PREVALENCE OF ENDOPARASITES OF PUBLIC HEALTH IMPORTANCE IN PIGS SLAUGHTERED IN DAR ES SALAAM CITY, TANZANIA

BY

ERNATUS MARTIN MKUPASI

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ABSTRACT

This study was carried out to establish the prevalence of porcine cysticercosis (caused by *Taenia solium*), hydatidosis and ascariosis in slaughter pigs, and assess the state and distribution of pig slaughter slabs in Dar es Salaam city, Tanzania, between November 2007 and January 2008. All 24 official slaughter slabs located in the three municipalities of Dar es Salaam city (Kinondoni, Ilala, Temeke), were included in the study. A geographical positioning system (GPS) was used to map the location of the slaughter slabs and a checklist was used to assess the state of the slaughter slabs. All the 731 pigs slaughtered in the study area during the study were examined for cysticercosis, hydatidosis, and ascariosis based on national meat inspection guidelines. Data were analysed using SPSS 11.5 and the distribution of pig slaughter slabs was mapped using ArcView 3.2. The pigs slaughtered originated from nine different regions of Tanzania. Out of the 731 pigs examined, (5.9%), (0.4%), and (8.1%) were infected with cysticercosis, hydatidosis, and ascariosis, respectively. There was an important regional variation in the prevalence of porcine cysticercosis, with the highest prevalence in pigs that originating from Manyara and Dodoma regions. The pig slaughter slabs were clustered in certain areas of Dar es Salaam city and most were in poor conditions. The government of Tanzania should devise strategies to control the pig and pork trades, which should include establishment of an appropriate number of well managed pig slaughter houses to enable proper meat inspection in order to safeguard public health.

DECLARATION

I, **Ernatus Martin Mkupasi**, do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work, and has not been or concurrently being submitted for a degree award in any other university.

……..…….. ……

Ernatus Martin Mkupasi Date

(MVM candidate)

The above declaration is confirmed by:

……... ….. ……

Dr. H. A. Ngowi Date

(Supervisor)

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DEDICATION

This work is dedicated to my father the late Martin Vangamasasi Mkupasi and my mother Delphina Mhume who laid a strong foundation for my school life, and to my fiancé Huldar, brothers and sisters for love and moral support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
°C	Degrees celcius
µm	Micrometer
CDC	U.S. Centers for Disease Control and Prevention
CESA	Cyticercosis in Eastern and Southern Africa Project
cm	Centimetre
CT	Computerized Tomography
DNA	Deoxyribonucleic Acid
EITB	Enzyme Immunoelectrotransfer Blot
ELISA	Enzyme -Linked Immunosorbent Assay
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical Information System
GPS	Global Positioning System
IHT	Indirect haemagglutination test
Km	Kilometre
mg/kg	Milligram per kilogram
NC	Neurocysticercosis
PCR	Polymerase Chain Reaction
SPSS	Statistical Package for Social Sciences
WHO	World Health Organization of the United Nations
L2	Second larvae stage
L3	Third larvae stage
L4	Fourth larvae stage
m. a. s. l	Meters above sea level

CHAPTER ONE

1.0 INTRODUCTION

Consumption of pig meat, popularly known as pork, has increased dramatically in recent years in the Eastern and Southern Africa (ESA) region (Lekule and Kyvsgaard, 2003; Phiri *et al.*, 2003). The increased demand for pork in urban areas of Tanzania has resulted in increased production and transportation of pigs from rural, resource-poor, smallholder communities to large populated areas such as Dar es Salaam and Arusha towns (Boa *et al.*, 2001; Boa *et al.*, 2002; Phiri *et al.*, 2003; Ngowi *et al.*, 2004a; Boa *et al*., 2006).

