed to reduced animal productivity. This has been observed that the pig rearing still traditional and farmers were characterized by low knowledge related in issues associated to the pig rearing (farm management, hygiene and health) and the impact on the pig productions in Tanzania and Nepal, respectively (Braae et al., 2016; Niraula et al., 2015). Same observation has been reported by Singh et al. (2019) in India. Maridadi et al. (2011) reported that 75% of farmers being aware of porcine cysticercosis in Tanzania and recognize that *Taenia solium* infections is a public health problem in the community. Thirty-two (32.5%) were not aware of the lifecycle and this can facilitate the transmission of the parasite in the community. Study by Kungu et al. (2015) demonstrated that in many developing countries of Latin America, Africa and South East Asia the lack of knowledge on porcine cysticercosis as a big challenge in the elimination of the disease. Results in this study confirm poor knowledge and low awareness of the risk factors associated with the transmission of *Taenia solium* by majority of farmers in Western Kenya. These may have led to a high risk of exposure to taeniasis and cysticercosis resulting to reduced pork production in Western Kenya.

This study showed that the perception of pork in the market by butcherswho attributed the high risk to the home slaughters and slaughter slabs compared to that from butchery and eateries (Appendix 4). This is probably because butchers don't trust the meat inspection practice done and some time the irregularity of it at the slaughter slabs but ignore that pork from the eateries could expose humans to taeniasis even though butchers were reported to contribute to the protection of humans through diseases prevention and control (Gayatri et al., 2017). The results from this study showed that health education could significantly increase knowledge and awareness of the disease and could inspire behavioral change that would reduce disease transmission through proper cooking.

Regarding consumer perceptions of safety practice, this study shows that pork sold in the market was generally safe but still there was a problem on the cooking practices. Pork consumers strongly agreed that meat from eateries exposed humans to taeniasis and related ailments even though they lacked awareness on porcine cysticercosis. With the habit of selling cooked pork from the eateries (FAO, 2012), it was shown that the majority of pork consumed in the markets, was eaten undercooked as a preference (Dahourou et al., 2018). Results from this study confirmed other reports on the preferable pork cooking method in the region which can expose consumers to *Taenia solium* (Ngowi et al., 2017). Therefore, results from this study suggests the need for planning a training workshop focused on one health approach for pork consumers on the pork cooking and eating practices to minimize the risk to *T. solium* infection in the study area.

The projected annual monetary loss of Kes 547,969.29equivalent to US$ 5,479.7 and Kes 1,613,465.10 equivalent to US$ 16,134.70 due to porcine cysticercosis was estimated at the slaughter slabs point in Busia and Kakamega Counties, with meat inspection and Ag-ELISA test, respectively. These losses, influenced by the number of animals condemned (n) and the average weight of pigs (W) found to be lower than losses from many other epidemic countries (Bhattarai et al., 2019; Kiswaga et al., 2016; Nkwengulila, 2014). This could be attributed to the lower prevalence of PC estimated in Western Kenya and confirmed what was stated by Ahmadi and Meshkehkar (2011) on disease control strategies. This has shown that there is a gap in the pig value chain in the study areas which result in the persistence of porcine cysticercosis in the study areas. There is also a gap in the dissemination of research findings by the researchers. This will require the development of mechanism of dissemination or reinforcement of the existing one by which researchers should go through to share their findings to help farmers ‘improvement through training workshop. The extension services of the University should also work or reinforce the existing collaboration with different institutions/stakeholders to facilitate this dissemination. Policymakers should also reinforce the meat inspection practice with equipped meat inspectors and reporting system whereby each slaughter slabs should keep record daily. Collaboration between DVOs (Directorate of Veterinary Services), Livestock officers and farmers should be reinforced to promote pig husbandry through technical assistance to farmers in Western Kenya, develop and modernize the pig sector. This suggests that porcine cysticercosis be eradicated through robust control measures in the study area.

The following logical framework (Appendix 5) for porcine cysticercosis eradication in Western Kenya is suggested: Firstly, smallholders pig farmers should be in groups by villages/county and each farmer organization should have a lead that can represent them at the County level. Smallholders pig farmers will then be sensitized based on the high prevalence of cysticercosis in their area and the related negative impact to their own health and domestic economy. This will therefore help farmers to think, and opt for change of mindset to the transformation of the traditional practices to improved production system. This process will be initiated by trainings to improved production system and access to finance. The real change will start if pig farmers stop free range system, build pig houses and feed them with local feeds. Farmers will be able to keep and control biosecurity measures in their pig houses. The adoption of those activities by all pig farmers is the paramount milestone of a sustainable improved pig production system.

Secondly, the expected output of those activities is pig farmers improve their pig production system, from free range system to controlled production system, which will be verified by two main indicators as all farmers feed pigs only in pig houses and people have and use adequately pit latrines, reported by veterinary officers. Thirdly, if this improved production system becomes widespresad or adopted and sustainable, the reduction of meat condemnation at slaughter as an indicator of PC eradication from pig production in Western Kenya (Kakamega and Busia) will be observed by all operators of pork value chain and verified by researchers.

7.2 Conclusions

i. Prevalence of porcine cysticercosis was 3.8% at production and 5.3% at the slaughter slabs points using Ag-ELISA test while 1.8% by meat inspection at the slaughter slabs in Busia and Kakamega Counties.

ii. Management practices for control of porcine cysticercosis infections frequently used was free range scavenging system (69.1%), presence of latrine at household (87.6%) though with high use of pit latrines (72.8%) at production and weak meat inspection (69.2) at slaughter points in Busia and Kakamega Counties.

iii. Farmers expressed low awareness about PC control and prevention actions with majority not aware (82.7%) of the link between pig management system and PC, not aware (75.9%) of *T. solium* parasite and not aware (78.4%) of risk factors in the transmission of PC infection. The butcher associated pork from slaughter slabs (76.9%) and home slaughters (73.1%) with high risk while they associated pork from the butchery (69.2%) and from eateries (61.5) with no risks. Consumers were in strong agreement that pork in the market is safe (86%), pork from the slaughter slabs is safer than pork from the farms (92%) and that pork from butcheries is safer than pork from the eateries (82%) in Busia and Kakamega Counties.

iv. The annual loss in carcass value associated with porcine cysticercosis infections was Kes 547,969.29 (US$ 5,478.7) worth of carcasses from meat inspection and would be Kes 1,613,465.10 (US$ 16,134.70) if carcasses were condemned on results of Ag-ELISA testing surveillance for Busia and Kakamega Counties.

7.3 Recommendations

The following recommendations are made for PC infections inWestern Kenya:

i. Eradication of porcine cysticercosis at production and slaughter levels in Busia and Kakamega Counties, facilitated by the reinforcement of the collaboration between the veterinary officers, livestock officers and farmers

ii. Sensitise pig farmers, butchers and slaughter slabs workers on the implementation of effective biosecurity measures at farm and slaughter slabs levels. Establishment of the basic guidelines by the Government Officials will be required to enforce mandatory pig confinement and effective use of latrines.

iii. Create awareness on the risk factors for the transmission and strategies for the control of porcine cysticercosis. Adopt one health approach and strengthen public education about PC risks and pork safety in the pork value chain through heat treatment and freezing. Consumers to adopt for effective cooking of pork at the core temperature of 63-71^{o}C (140-149^{o}F) and freezing at 10^{o}C for 10 days to lower the risk of exposure to infection with *Taenia solium*.

iv. Strengthen the pig value chain and and enforce meat inspection at slaughter slabs for public health protection and increase income generation for farmers.