Porcine helminthoses among other health problems represents one of the most important constraints to increasing pig production (Lekule and Kyvsgaard, 2003). Some of the pig parasites are known to cause important human diseases in affected areas, while others cause economically important diseases, threatening man's food supply and some may have both effects (Phiri *et al*., 2003). Several studies in different parts of Tanzania have indicated that porcine zoonotic endoparasites are present in some of the pig raising areas of the country (Nsengwa, 1995; Nsengwa and Mbise, 1995; Boa *et al*., 1995; Boa *et al*., 2001; Ngowi *et al*., 2004a). So there is a possibility of transportation of pigs infected with these zoonotic parasites to Dar es Salaam City and other urban centers, where pigs are slaughtered in large numbers (Boa *et al.*, 2001; Boa *et al.*, 2002; Phiri *et al.*, 2003; Ngowi *et al.*, 2004a; Boa, *et al*., 2006). Thus, pork reaching consumers, if not properly examined during meat inspection may cause serious public health problems. The most common porcine zoonotic endoparasites that have been reported in Tanzania include porcine cysticercosis caused by *Taenia solium*, hydatidosis caused by *Echinococcus granulosus*, and *Ascaris suum*.

Porcine cysticercosis is an infection caused by the larval stage of *T. solium*. In the life cycle of this parasite, humans are the definitive hosts harbouring the adult tapeworm in the small intestine, whereas pigs are the common intermediate hosts. However, humans can also harbour the cystic stage after inadvertently swallowing *T. solium* eggs (Soulsby, 1982; Flisser and Gyorkos, 2007). Massive infection in pigs is facilitated by their coprophagic habits (Sarti *et al*., 1992). In northern Tanzania, porcine cysticercosis has been reported in the northern highlands with prevalence ranging from 0.3 - 13.3% in slaughter pigs (Nsengwa and Mbise, 1995; Boa *et al*,. 1995) and 3.2 - 46.7% (average 17.4%) in smallholder pig-farming villages based on lingual examination (Ngowi *et al*., 2004a). In southern regions of the country, prevalence ranging from 5.5 - 16.9% has been reported based on lingual examination (Boa *et al*., 2001; Boa *et al*., 2006).

Echinococcus granulosus infection in intermediate hosts causes a condition called hydatidosis or cystic echinococcosis while infection in the definitive host is commonly referred to as echinococcosis. Hydatidosis and echinococcosis occur worldwide, but it is particularly important in developing countries where many rural inhabitants live under poor sanitary conditions and in close proximity with dogs (Anderson, 1997). The life cycle of the parasite involves the dog as the definitive host while ruminants and pigs are intermediate hosts. Human being is accidental intermediate hosts (Soulsby, 1982). In eastern Africa, hydatidosis is a public health problem among the nomadic pastoralists of Turkana, Kenya and northern Tanzania (Macpherson, 1985; Macpherson *et al*., 1989a; Macpherson *et al*., 1989b; Macpherson and Wachira, 1997).

The role of pigs in transmitting echinococcosis is increased in areas where pigs are raised in free range system. This system increases the possibility of pigs acquiring infection from

the contaminated environment and in turn the definitive host becoming infected with the tapeworms through eating the affected pig organs if not properly disposed of during pig slaughter. Few reports on the infection in pigs are available in Tanzania where prevalence of 4.3% was reported in slaughter pigs in the northern highlands (Ngowi *et al.*, 2004b). More investigations on the parasite infection in pigs in Tanzania needed to be done to establish the magnitude of the problem and potential control measures.

Ascariosis is a common infection of pigs caused by *Ascaris suum.* The life cycle of this nematode involves only a single host, the pig, which becomes infected when it ingests infective Ascaris eggs from contaminated environment. The pathological effects of adult worms in the small intestine are less dramatic compared to the larval migrations in the animal tissues such as the liver and lungs. However, massive infestation may lead to occlusion of the intestinal tract. A study carried out in the northern highlands of Tanzania showed that the infection is prevalent in pigs (Ngowi *et al*., 2004b). *Ascaris suum* was formally considered to be a parasite of pigs only but recent studies have reported the occurrence of cross-infection to human (Nejsum *et al*., 2005; Nejsum *et al*., 2006).

1:1 Problem Statement and Justification

In spite of the increased consumption of pork in developing countries there is still a general lack of slaughter facilities for pigs, thus, inspection and control of pork is poor or absent (Phiri *et al*., 2003). This poses a health risk to pork consumers. Dar es Salaam city receives a large number of pigs for slaughter from different regions of Tanzania.

1:2 Objectives

1:2:1 Overall Objective

The present study aimed at assessing the prevalence of endoparasites of public health importance in pigs slaughtered in Dar es Salaam City and opportunities for planning effective control strategies to safeguard consumers.

1:2:2 Specific Objectives

(a) To map the distribution of pig slaughter slabs and assess their statuses in Dar es Salaam city, Tanzania;

(b) To establish the prevalence of porcine cysticercosis, hydatidosis and ascariosis in pigs slaughtered in Dar es Salaam city, Tanzania;

(c) To establish the origin of pigs infected with porcine cysticercosis, hydatidosis and ascariosis in pigs slaughtered in Dar es Salaam city, Tanzania.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

Parasitic zoonoses are increasingly becoming important in the spectrum of emerging and re-emerging diseases in both developed and developing countries (Chomel, 2008). Tapeworm zoonoses form an important group of such pathogens and are recognized more and more as a public health problem in many parts of the world (Pathak, 1987). Zoonoses with reservoir of infection in domestic animals impose a particularly serious burden of ill health on the vast number of people who live in rural areas and earn their livelihoods through animal farming and other forms of agriculture (Pathak, 1987). In addition, they cause great economic losses for the meat industry due to massive condemnations of the affected animals. Some parasitic zoonoses such as neurocysticercosis, besides causing ill health in human and considerable economic losses, they lead to social segregation as well as unemployment or underemployment of the infected individuals because of the stigma attached to conditions such as epilepsy, which are manifested by the infected individuals (Zoli *et al*., 2003; Carabin *et al*., 2006).

From a public health point of view, three tapeworm species are responsible for the most important cestode zoonoses; these are *Taenia solium* which causes taeniosis/cysticercosis, *Echinococcus granulosus* which causes cystic echinococcosis/hydatidosis (CE) and *Echinococcus multilocularis* which causes alveolar echinococcosis/hydatidosis (AE). All three infections exhibit a chronic course in humans, typically due to a slow growing larval cystic stage deep in body organs or tissues (Pathak, 1987).

In Tanzania, several helminthic zoonoses have been reported in pigs and human. These include porcine cysticercosis (Nsengwa and Mbise, 1995; Boa *et al*., 1995; Ngowi *et al.*, 2004a, Boa *et al*., 2006), cystic echinococcosis (Macpherson *et al*., 1989a; Ngowi *et al.*, 2004b), trichinellosis (Bura and Willet, 1977), and *Ascaris suum* infections in pigs (Ngowi *et al.*, 2004b). Trichinellosis caused by the nematode *Trichinella spiralis* is highly pathogenic in human (Gracey, 1986). Nevertheless, the prevalence of *T. spiralis* has not been reported in domesticated pigs in East Africa (Ngowi *et al.*, 2004b).

2.2 Specific Disease Conditions

2.2.1 Porcine cysticercosis

2.2.1.1 Aetiology

Taenia solium belongs to the genus Taenia, family Taeniidae, class Eucestoda, and phylum Platyhelminthes (Soulsby, 1986). *T. solium* is a hermaphroditic tapeworm with no alimentary canal. Hence the food is absorbed through its body surface (Soulsby, 1986).

The adult worm is flat with a tape-like shape. A globular head (scolex) has a retractable short rostellum with a double row of 26-28 hooks. The head is connected to the strobila by a slender neck (Gracey, 1986; Macpherson and Craig, 1991). The strobila measures between two and eight metres in length with a total of 800 to 1 000 proglottids. Mature proglottids are 10-12 mm long by five to six mm wide. Each contains 30 000 to 50 000 eggs. The eggs are spherical and measure 26-34 µm in diameter (Soulsby, 1982). Gravid proglottids detach from the strobila in groups of five or six and are expelled with faeces.

The larval stage or metacestode of *T. solium* is commonly known as *Cysticercus cellulosae* (Soulsby, 1982; Gracey, 1986). The morphology of the cysticercus is that of a

vesicle measuring eight to twelve mm in diameter, but at times, in the brain, this morphology can vary to irregular forms (racemose form) (White, 2000). The cyst is delicate and translucent so that the invaginated scolex appears as a small white spot (Gracey, 1986).