Recommendation for further studies

Further studies are recommended:

i. To identify different *Taenia* species in cysticercoids pigs in the region for public health purposes because the cause of disease development in human is more by *T. solium* proglottids compared to *T. saginata* proglottids. To use PCR as a very sensitive method of diagnosis compared to Ag-ELISA test to get more precision on the picture of the disease in Western Kenya.

ii. To determine the monetary loss caused by porcine cysticercosis in others Counties of Kenya

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APPENDICES

Appendix 1: Questionnaires for farmers, butchers, slaughter sabs workers and consumer's interviews

EGERTON UNIVERSITY

Faculty of Agriculture - Department of Animal Sciences

Research topic: Assessing prevalence, biosecurity measures and lost carcass-value associated with porcine cysticercosis along pork value chain in Western Kenya

Questionnaires for farmers, butchers, slaughter sabs workers and consumer's interviews

Consent seeking

Dear Sir/Madam, this survey is conducted by Marie-Françoise Mwabonimana, a PhD student of Egerton University-Njoro Campus, in the Department of Animal Sciences in partial fulfillment for a PhD in Livestock Production Systems. I am collecting blood samples on pig, data on management practices at farm and slaughter slabs points, awareness factors associated with *T. solium* cysticercosis transmission, Bucthers 's attitudes to risk related to pork meat in the market and consumer 's perceptions on safety practices. The interview will take approximately 20 minutes and your participation is keystone to the success of this study. We are kindly asking for your consent to be part of the study. Results from this survey will be usefull in the control of porcine cysticercosis through application of effective biosecurity measures, improvement of pork safety for consumers and increase income from pig production and trade with effective biosecurity measures in the pork value chain. The information provided will be used for academic purposes only and will be treated with ultimate confidentiality.

Farmer consent obtained / __ /1. Yes 2. No

Thank you

PART I. Objective 1

Prevalence of porcine cysticercosis in scavenging pigs in Western Kenya

SECTION A: Demographic characteristics of farmers

Date--- Questionnaires no--------------------------

Enumerators name----------------------------------- Tel no---------------------------------------

Name of the farmer/spouse/herdsman (i.e. the person interviewed): ----------------------------

County------------------------Village---------------------------- (1=Busia; 2= Kakamega)

Gender: [ ] [1= male; 2 = female]

Educational level [ ][1 = none; 2 = primary; 3 = secondary; 4 = College/University]

Age in years: [ ] [1 = 11-20; 2 = 21-30; 3 = 31-40; 4 = 41-50; 5 = 51-60; 6 = 61-70]

Occupation: [ ] [1= Farming; 2= Public employee; 3= Private employee]

Years kept pigs: [ ][1= *1-5*; 2= *6-10*; 3= *11-15*; 4= *16-20*; 5= *21-25*]

Herd characteristics: Female: F; Male: M

	Piglets	Weaners	growers	Breeding growers
Females				
Males				
Herd sum				

SECTION B: Blood sample collection B1/at the farm

	Pig 1	Pig 2	Pig 3	Pig 4	Pig 5
Serology test					

B2/at the slaughter slabs

	Pig 1	Pig 2	Pig 3	Pig 4	Pig 5
Serology test					
Meat inspection (1= Passed; 0 = Condemned)					

PART II. Objective 2

Questionnaire for research on the management practices in pig farms and meat inspection practice at slaughter slabs in Busia and Kakamega Counties, Western Kenya

Questionnaire for farmers, butchers and slaughter slabs workers

SECTION A: Pig farm

A.1. Farmers demographic characteristics

Date--- Questionnaires no--------------------------

Enumerators name----------------------------------- Tel no--------------------------------------

Name of the farmer/spouse/herdsman (i.e. the person interviewed): ----------------------------

County-----------------------Village---------------------------- (1=Busia; 2= Kakamega)

Gender: [ ] [1= male; 2 = female]

Educational level [ ][1 = none; 2 = primary; 3 = secondary; 4 = College/University]

Age in years: [ ] [1 = 11-20; 2 = 21-30; 3 = 31-40; 4 = 41-50; 5 = 51-60; 6 = 61-70]

Occupation: [ ] [1= Farming; 2= Public employee; 3= Private employee]

Years kept pigs: [ ][1= *1-5*; 2= *6-10*; 3= *11-15*; 4= *16-20*; 5= *21-25*]

A.2. Pig farming management practices implemented in Busia and Kakamega Counties

Sample dicrete choice: Please score the implemented measure for stopping the spread of porcine cysticercosis on and in the farm and slaughter slabs

No.	**Management practices**	**Type of Questions**	**Practice (1,0)**	
	Respondent: Farmers		**Frequently practiced (1) = Yes**	**Not Frequently practiced (0) = No**
1.	Free range pig keeping	Are your pigs kept outdoors?		
2.	Use of outdoor defecation	Are outdoor bushes used for defecation?		
3.	Presence of latrine at household	Does the household own a pit latrine?		
4.	Use of pit latrine by household	Does the household member use the pit latrine?		
5.	Sourcing water outside the farm	Whether farmers Sourcing water outside the farm or not?		
6.	Sourcing feed outside the farm	Whether farmers Sourcing feed outside the farm or not?		
7.	Routine de-worming	Are often your pigs dewormed?		
8	Routine vaccination	Whether farmer vaccinated pigs or not?		
9	Presence of a fenced farm	Whether farm had a fenced pig pen or not?		

SECTION B: Slaughter slabs

B.1. Butchers and slaughters worker 's demographic characteristics

Date--- Questionnaires no--------------------------

Enumerators name---------------------------------- Tel no--------------------------------------

Name of the butchers or slaughter slabs worker interviewed: ---------------------------- County------ ------------------Slaughter slabs----------------------------- (1=Busia; 2= Kakamega)

Gender: [ ] [1= male; 2 = female]

Educational level [ ][1 = none; 2 = primary; 3 = secondary; 4 = College/University]

Age in years: [ ] [1 = 11-20; 2 = 21-30; 3 = 31-40; 4 = 41-50; 5 = 51-60; 6 = 61-70]

Occupation: [ ] [1= Farming; 2= Public employee; 3= Private employee]

Only for Butchers Years of selling pork: [ ][1= *1-5*; 2= *6-10*; 3= *11-15*; 4= *16-20*; 5= *21-25*]

B.2. Meat inspection practice implementation at slaughter slabs within Busia and Kakamega Counties

Sample dicrete choice: **Please score the meat inspection as whether it was adequately implemented or not at the slaughter slabs in Busia/Kakamega Counties?**

No.	**Respondents**	**Meat inspection/Question**	**Practice (1,0)**	
			Frequently practiced (1) = Yes	**Not Frequently practiced (0)= No**
1.	Butchers	Whether meat was adequately inspected at the slaughter slabs in Busia/Kakamega or not?		
2.	Slaughter slabs Workers	Whether meat was adequately inspected at the slaughter slabs in Busia/Kakamega or not?		

Thank you for your participation.

PART III. Objective 3

Questionnaire for research on porcine cysticercosis risks: Awareness, attitudes and perceptions on safety practices by farmers, butchers and consumers in Western Kenya

Questionnaire for farmers, butchers and consumers

SECTION A: Pig farm/Butchers/Slaughter slabs Workers

A.1. Farmers demographic characteristics

Date--- Questionnaires no-------------------------

Enumerators name----------------------------------- Tel no--------------------------------------

Name of the farmer/spouse/herdsman (i.e. the person interviewed): ----------------------------

County------------------------Village---------------------------- (1=Busia; 2= Kakamega)

Gender: [ ] [1= male; 2 = female]

Educational level [ ][1 = none; 2 = primary; 3 = secondary; 4 = College/University]

Age in years: [ ] [1 = 11-20; 2 = 21-30; 3 = 31-40; 4 = 41-50; 5 = 51-60; 6 = 61-70]

Occupation: [ ] [1= Farming; 2= Public employee; 3= Private employee]

Years kept pigs: [ ][1= *1-5*; 2= *6-10*; 3= *11-15*; 4= *16-20*; 5= *21-25*]

Only for Butcher-owners

Years of selling pork: [ ][1= *1-5*; 2= *6-10*; 3= *11-15*; 4= *16-20*; 5= *21-25*]

SECTION B: Awareness, attitude and perceptions on safety practices by farmers, butchers and consumers

B/1. Farmer subjective awareness about risk factors in the transmission of porcine cysticercosis
Please rate your awareness on the following issues:

No.	Statement	Codes **(1,0)**	
		Aware (1)	**Not aware(0)**
1	Awareness of knowlegde about *taenia solium* cysticercosis		
2	Awareness of knowledge about the link between pigs management systems and PC		
3	Awareness of knowledge about risks for PC transmission (free ranging system of pigs, ignorance about life cycle of *T. solium* parasite, lack or absence of toilets, lack of pork inspection and home slaughter)		

B/2.Bucthers 'attitudes

Rank the following pork safety issues according to how concerned you are about them

Risk perception	**Pork sale point**			
	Pork from home slaughter (the farm)	Pork from the slauther slabs	Pork from the butchersy	Pork from the eateries
High risk (1)				
No (0)				

B/3.Consumer 's perceptions on safety practices of pork in the market

No.	**Perception**	**Agreement (1,0)**	
		Strongly agree (1)	**Strongly disagree (0)**
1.	Pork sold in Busia/Kakamega is in general safe		
2.	I always well cook the pork before eating		
3.	Undercooked pork is more likely to transmit cysticercosis to human		
4.	Pork from the slauther slab is safer than pork from the farm		
5.	Pork from the butchers is generally safe than pork from the eateries		
6.	Pork from the eateries expose human to taeniasis		

Thank you for your contribution.

PART IV. Objective 4

Loss in carcass value from porcine cysticercosis infection at the slaughter during the period of the study

<u>Questionnaire for slaughter slab owners and butchers</u>

Q1. How many pigs are they slaughtered daily?

Q2. What is the unit price of pork per Kg in the market, in Kes?

Q3. What is the average carcass yield?

Thank you for your contribution.

Appendix 2: Research clearance permit from the National Commission for Science Technology and Innovation

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 22944

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MS. MWABONIMANA MARIE FRANCOISE
of EGERTON UNIVERSITY, 0-0
Nakuru,has been permitted to conduct research in *Busia County*

on the topic: *ASSESSING PREVALENCE, BIOSECURITY MEASURES AND LOST CARCASS-VALUE ASSOCIATED WITH PORCINE CYSTICERCOSIS ALONG PORK VALUE CHAIN IN BUSIA AND KAKAMEGA COUNTIES, KENYA*

for the period ending:
1st February,2020

....
Applicant's Signature

Permit No : NACOSTI/P/19/80633/27786
Date Of Issue : 1st February,2019
Fee Recieved :Ksh 2000

....
Director General
National Commission for Science, Technology & Innovation

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. The License is valid for the proposed research, location and specified period.
2. The License and any rights thereunder are non-transferable.
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Appendix 3: Statistical analysis details

3.1 Objective 1: Determining prevalence of porcine cysticercosis at farm and slaughter levels Busia and Kakamega

3.1.1 SAS results

a. The PC prevalence based on Ag-ELISA at farm level in Busia and Kakamega Counties

a.1) The PC prevalence based on Ag-ELISA at farm level in Busia County The SAS System

The FREQ Procedure

ELISAFarmBu	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	9	4.50	9	4.50
0	191	95.50	200	100.00

Chi-Square Test for Equal Proportions

Chi-Square 165.6200
DF 1
Pr > ChiSq <.0001
Sample Size = 200

a.2) The PC prevalence based on Ag-ELISA at farm level in kakamega County
The SAS System

The FREQ Procedure

ELISAFarmKa	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	85	97.70	85	97.70
1	2	2.30	87	100.00

Chi-Square Test for Equal Proportions

Chi-Square 79.1839
DF 1
Pr > ChiSq <.0001
Sample Size = 87

a.3)The mean PC prevalence based on Ag-ELISA at farm level within Busia and kakamega Counties
The SAS System

The MEANS Procedure

Analysis Variable: ELISAFarmBuKa

N	Mean	Std Dev	Minimum	Maximum
287	0.0383275	0.1923211	0	1.0000000

The SAS System

The FREQ Procedure

ELISAFarmBuKa	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	11	3.83	11	3.83
0	276	96.17	287	100.00

Chi-Square Test for Equal Proportions

Chi-Square	244.6864
DF	1
Pr > ChiSq	<.0001

Sample Size = 287

b) The PC prevalence based on Ag-ELISA at slaughter slabs level in Busia and Kakamega

b.1) The PC prevalence based on Ag-ELISA at slaughter slabs level in Busia County

The SAS System

The FREQ Procedure

ELISASlgtBu	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	80	95.24	80	5.24
1		44.76	84	100.00

Chi-Square Test for Equal Proportions

Chi-Square	68.7619
DF	1
Pr > ChiSq	<.0001

Sample Size = 84

b.2) The PC prevalence based on Ag-ELISA at slaughter slabs level in Kakamega County

The SAS System

The FREQ Procedure

ELISASlgtKa	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	27	93.10	27	3.10
1	2	6.90	29	100.00

Chi-Square Test for Equal Proportions

Chi-Square	21.5517
DF	1
Pr > ChiSq	<.0001

Sample Size = 29

b.3) The mean PC prevalence based on Ag-ELISA at slaughter slabs level within Busia and Kakamega Counties

The SAS System

The MEANS Procedure

Analysis Variable: ELISASlgtBuKa

N	Mean	Std Dev	Minimum	Maximum
113	0.0530973	0.2252264	0	1.0000000

The SAS System

The FREQ Procedure

ELISASlgtBuKa	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1107	94.69	107	94.69	
0	6	5.31	113	100.00

Chi-Square Test for Equal Proportions

Chi-Square 90.2743
DF 1
Pr > ChiSq <.0001
Sample Size = 113

c) The PC prevalence based on meat inspection at slaughter slabs level in Busia and Kakamega Counties

c.1) The PC prevalence based on meat inspection in Busia County

The SAS System

The FREQ Procedure

MeatinspSlgtBu	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	82	97.62	82	97.62
0	2	2.38	84	100.00

Chi-Square Test for Equal Proportions

Chi-Square 76.1905
DF 1
Pr > ChiSq <.0001
Sample Size = 84

c.2) The PC prevalence based on meat inspection in Kakamega County The SAS System

The FREQ Procedure

MeatinspSlgtKa	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	29	100.00	29	100.00

Chi-Square Test for Equal Proportions

Chi-Square 0.0000
DF 0
Pr > ChiSq .
Sample Size = 29

c.3) The mean PC prevalence based on meat inspection at slaughter slabs level within Busia and Kakamega Counties

The SAS System

The MEANS Procedure

Analysis Variable: MeatinspSlgtBuKa

N	Mean	Std Dev	Minimum	Maximum
113	0.0176991	0.1324428	0	1.0000000

The SAS System

The FREQ Procedure

MeatinspSlgtBuKa	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	111	98.23	111	98.23
1	2	1.77	113	100.00

Chi-Square Test for Equal Proportions

Chi-Square 105.1416
DF 1
Pr > ChiSq <.0001
Sample Size = 113

3.1.2 Summary of prevalence by County/village and slaughter

a) Prevalence of meat inspection records by County/village and slaughter

County	Slaughter	Pigs sampled	Positive cases	Prevalence (%)
Busia	Musambaruwa	79	2	2.5
	Matayos	5	0	0
	Sub/Total	84	2	2.9
Kakamega	Malinya	9	0	0
	Khahega	13	0	0
	Shinyalu	7	0	0
	Sub/Total	29	0	0
	Total	**113**	**2**	**1.8**

b) Seroprevalence by County/ Village at farm level based on Ag-ELISA

County	Village	Pig sampled	Positive cases	Prevalence (%)
Busia	Mundika	51	5	9.8
	Bugengi	39	2	5.1
	Nang'oma	42	1	2.4
	Lwanya	58	1	1.7
	Murende	10	0	0
	Sub/Total	200	9	4.5
Kakamega	Idakho Central (3)	54	1	1.9
	Idakho North (1)	33	1	3
	Sub/Total	87	2	2.3
	Total	**287**	**11**	**3.8**