Taenia solium should be differenticated from two closely related species – *T. saginata saginata* and *T. saginata asiatica*, because they can occur in the same area or animal species. Table 1 presents important features that can help distinguish between the three species. However, note that some characteristics overlap between the different species.

Table 1: Comparison between *T. solium*, *T. saginata saginata* and *T. saginata asiatica*

Characteristic	***T. solium***	***T. saginata***	***T. saginata asiatica***
Intermediate host	Pig, wild boar, human, camels	Cattle, reindeer	Pig, cattle, goat, some wild mammals
Metacestodes			
Site	Brain, skin, muscle	Muscle, viscera	Liver (exclusively)
Size (mm)	5.6-8.5 x 3.1-6.5	7-10 x 4-6	2 x 2
Scolex	Rostellum with hooks	No rostellum	Rostellum with rudimendary hooks(1-37)
Bladder surface	Wart-like formations	Rugae	Wart-like formations
Adult tapeworm			
Scolex			
Number of suckers	4	4	4
Rostellum	Present	Absent	Present
Number of hooks	22-32	Absent	Absent
Proglottids			
Length (mm)	1.5-8	4-12	c.3.5
Number of proglottids	700-1 000	c.2 000	260-1 016
Mature proglottids			
Number of testes	375-575	800-1 200	868-904
Ovary	Three lobes	Two lobes	Two lobes
Vaginal sphincter	Absent	Present	Present
Cirrus pouch extending to excretory vessels	Yes	No	No
Gravid proglottids			
Number of uterine branches	7-12	18-32	16-12
Branching pattern	Dendritic	Dichotomous	Dichotomous
Expulsion from host	Many in groups, passively	Single, spontaneously	Single, spontaneously

Source: Pawlowiski, (2002).

2.2.1.2 Epidemiology

Taeniosis/cysticercosis remains an important public health problem in several parts of the world where the reasons for its persistence have not been addressed effectively (Sikasunge *et al.*, 2007). It is particularly prevalent in most of Latin America, the Slavic countries, Africa, Southeast Asia, India and China (Schantz *et al*., 1992). In Africa, porcine cysticercosis has been reported in several countries including Cameroon, Zaire/D.R. Congo, South Africa, Nigeria, Kenya, Zambia, Zimbabwe, Rwanda, Burundi, Mozambique, Uganda, Kenya and Tanzania (Nsengwa and Mbisse, 1995; Phiri *et al*., 2003; Shey-Njila *et al*., 2003; Zoli *et al.*, 2003; Sikasunge *et al*., 2007).

Domesticated pigs are the most common intermediate hosts, but bush pigs, dogs, cats, rats and camels may also harbour the cystic stage (Soulsby, 1982). Of particular importance is the fact that humans can also be infected with the metacestode (Gracey, 1986). Man is the only natural definitive host but it has been reported that taeniosis may establish in the lar baboon (*Hylobates lar)*, the Chacma baboon (*Papio ursinus*) and the golden hamster (*Mesocricetus auratus*) Pawlowski (1982), cited by Pawlowski (2002) and Chinchilla (Maravilla *et al*., 1998).

Occurrence and prevalence of taeniosis/cysticercosis 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. Infection is common in areas where villages are not or are poorly supplied with sanitary facilities and where free range of pigs is practiced (Boa *et al*., 2001; Phiri *et al*., 2003; Ngowi *et al*., 2004a; Willingham and Engels, 2006; Flisser *et al*., 2006; Sikasunge, 2008). Many governments in the developing countries where pork is consumed have not taken necessary steps to improve

sanitary conditions and to reinforce regulations such as the need for confinement of pigs and strict meat inspection that would facilitate the control and eventually elimination of *T. solium* (Suroso *et al*., 2006).