Idakho Central villages: Shikulu, Shivagala, Lunenele and Idakho North: Mukongolo

c) Seroprevalence by County/Village at slaughter slabs level

County	Slaughter	Pigs sampled	Positive cases	Prevalence (%)
Busia	Musambaruwa	79	4	5.1
	Matayos	5	0	0
	Sub/Total	84	4	4.8
Kakamega	Malinya	9	0	0
	Khahega	13	2	15.4
	Shinyalu	7	0	0
	Sub/Total	29	2	6.9
	Total	**113**	**6**	**5.3**

3.1.3 Sensitivity and specificity of the Ag-ELISA test

	Condition		
	Absent	Present	Totals
Test Positive	4	2	6
Test Negative	107	0	107
Totals	111	2	113

	Estimated Value	95% Confidence Interval	
		Lower Limit	Upper Limit
Prevalence	0.017699	0.003072	0.068789
Sensitivity	1	0.197868	1
Specificity	0.963964	0.904882	0.988394
For any particular test result, the probability that it will be:			
Positive	0.053097	0.021768	0.116724
Negative	0.946903	0.883276	0.978232
For any particular positive test result, the probability that it is:			
True Positive	0.333333	0.05999	0.758921
False Positive	0.666667	0.241079	0.94001
For any particular negative test result, the probability that it is:			
True Negative	1	0.956809	1
False Negative	0	0	0.043191
likelihood Ratios: [C] = conventional [W] = weighted by prevalence			
Positive [C]	27.75	10.602344	72.631342
Negative [C]	0	0	NaN
Positive [W]	0.5	0.141099	1.77181
Negative [W]	0	0	Na

3.2 Objective 2: Identifying management practices in pig's farms and meat inspection practice at slaughter slabs

a) Farmer's demographic characteristic by County

Variables	**Statement**	**Busia County (n =102)**	**Kakamega County (n = 60)**	**Overall (n = 162)**
Age *(years)*	11-20	29.4 % (30)	18.3 % (11)	25.3 % (41)
	21-30	40.2 % (41)	33.3 % (20)	37.7 % (61)
	31-40	25.5 % (26)	28.3 % (17)	25.5 % (43)
	41-50	4.9 % (5)	20.0 % (12)	10.5 % (17)
Gender	Male	50.0 % (51)	41.7% (25)	46.9 % (76)
	Female	50.0 % (51)	58.3 % (35)	53.1 % (86)
Education level	None	43.1 % (44)	38.3 % (23)	41.4 % (67)
	Primary	17.6 % (18)	38.3 % (23)	25.3 % (41)
	Secondary	33.3 % (34)	20.0 % (12)	28.4 % (46)
	College/University	5.9 % (6)	3.3 % (2)	4.9 % (8)
Farmer occupation	Farming	92.2 % (94)	98.3 % (59)	94.4 % (153)
	Public employee	2.9 % (3)	1.7 % (1)	2.5 % (4)
	Private employee	4.9 % (5)	0.0 % (0)	3.1 % (5)
Farmers' pig production experience *(years)*	1-10	86.3 % (88)	61.6 % (37)	77.2 % (125)
	11-20	10.8 % (11)	33.3 % (20)	19.1 % (31)
	21-30	3.0 % (3)	1.7 % (1)	2.5 % (4)
	31-40	0.0 % (0)	1.7 % (1)	0.6 % (1)
	41-50	0.0 % (0)	1.7 % (1)	0.6 % (1)

b) Pig farming management practices implemented in Busia County (n=102)

Managemnt practices	Practice (0,1)	
	Frequently(1)	Not frequently (0)
Free ranging pig rearing	77.5% (79)	22.5% (23)
Use of outdoor defecation by humans	27.5% (28)	72.5% (74)
Latrine ownership by household	86.3% (88)	13.7% (14)
Use of latrine in household	68.6% (70)	31.4% (32)
Source of water use	10.8% (11)	89.2% (91)
Source of feed	13.7% (14)	86.3% (88)
Routine de-worming	42.2% (43)	57.8% (59)
Routine vaccination	12.8% (13)	87.2% (89)
Fencing of the farm	20.6% (21)	79.4% (81)

N= number of farmers intervieuwed; had not frequently (0) implies the management practicesbiosecurity measure was not practiced by the household while had frequent (1) implied the management practices was frequently practiced.

c) Pig farming management practices implemented in Kakamega County (n=60)

Management practices	Practice (0,1)	
	Frequently (1)	Not frequently(0)
Free range pig keeping	55.0% (33)	45.0% (27)
Use of outdoor defecation by humans	43.3% (26)	56.7% (34)
Latrine ownership by household	90.0% (54)	10.0% (6)
Use of latrine by household	80.0% (48)	20.0% (12)
Source of water use	3.3% (2)	96.7% (58)
Source of feed	11.7 %(7)	88.3% (53)
Routine de-worming	8.3% (5)	91.7%(55)
Routine vaccination	60.0% (36)	40.0% (24)
Fencing of the farm	25.0% (15)	75.0% (45)

n= number of farmers intervieuwed; Not frequently (0) implies themanagement practices was not practiced by the household while Frequent (1) implied the management practiceswas frequently practiced.

d. Assessment of meat inspection implementation by respondents by County

Meat inspection	Level	Practice (0,1)	Busia	Kakamega	Overall %
	Butchers	Not frequently (0)	30.8 % (4)	15.4 % (2)	23.1% (6)
		Frequently (1)	69.2 % (9)	84.6% (11)	76.9 %(20)
	Workers	Not frequently (0)	41.7 % (6)	33.3% (4)	38.5% (10)
		Frequently (1)	58.3 % (8)	66.7 % (8)	61.5% (16)

n= number of farmers intervieuwed; Not (0) implies adequate meat inspection was not done by respective respondents while frequent (1) implies adequate meat inspection was frequently done.

e. SAS results

e.1) Biosecurity measures practiced at farm level in Busia and Kakamega Counties (n=162)

e.1.1) Biosecurity measures proportions

The SAS System

The FREQ Procedure

ELISA	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	11	6.79	11	6.79
0	151	93.21	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square 120.9877
DF 1
Pr > ChiSq <.0001
Sample Size = 162

frange	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	112	69.14	112	69.14
0	50	30.86	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square 23.7284
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Outdoor	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	108	66.67	108	66.67
1	54	33.33	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square 18.0000
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Hlatr	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	142	87.65	142	87.65
0	20	12.35	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square 91.8765
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Uselatr	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	118	72.84	118	72.84
0	44	27.16	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square 33.8025
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Water	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	149	91.98	149	91.98
1	13	8.02	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square 114.1728
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Feed	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	21	12.96	21	12.96
0	141	87.04	162	100.00

Chi-Square Test for Equal Proportions
Chi-Square 88.8889
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Dew	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	114	70.37	114	70.37
1	48	29.63	162	100.00

Chi-Square Test for Equal Proportions
Chi-Square 26.8889
DF 1
Pr > ChiSq <.0001
Sample Size = 162

Vacc	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	113	69.75	113	69.75
1	49	30.25	162	100.00

Chi-Square Test for Equal Proportions
Chi-Square 25.2840 DF
1
Pr > ChiSq <.0001
Sample Size = 162

Fence	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	126	77.78	126	77.78
1	36	22.22	162	100.00

Chi-Square Test for Equal Proportions
Chi-Square 50.0000
DF 1
Pr > ChiSq <.0001
Sample Size = 162

e.2) Meat Inspection implementation at Slaughter Slabs (n = 52)

e.2.1) Assessment of the attitude Butcher-owners on meat inspection practice in the two Counties (n = 26)

The SAS System

The MEANS Procedure

Analysis Variable: ButcherAttitude

N	Mean	Std Dev	Minimum	Maximum
26	0.7692308	0.4296689	0	1.0000000

The FREQ Procedure

ButcherAttitude	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	6	23.08	6	23.08
1	20	76.92	26	100.00

Chi-Square Test for Equal Proportions

Chi-Square	7.5385
DF	1
Pr > ChiSq	0.0060

Sample Size = 26

e.2.2) Assessment of the attitude slaughter slabs workers on meat inspection practice in the two Counties (n = 26)

The SAS System

The MEANS Procedure

Analysis Variable: WorkersAttitude

N	Mean	Std Dev	Minimum	Maximum
26	0.6153846	0.4961389	0	1.0000000

The FREQ Procedure

WorkersAttitude	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	16	61.54	16	61.54
0	10	38.46	26	100.00

Chi-Square Test for Equal Proportions

Chi-Square	1.3846
DF	1
Pr > ChiSq	0.2393

Sample Size = 26

3.3 Objective 3: Determining the level of awareness, attitudes and perceptions on safety practices among farmers, butchers and consumers in Western Kenya

1. SAS results

a) Determining farmer subjective awareness on factors associated with *T. solium* cysticercosis transmission

a.1) SAS results on awareness of farmers for Busia County The SAS System

The FREQ Procedure

Tsolium	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	86	84.31	86	84.31
1	16	15.69	102	100.00

Chi-Square Test for Equal Proportions

Chi-Square 48.0392
DF 1
Pr > ChiSq <.0001
Sample Size = 102

Mngt	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	92	90.20	92	90.20
1	10	9.80	102	100.00

Chi-Square Test for Equal Proportions

Chi-Square 65.9216
DF 1
Pr > ChiSq <.0001
Sample Size = 102

Risk	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	88	86.27	88	86.27
1	14	13.73	102	100.00

Chi-Square Test for Equal Proportions

Chi-Square 53.6863
DF 1
Pr > ChiSq <.0001
Sample Size = 102

a.2) SAS results on awareness for Kakamega County

The SAS System

The FREQ Procedure

Tsolium	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	37	61.67	37	61.67
1	23	38.33	60	100.00

Chi-Square Testfor Equal Proportions

Chi-Square 3.2667
DF 1
Pr > ChiSq 0.0707
Sample Size = 60

Mngt	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	42	70.00	42	70.00
1	18	30.00	60	100.00

Chi-Square Testfor Equal Proportions

Chi-Square 9.6000
DF 1
Pr > ChiSq 0.0019
Sample Size = 60

Risk	Frequency	Percent	Cumulative Frequency	Cumulatie Percent
0	39	65.00	39	65.00
1	21	35.00	60	100.00

The FREQ Procedure

Chi-Square Test for Equal Proportions

Chi-Square 5.4000
DF 1
Pr > ChiSq 0.0201
Sample Size = 60

a.3) Overall farmer's subjective awareness on factors associated with T. solium cysticercosis transmission within Busia and Kakamega Counties (n = 162)

The SAS System

The FREQ Procedure

Tsolium	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	123	75.93	123	75.93
1	39	24.07	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square	43.5556
DF	1
Pr > ChiSq	<.0001

Sample Size = 162

Mngt	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	134	82.72	134	82.72
1	28	17.28	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square	69.3580
DF	1
Pr > ChiSq	<.0001

Sample Size = 162

Risk	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	127	78.40	127	78.40
1	35	21.60	162	100.00

Chi-Square Test for Equal Proportions

Chi-Square	52.2469
DF	1
Pr > ChiSq	<.0001

Sample Size = 162

b) Determination of overall Butchers's attitudes to pork meat safety issues in the market within Busia and Kakamega (n = 26)

b.1Butchers's demographic characteristic

Variables	Statement	Busia County (N =13)	Kakamega County (N = 13)	Overall (N = 26)
Age *(years)*	11-20	38.4 % (5)	69.2 % (9)	53.9 % (14)
	21-30	30.8 % (4)	7.7 % (1)	19.2 % (5)
	31-40	30.8 % (4)	7.7 % (1)	19.2 % (5)
	41-50	0.0 % (0)	15.4 % (2)	7.7 % (2)
Gender	Male	84.6 % (11)	100.0 % (13)	92.3 % (24)
	Female	15.4 % (2)	0.0 % (0)	7.7 % (2)
Education level	None	0.0 % (0)	0.0 % (0)	0.0 % (0)
	Primary	53.9 % (7)	15.4 % (2)	34.6 % (9)
	Secondary	38.4 % (5)	76.9 % (10)	57.7 % (15)
	College/University	7.7 % (1)	7.7 % (1)	7.7 % (2)
Year of selling pig	1-5	30.8 % (4)	61.5 % (8)	46.2 % (12)
	6-10	61.5 % (8)	7.7 % (1)	34.6 % (9)
	11-15	7.7 % (1)	30.8 % (4)	19.2 % (5)
	16-20	0.0 % (0)	0.0 % (0)	0.0 % (0)

b.2 SAS outputs

The SAS System

The FREQ Procedure

Home	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	19	73.08	19	73.08
0	7	26.92	26	100.00

Chi-Square Test for Equal Proportions

Chi-Square 5.5385
DF 1
Pr > ChiSq 0.0186
Sample Size = 26

Slaughter	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	6	23.08	6	23.08
1	20	76.92	26	100.00

Chi-Square Test for Equal Proportions

Chi-Square 7.5385
DF 1
Pr > ChiSq 0.0060
Sample Size = 26

Butchery	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	8	30.77	8	30.77
0	18	69.23	26	100.00

Chi-Square Test for Equal Proportions

Chi-Square 3.8462
DF 1
Pr > ChiSq 0.0499
Sample Size = 26

Eateries	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	16	61.54	16	61.54
1	10	38.46	26	100.00

Chi-Square Test for Equal Proportions

Chi-Square 1.3846
DF 1
Pr > ChiSq 0.2393
Sample Size = 26

c) Determining practices of consumers about pork quality and safety within Busia and Kakamega (n = 92)

c.1Demographic characteristic of Consumers within Busia and Kakamega Counties

Variables	Statement	Busia (n = 52)	Kakamega (n = 40)	Overall (n = 92)
Age in year	11-20	25.0 % (13)	7.5 % (3)	17.4 % (16)
	21-30	21.2 % (11)	35.0 % (14)	27.2 % (25)
	31-40	46.2 % (24)	52.5 % (21)	48.9 % (45)
	41-50	7.7 % (4)	5.0 % (2)	6.5 (6)
Gender	Male	17.3 % (9)	15.0 % (6)	16.3 % (15)
	Female	82.7 % (43)	85.0 % (34)	83.7 (77)
Education level	None	65.4 % (34)	22.5 % (9)	46.7 % (43)
	Primary	34.6 % (18)	47.5 % (19)	40.2 % (37)
	Secondary	0.0 % (0)	30.0 % (12)	13.1 % (12)
	College/University	0.0 % (0)	0.0 % (0)	0.0 % (0)

n = Number of consumers interviewed

c.2 SAS outputs

The SAS System

The FREQ Procedure

Porksold	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	79	85.87	79	85.87
0	13	14.13	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 47.3478
DF 1
Pr > ChiSq <.0001
Sample Size = 92

Welcooked	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	54	58.70	54	58.70
0	38	41.30	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 2.7826
DF 1
Pr > ChiSq 0.0953
Sample Size = 92

Undercooked	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	40	43.48	40	43.48
1	52	56.52	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 1.5652
DF 1
Pr > ChiSq 0.2109
Sample Size = 92

Unfit	Frequency	Percent	Cumulative Frequency	Cumulative Percent	
1	85	92.39	85	92.39	0
7	7.61	92	100.00		

Chi-Square Test for Equal Proportions

Chi-Square 66.1304
DF 1
Pr > ChiSq <.0001
Sample Size = 92

Safer	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	75	81.52	75	81.52
0	17	18.48	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 36.5652
DF 1
Pr > ChiSq <.0001
Sample Size = 92

Cysticercosis	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	33	35.87	33	35.87
0	59	64.13	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 7.3478
DF 1
Pr > ChiSq 0.0067
Sample Size = 92

Porksold	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	79	85.87	79	85.87
0	13	14.13	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 47.3478
DF 1
Pr > ChiSq <.0001
Sample Size = 92

Welcooked	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	55	59.78	55	59.78
0	37	40.22	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 3.5217
DF 1
Pr > ChiSq 0.0606
Sample Size = 92

Undercooked	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	40	43.48	40	43.48
1	52	56.52	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 1.5652
DF 1
Pr > ChiSq 0.2109
Sample Size = 92