In Tanzania, porcine cysticercosis was first reported in the late1980`s when pigs exported to Kenya from Mbulu district (northeastern Tanzania) were found severely infected with *T. solium* cysticercosis (Nsengwa, 1995). Studies were thereafter conducted in major pig slaughter slabs in northeastern Tanzania and in the local communities of Mbulu district (Nsengwa, 1995; Nsengwa and Mbise, 1995; Boa *et al*., 1995; Ngowi *et al.*, 2004a; Ngowi *et al*., 2004b), Chunya, Iringa Rural and Songea districts (southern Tanzania) (Boa *et al*., 2001; Boa *et al*., 2006). The prevalence of porcine cysticercosis was found to be widespread. Community based studies on porcine cysticercosis indicated an overall prevalence of 17.4% in Mbulu district (Ngowi *et al*., 2004a) and a prevalence range of 5.1-16.9% in the southern highland districts (Boa *et al*., 2001; Boa *et al*., 2006), based on lingual examination of live pigs.

Taenia solium is now increasingly recognized as a parasite with international public health implications and the capability of spreading to non-endemic areas and also to non pork-eating communities because of increased migration and tourism (Pawlowski *et al*., 2005). Neurocysticercosis has been reported in developed countries including The Netherlands, UK, Spain, Portugal, France, Germany, Italy, Yugoslavia, Bosnia, Czech Republic and Switzerland (Overbosch *et al*., 2002).

2.2.1.3 Life cycle

The life cycle of *T. solium* includes the human as the definitive host, carrying the adult tapeworm and the pig as an intermediate host carrying the larval stage (Soulsby, 1982).

The adult tapeworm is found in the small intestine of humans and occasionally in lar gibbons and Chacma baboon (Soulsby, 1982; Gracey, 1986). Humans become infected through ingesting mature viable cysticerci from raw or undercooked pork (Soulsby, 1982; Gracey, 1986; Flisser and Gyorkos, 2007). Following ingestion of the cysticerci, the protoscolex evaginates in the intestinal tract and attachs to the small intestinal mucosa by means of hooks and suckers. The proglottids develop from the neck and mature posterially. It takes approximately ninety days after ingestion of the cysticerci when gravid proglottids containing eggs start to appear in human stool (Gracey, 1986).

An intermediate host such as the pig acquires cysticercosis through ingestion of viable eggs of *T. solium* in human stool directly or through consumption of contaminated feed or water (Flisser and Gyorkos, 2007). In the gastrointestinal tract the egg hatches releasing the oncospheral stage which becomes active under the influence of gastric and intestinal juices and penetrates the intestinal mucosa to reach the general circulation. The embryos are disseminated throughout the body. The cysticerci predilection sites are skeletal muscles, cardiac muscles and nervous tissues, where they are fully developed approximately two months following ingestion of mature viable eggs (Soulby, 1982). Congenital transmission in piglets has been suspected (Phiri *et al*., 2003). The fully developed cysticercus measures up to 20 by 10 mm and are infective after about nine to ten weeks, and remain infective for about one year (Soulsby, 1982). The life cycle may be repeated when a human consumes raw or undercooked infected (measly) pork.

Humans may occasionally harbour the cystic stage upon ingestion of parasite eggs in contaminated food or from dirty hands. Cysticerci of *T. solium* in human develop primarily

in the subcutaneous tissue, the brain and the ocular tissue (Soulsby, 1986), but may also develop in striated muscles. Figure 1 summarises the lifecycle of *T. solium*.