Unfit	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	85	92.39	85	92.39
0	7	7.61	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 66.1304
DF 1
Pr > ChiSq <.0001
Sample Size = 92

Safer	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	75	81.52	75	81.52
0	17	18.48	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 36.5652
DF 1
Pr > ChiSq <.0001
Sample Size = 92

Cysticercosis	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	33	35.87	33	35.87
0	59	64.13	92	100.00

Chi-Square Test for Equal Proportions

Chi-Square 7.3478
DF 1
Pr > ChiSq 0.0067
Sample Size = 92

3.4 Objective 4: Determination of the monetary loss in carcass value associated with porcine cysticercosis infestations at the slaughter Western Kenya

a) Monetary loss estimation due to meat inspection and Ag-ELISA due to porcine cysticercosis in Western Kenya

Total nb slaughtered	113		DEL=nW*Av.P/Kg			
% condemned/ meat inspection	1.8					
% condemned/ Ag/ELISA	5.3					
n1 meat inspection	2.034					
n2 Ag-ELISA	5.989					
W/pig	50			KES	Dolla	
Total W n1	101.7			1	0.01	
Total W n2	299.45			100	1	
Average price/Kg	310					
Average pig/day	5		**Annual/Pigs**		Weeks	Annual in dolla
Working days	21	Dollar	1,825	365 days	52	
Economic loss n1	**Kes 31,527.0**	**$ 315.3**	**Kes 547,969.3**	Kes 547,969.3	Kes 546,468.0	**$ 5,479.7**
Economic loss n2	**Kes 92,829.5**	**$ 928.3**	**Kes 1,613,465.1**			**$ 16,134.7**

b) Sensitivity analysis for estimated economic loss of PC by meat inspection and Ag-ELISA based on change in the number of condemned (n) pork in Western Kenya

	Meat inspection	Kes	Dolla	**Ag-ELISA**	Kes	Dolla
	1.80	Kes 31,527.0	$ 315.3	5.3	Kes 92,829.5	$ 928.3
	1	Kes 15,500.0	$ 155.0	1	Kes 17,515.0	$ 175.2
	2	Kes 31,000.0	$ 310.0	2	Kes 35,030.0	$ 350.3
	3	Kes 46,500.0	$ 465.0	3	Kes 52,545.0	$ 525.5
	4	Kes 62,000.0	$ 620.0	4	Kes 70,060.0	$ 700.6
	5	Kes 77,500.0	$ 775.0	5	Kes 87,575.0	$ 875.8
Variable n	6	Kes 93,000.0	$ 930.0	6	Kes 105,090.0	$ 1,050.9
	7	Kes 108,500.0	$ 1,085.0	7	Kes 122,605.0	$ 1,226.1
	8	Kes 124,000.0	$ 1,240.0	8	Kes 140,120.0	$ 1,401.2
	9	Kes 139,500.0	$ 1,395.0	9	Kes 157,635.0	$ 1,576.4
	9	Kes 139,500.0	$ 1,395.0	9	Kes 157,635.0	$ 1,576.4
	10	Kes 155,000.0	$ 1,550.0	10	Kes 175,150.0	$ 1,751.5
	11	Kes 170,500.0	$ 1,705.0	11	Kes 192,665.0	$ 1,926.7
	12	Kes 186,000.0	$ 1,860.0	12	Kes 210,180.0	$ 2,101.8

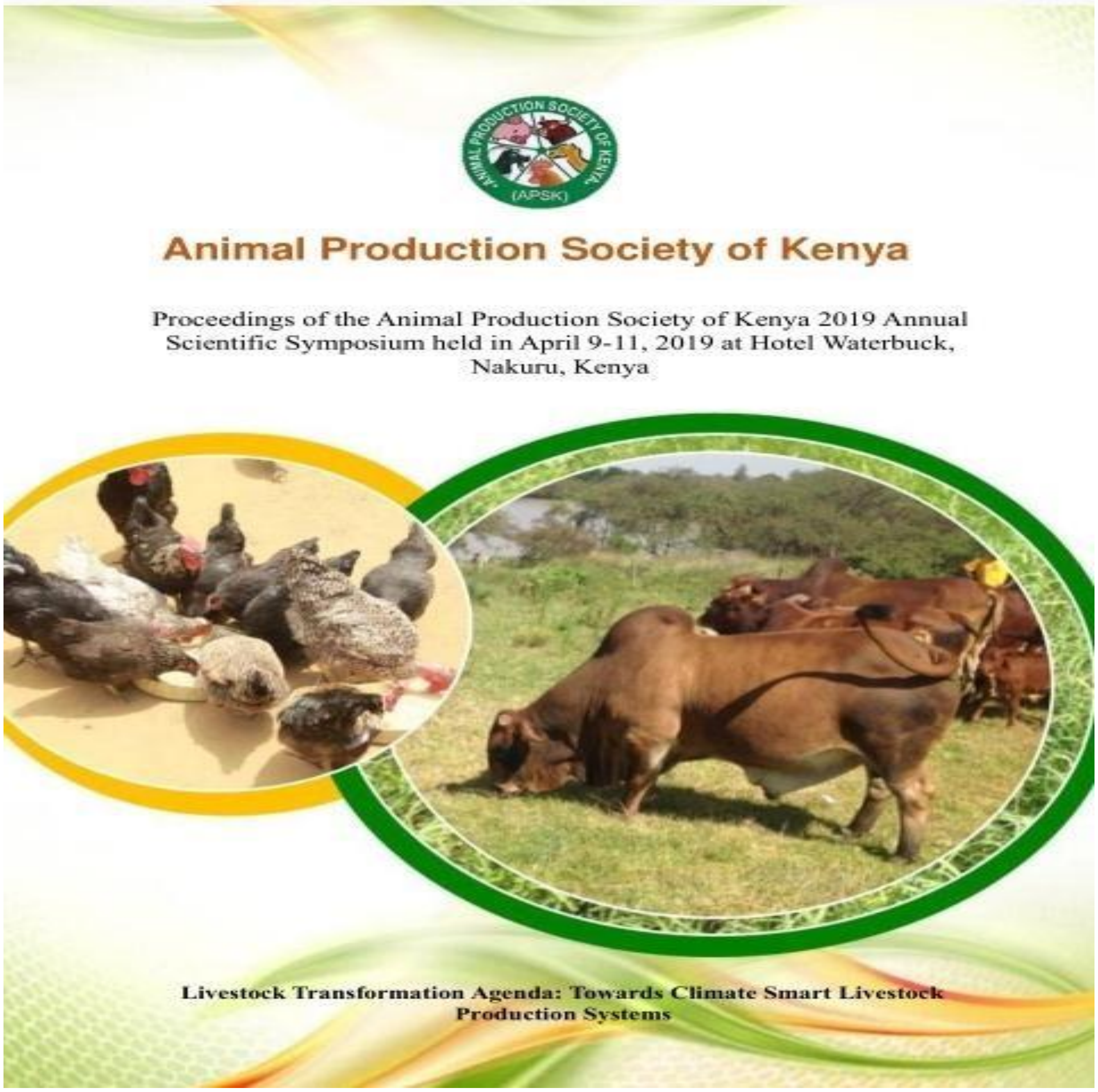
c) Sensitivity analysis for estimated economic loss of PC by meat inspection at slaughter slabs when both n and W vary in Western Kenya

					Variable weigth (W)			
	Kes 31,527.0	30	35	40	45	50	55	60
	1	Kes 9,300.0	Kes 10,850.0	Kes 12,400.0	Kes 13,950.0	Kes 15,500.0	Kes 17,050.0	Kes 18,600.0
	2	Kes 18,600.0	Kes 21,700.0	Kes 24,800.0	Kes 27,900.0	Kes 31,000.0	Kes 34,100.0	Kes 37,200.0
	3	Kes 27,900.0	Kes 32,550.0	Kes 37,200.0	Kes 41,850.0	Kes 46,500.0	Kes 51,150.0	Kes 55,800.0
	4	Kes 37,200.0	Kes 43,400.0	Kes 49,600.0	Kes 55,800.0	Kes 62,000.0	Kes 68,200.0	Kes 74,400.0
	5	Kes 46,500.0	Kes 54,250.0	Kes 62,000.0	Kes 69,750.0	Kes 77,500.0	Kes 85,250.0	Kes 93,000.0
Variable n	6	Kes 55,800.0	Kes 65,100.0	Kes 74,400.0	Kes 83,700.0	Kes 93,000.0	Kes 102,300.0	Kes 111,600.0
	7	Kes 65,100.0	Kes 75,950.0	Kes 86,800.0	Kes 97,650.0	Kes 108,500.0	Kes 119,350.0	Kes 130,200.0
	8	Kes 74,400.0	Kes 86,800.0	Kes 99,200.0	Kes 111,600.0	Kes 124,000.0	Kes 136,400.0	Kes 148,800.0
	9	Kes 83,700.0	Kes 97,650.0	Kes 111,600.0	Kes 125,550.0	Kes 139,500.0	Kes 153,450.0	Kes 167,400.0
	10	Kes 93,000.0	Kes 108,500.0	Kes 124,000.0	Kes 139,500.0	Kes 155,000.0	Kes 170,500.0	Kes 186,000.0
	11	Kes 102,300.0	Kes 119,350.0	Kes 136,400.0	Kes 153,450.0	Kes 170,500.0	Kes 187,550.0	Kes 204,600.0
	12	Kes 111,600.0	Kes 130,200.0	Kes 148,800.0	Kes 167,400.0	Kes 186,000.0	Kes 204,600.0	Kes 223,200.0
	13	Kes 120,900.0	Kes 141,050.0	Kes 161,200.0	Kes 181,350.0	Kes 201,500.0	Kes 221,650.0	Kes 241,800.0
	14	Kes 130,200.0	Kes 151,900.0	Kes 173,600.0	Kes 195,300.0	Kes 217,000.0	Kes 238,700.0	Kes 260,400.0
	15	Kes 139,500.0	Kes 162,750.0	Kes 186,000.0	Kes 209,250.0	KES 232,500.0	Kes 255,750.0	Kes 279,000.0
	16	Kes 148,800.0	Kes 173,600.0	Kes 198,400.0	Kes 223,200.0	KES 248,000.0	Kes 272,800.0	Kes 297,600.0
	17	Kes 158,100.0	Kes 184,450.0	Kes 210,800.0	Kes 237,150.0	KES 263,500.0	Kes 289,850.0	Kes 316,200.0
	18	Kes 167,400.0	Kes 195,300.0	Kes 223,200.0	Kes 251,100.0	Kes 279,000.0	Kes 306,900.0	Kes 334,800.0
	19	Kes 176,700.0	Kes 206,150.0	Kes 235,600.0	Kes 265,050.0	Kes 294,500.0	Kes 323,950.0	Kes 353,400.0
	20	Kes 186,000.0	Kes 217,000.0	Kes 248,000.0	Kes 279,000.0	Kes 310,000.0	Kes 341,000.0	Kes 372,000.0
	21	Kes 195,300.0	Kes 227,850.0	Kes 260,400.0	Kes 292,950.0	Kes 325,500.0	Kes 358,050.0	Kes 390,600.0
	22	Kes 204,600.0	Kes 238,700.0	Kes 272,800.0	Kes 306,900.0	Kes 341,000.0	Kes 375,100.0	Kes 409,200.0
	23	Kes 213,900.0	Kes 249,550.0	Kes 285,200.0	Kes 320,850.0	Kes 356,500.0	Kes 392,150.0	Kes 427,800.0
	24	Kes 223,200.0	Kes 260,400.0	Kes 297,600.0	Kes 334,800.0	Kes 372,000.0	Kes 409,200.0	Kes 446,400.0
	25	Kes 232,500.0	Kes 271,250.0	Kes 310,000.0	Kes 348,750.0	Kes 387,500.0	Kes 426,250.0	Kes 465,000.0
	26	Kes 241,800.0	Kes 282,100.0	Kes 322,400.0	Kes 362,700.0	Kes 403,000.0	Kes 443,300.0	Kes 483,600.0
	27	Kes 251,100.0	Kes 292,950.0	Kes 334,800.0	Kes 376,650.0	Kes 418,500.0	Kes 460,350.0	Kes 502,200.0
	28	Kes 260,400.0	Kes 303,800.0	Kes 347,200.0	Kes 390,600.0	Kes 434,000.0	Kes 477,400.0	Kes 520,800.0
	29	Kes 269,700.0	Kes 314,650.0	Kes 359,600.0	Kes 404,550.0	Kes 449,500.0	Kes 494,450.0	Kes 539,400.0
	30	Kes 279,000.0	Kes 325,500.0	Kes 372,000.0	Kes 418,500.0	Kes 465,000.0	Kes 511,500.0	Kes 558,000.0
	31	Kes 288,300.0	Kes 336,350.0	Kes 384,400.0	Kes 432,450.0	Kes 480,500.0	Kes 528,550.0	Kes 576,600.0
	32	Kes 297,600.0	Kes 347,200.0	Kes 396,800.0	Kes 446,400.0	Kes 496,000.0	Kes 545,600.0	Kes 595,200.0
	33	Kes 306,900.0	Kes 358,050.0	Kes 409,200.0	Kes 460,350.0	Kes 511,500.0	Kes 562,650.0	Kes 613,800.0
	34	Kes 316,200.0	Kes 368,900.0	Kes 421,600.0	Kes 474,300.0	Kes 527,000.0	Kes 579,700.0	Kes 632,400.0
	36	Kes 334,800.0	Kes 390,600.0	Kes 446,400.0	Kes 502,200.0	Kes 558,000.0	Kes 613,800.0	Kes 669,600.0
	36	Kes 334,800.0	Kes 390,600.0	Kes 446,400.0	Kes 502,200.0	Kes 558,000.0	Kes 613,800.0	Kes 669,600.0
	37	Kes 344,100.0	Kes 401,450.0	Kes 458,800.0	Kes 516,150.0	Kes 573,500.0	Kes 630,850.0	Kes 688,200.0

Appendix 4: List of conferences presentations and publications

I. Conferences presentations

1. Animal Production Society of Kenya



Mwabonimana, F., King'ori, A., Ingwaya, C., Shakala, E. and Bebe, B. (2019). Prevalence for Porcine Cysticercosis in Busia and Kakamega Counties, Western Kenya. Proceedings of the Animal Production Society of Kenya (APSK) 2019 Annual Scientific Symposium held in April 9-11, 2019 at Hotel Waterbuck, Nakuru, Kenya. Pp 114-120.

2. AGRO 2019 Conference and Exhibition

Mwabonimana, F., King'ori, A., Ingwaya, C. and Bebe, B. (2019). Biosecurity measures for porcine cysticercosis infections at farm and slaughter in Busia and Kakamega Counties, Western Kenya. Paper presented and certificate issued at the Agro 2019 Conference and Exhibition, University of Nairobi, College of Agriculture and Veterinary Sciences, Faculty of Agriculture, Kabete, Kenya.

II. Abstracts of publications

Paper one

Mwabonimana et al., Afr., J. Infect. Dis. (2020) 14 (2): 57-62
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PREVALENCE OF PORCINE CYSTICERCOSIS AMONG SCAVENGING PIGS IN WESTERN KENYA

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Abstract

Background: Porcine Cysticercosis (PC) infection is globally classified as a neglected and re-emerging tropical disease. The disease is endemic in Western Kenya yet smallholder farmers continue to practice scavenging pig production, thereby posing public health risk. This study determined the prevalence of PC infection at the farms and slaughter slabs in a cross-sectional survey in two Counties (Busia and Kakamega) of Western Kenya.
Materials and Methods: Two hundred and eighty-seven (287) heparinized blood samples were collected at the farm from 162 households in 9 villages and 113 pigs from 5 slaughter slabs. The prevalence of PC was detected through meat inspection at slaughter slabs, and the prevalence of *Taenia solium* antigen determined by using the ApDia Ag-ELISA test at the farms and slaughter slabs.
Results: At meat inspection, the PC prevalence was 1.8%, while prevalence of *Taenia Species* cysts detected with Ag-ELISA test was 3.8% at the farms, and 5.3 % at the slaughter slabs. The Ag-ELISA test had sensitivity of 100% (95% CI: 19.79– 100.00) and specificity of 96.4% (95% CI: 90.49– 98.84).
Conclusion: The PC prevalence levels observed among scavenging pigs in Western Kenya should be a cause of public health risk concern. This observation warrant enforcing mandatory pig confinement, and use of latrines at the farms and meat inspection at local slaughter slabs. Further studies are recommended to identify different *Taenia* species in cysticercoids pigs in the region, which this study could not differentiate.