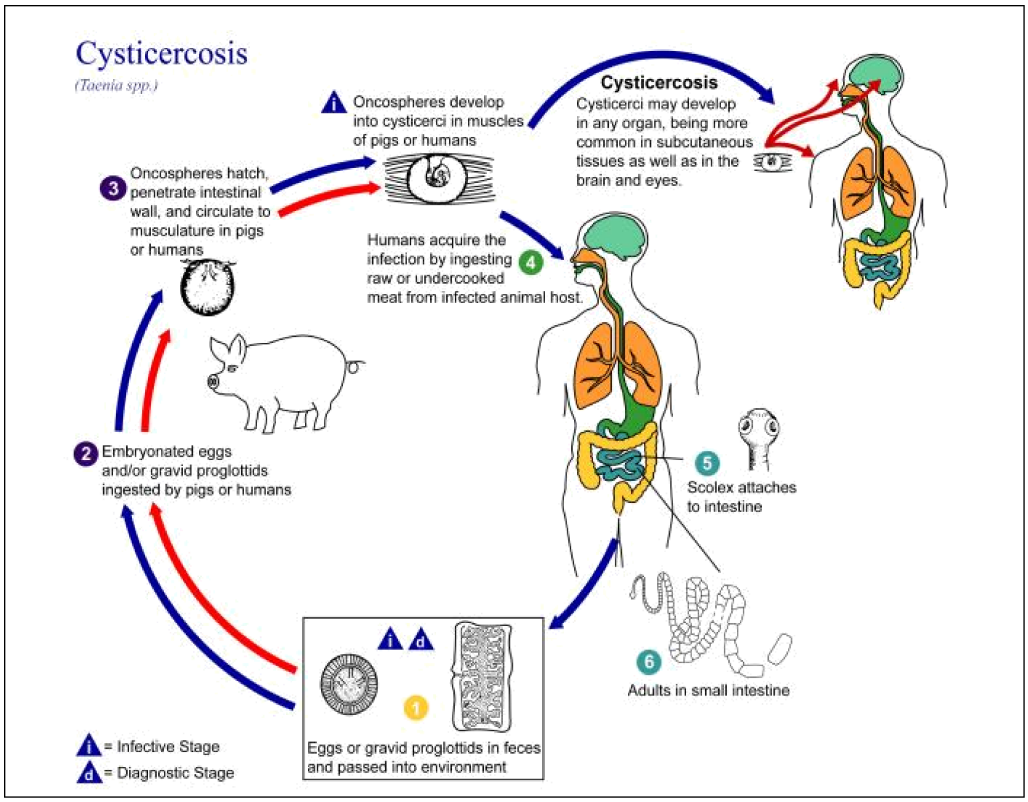

Figure 1: Life cycle of *Taenia solium*

Source: U.S. Centres for Disease Control and Prevention. [http://www.dpd.cdc.gov/dpdx]

2.2.1.4 Clinical signs

Porcine cysticercosis is usually without conspicuous signs but heavy infection may lead to transient diarrhoea, myositis and central nervous system involvement if cysts invade brain tissue (Gonzalez *et al*., 2003). A pig with numerous cysts (over 400) in the brain from Mbulu district was observed to be frequently circling (Boa *et al*., 2002), although it was difficult to establish the cause-effect relationship from the epidemiological point of view.

In humans, symptoms of taeniosis include anorexia, loss of weight, abdominal pain and digestive upsets (Gracey, 1986). On the other hand human cysticercosis symptoms depend on the location, number of the cysts and the stage of degeneration of the cysticerci in the host (Serpa *et al.*, 2006). Cysts in subcutaneous and muscle tissue may cause myositis while those in ocular tissues may lead to visual impairment. On the other hand brain cysts or those in other central nervous system sites may cause neurocysticercosis leading to various symptoms including serious headache, epilepsy, paralysis and even death (Gracey, 1986; White, 2000). Neurocysticercosis has been established as an important cause of acquired epilepsy worldwide (Senanayake and Roman, 1993; Garcia *et al*., 2005; Shandera and Kass, 2006; Flisser and Gyorkos, 2007). Degerating cysts are known to be more responsible for the symptoms than viable cysts (Garcia *et al*., 2005).

2.2.1.5 Diagnosis in pigs

Routine diagnosis of porcine cysticercosis is usually made at post-mortem meat inspection (Soulsby, 1982) and the confirmation is done through examination of hooks on the protoscolex.

Tongue examination method has been found to be of low sensitivity (less than 50%) and high specificity (100%) for field screening of porcine cysticercosis in live pigs, which has been found to be similar to postmortem inspection (Dorny *et al*., 2004). In endemic developing countries pre-slaughter selection is done by examination for cysts on the underside of the tongue (Boa *et al*., 1995; Sarti *et al*., 1992; Garcia-Noval *et al*., 1996). Infected pigs can also be screened by antemortem serological methods. The Enzyme-linked immunoelectrotransfer blot assay (EITB) using a purified glycoprotein antigen from cysticerci has been found to provide best results in the serodiagnosis of porcine

cysticercosis (Gonzalez *et al*., 1990). However, like antibody ELISA, false positive results may be obtained due to presence of maternal antibodies, recovery from previous infection, and exposure without infection. Antigen ELISA provides the best diagnostic tool for clinical diagnosis with sensitivity of 86.7% and specificity of 94.7% (Dorny *et al*., 2004).