Keywords: Pig, *Taenia spps*, meat inspection, ELISA test, Slaughter slabs, Smallholder farmers.

List of Abbreviations: Ag: Antigen, DVOs: Directorate of Veterinary Services, ELISA: Enzyme-linked immunosorbent assay, CESAAM: African Centre of Excellence in Sustainable Agriculture and Agribusiness Management, EITB: Enzyme-linked Immuno electro transfer Blot, ILRI: International Livestock Research Institute, KNBS:Kenya National Bureau of Statistics , NACOSTI: National Commission for Sciences, Technology and Innovation, PC: Porcine Cysticercosis, SAS: Statistical Analysis System, *spp.*: Species, *T. solium*: *Taenia solium*, VIL: Veterinary Investigation Laboratory, WHO: World Health Organization.

Introduction

Porcine Cysticercosis (PC) is a zoonotic, neglected food-borne disease of global public health concern and trade implications. The disease manifests itself as seizures and death in pigs and humans (Wardrop *et al*., 2016). Cysticercosis in pigs is transmitted by two species of tapeworms: *Taenia solium,* the zoonotic and *T. hydatigena,* the non-zoonotic with the latter being rare in Africa (Nguyen *et al*., 2016; Gomez-Puerta *et al*., 2019). The zoonotic tapeworm *T. solium* has a two host life cycles; the indirect cycle with humans as the definitive hosts, and in pigs as a normal intermediate host harboring the larval cysticerci (Donadeu *et al*., 2017). Cysticercosis in pigs results from ingesting *T. solium* eggs directly by fecal-oral route, or from environments contaminated with human harboring adult *T. solium* (Fleury *et al*., 2013). Human transmission of *T. solium* is typically through consumption of under-cooked pork or water containing fecal matter (indirect) (Kungu *et al*., 2017). The World Health Organization (WHO) classify PC as

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Paper Two

Hindawi
Veterinary Medicine International
Volume 2020, Article ID 7935656, 6 pages
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Research Article

Porcine Cysticercosis Control in Western Kenya: The Interlink of Management Practices in Pig Farms and Meat Inspection Practice at Slaughter Slabs

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This study assessed the management practices for controlling porcine cysticercosis (PC) on pig farms and in pork at the slaughter slabs in two counties (Busia and Kakamega) of Western Kenya. A total of 162 pig-rearing households at the farm level, 26 butcher owners, and 26 slaughter slab workers at the slaughter slab level were interviewed using a structured questionnaire. Data were analyzed using the "Statistical Analysis System" (SAS) programme. Results indicated that the frequent management practices used at the farm level ($p < 0.05$) were rearing pigs under free range (69.1%), latrine ownership by households (87.7%), and use of pit latrines (72.8%) in households. At the slaughter level ($p < 0.05$), results of the butcher owners (76.9%) and slaughter slab workers (62.5%) revealed that meat inspection was not practiced adequately in the two areas of study. The results imply that slaughtered pigs for human consumption were not adequately inspected, and thus, the study recommends for implementation of effective pig management practices at the farm level and pork meat inspection at slaughter slabs to prevent PC infections and assure food safety along the pork value chain.

1. Introduction

Porcine cysticercosis (PC) is an infection of pigs which is prevalent in many developing countries [1] with high effect on public health and agriculture [2, 3]. The disease is caused by *Taenia solium* which also causes cysticercosis in pigs, seizures and death in pigs [4, 5], and epilepsy in humans [6, 7]. The zoonotic tapeworm *T. solium* has a two-host life cycle: the indirect one in humans as the definitive host harboring the mature tapeworm in the small intestine, causing taeniasis and the second with pigs as a normal intermediate host harboring the larval *Cysticerci* which encyst in the muscles and brain and cause porcine cysticercosis [8]. Transmission of *T. solium* is related to socioeconomic, behavioural, and environmental factors [9, 10]. This was confirmed in a study in Western Kenya [11] which reported that inadequacy in meat inspection, sanitation, and cooking habits were contributing factors to cysticercosis transmission for *Taenia* spp. Contact with infected human faecal waste by pigs is a requisite for the successful propagation of the parasite's lifecycle [12].

In pig farming, external and internal biosecurity measures are critical tools in preventing the transmission of diseases, contributing to public health and improving livelihood of pig farmers [13]. Biosecurity encompasses bioexclusion, biocontainment, and biomanagement. The three practices are distinct but often blended with sets of actions and overlapping components. Most often, pig

Paper Three

Mwabonimana et al., Afr., J. Infect. Dis. (2020) 14 (2): 16-22
https://doi.org/10.21010/ajid.v14i2.3

PORCINE CYSTICERCOSIS RISKS: AWARENESS, ATTITUDES AND PERCEPTIONS ON SAFETY PRACTICES AMONG FARMERS, BUTCHER-OWNERS AND CONSUMERS IN WESTERN KENYA

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Abstract

Background: The demand for pork is increasing in Africa with the increasing need for animal protein in the household diets. But pork safety and quality remains a pervasive concern that needs intervention to assure consumers of protection from Porcine Cysticercosis (PC) contamination. This study assessed among farmers, butcher-owners and consumers in Western Kenya about their awareness, attitudes and perceptions about safety practices regarding risk of PC.
Materials and Methods: Data were obtained using structured questionnaires in cross-sectional survey interviews with 162 farmers, 26 butcher-owners and 92 consumers from Busia and Kakamega Counties. The data were in binary response, so were analyzed with Chi - square test.
Results: Only two in ten farmers had knowledge of *Taenia solium* parasite (24.1%), risk factors in PC transmission (21.6%) and could associate pig management system with PC (17.3%). A larger proportion ($p<0.01$) of the butcher owners perceived pork from slaughter slabs (76.9%) and home slaughters (73.1%) as presenting high risks but considered pork from the butcheries (69.1%) and eateries (61.5%) as presenting no risks. Among the consumers, majority strongly agreed ($p<0.05$) that pork in the market (85.9%), from slaughter slabs (92.4%) and butchery (81.5%) was safe but a larger proportion strongly disagreed that pork from the eateries exposed them to cysticercosis (64.1%).
Conclusion: The awareness about risks of PC was low among farmers. Butcher-owners and consumers perceived pork safety differently along the value chain. Strengthening public education about PC risks and pork safety among all actors in the pork value chain in Western Kenya is recommended.

Keywords: Pork; quality; safety; *T. solium;* porcine cysticercosis; value chain actors

List of Abbreviations: CESAAM: African Centre of Excellence in Sustainable Agriculture and Agribusiness Management, FAO: Food and Agriculture Organization, GALVmed: Global Alliance for Livestock Veterinary Medicines, OIE: World Organisation for Animal Health, PC: Porcine Cysticercosis, SAS: Statistical Analysis System, *T. solium*: *Taenia solium*, TDR: Special Program for Research and Training in Tropical Diseases, USDA: United States Department of Agriculture, Vs.: Versus, WHO: World Health Organization, χ^2 = Chi-square.

Introduction

The pork industry in Kenya is growing and is differentiated into specialized business units along the value, consisting of feed millers, producers, abattoirs, processors and retailers. The pork value chain is organized in a way

Appendix 5: Proposed Strategy for the Control of porcine cysticercosis in Western Kenya (Busia and Kakamega, Counties)