2.2.1.6 Diagnosis in human

Microscopic examination of a patient stool sample to determine presence or absence of *Taenia* eggs is the method commonly used in the diagnosis of taeniosis in human in developing countries. This method however cannot differentiate the parasites beyond the genus level and it has low sensitivity.

Coproantigen assays based on capture-type ELISA have been demonstrated to be useful even in the absence of the adult parasite or its eggs. This method like microscopy cannot discriminate the parasite beyond the genus level. However, extensive field studies in Mexico, Guatemala, and China have shown that a coproantigen test detects up to 2.5 times more cases of taeniosis compared to microscopy (Schantz, 1996). Unfortunately, coproantigen assays have not been widely available for clinical use.

Clinical neurocysticercosis (NC) may be diagnosed based on epileptic convulsions or other neurological manifestations. However, differentiation from other neurological diseases is necessary (Pathak, 1987). In the diagnosis of neurocysticercosis in human, computerized tomography (CT) scanning has provided a major advance in the reliable diagnosis of neurocysticercosis. However the procedure has been found to be expensive and rarely available in rural areas where *T. solium* is endemic, and it is impractical to screen large numbers of people by the method (Tsang and Wilson, 1995). For example, in

Tanzania currently (2008) it costs approximately US $200 for one CT scan, which is too expensive for most citizens.

Alternatively, serodiagnosis allows the rapid screening of patients with neurological symptoms. The EITB has also been found to provide relatively better results in the serodiagnosis of human cysticercosis (Tsang and Wilson, 1995). At the Centers for Disease Control and prevention (CDC), the EITB with purified glycoprotein antigen was found to detect 98% of parasitologically proven cases with two or more cysts, and it was 100% specific (Tsang and Wilson, 1995). Remarkable advances have been made on the use of EITB for diagnosis of NC and *T. solium* tapeworms, permiting sensitive identification of tapeworm carriers which will help to identify the relationship between taeniosis and NC, prevalence of taeniosis in a given community and other parameters necessary to develop meaningful strategies for controlling or eliminating taeniosis/neurocysticercosis (Wilkins *et al*., 2002).

2.2.1.7 Prevention and control of *Taenia solium* infections

Human tapeworm carriers and the infected intermediate hosts, especially pigs, are important in terms of transmission of *T. solium* (Garcia *et al*., 2003). Strategies for control of the parasite aim at interruption of various points in the lifecycle.

Treatment of infected humans

Treatment of human carriers of the adult *T. solium* is based on the assumption that if egg dispersion is stopped, the disease transmission cycle will be broken, preventing the intermediate hosts from acquiring cysticercosis (Gemmell *et al*., 1983; Gonzalez *et al*., 2003). According to Garcia *et al.* (2003), the frequency of human taeniosis can be reduced

by either detection and treatment of tapeworm carrier or by the treatment of whole population with the introduction of anthelmintic drugs such as praziquantel or niclosamide, both of which are effective against human taeniosis. Mass chemotherapy has been tried in several endemic areas, especially in Latin America (Keilbach *et al*., 1989; Cruz *et al.*, 1989; Sarti *et al*., 1997; Sarti *et al*., 2000). Despite the presence of effective drugs for treatment of taeniosis, some previous interventions involving treatment of tapeworm carriers were not successful (Keilbach *et al*., 1989). It is thought that lack of community involvement leading to poor compliance for implementing the interventions might have contributed to the observed failures (Keilbach *et al*., 1989; Sarti *et al*., 1997; Sart and Rajshekhar, 2003). A reduction of 53% after six months and of 56% after 42 months for human taeniosis was achieved following mass treatment with praziquantel at a single dose of 5 mg/kg (Sarti *et al*. 2000). Targeting treatment of human carriers instead of mass treatment has been recommended in order to reduce the costs (Flisser *et al*., 2003).

Treatment of people with neurocysticercosis has no bearing on transmission as the cysticercotic people are normally dead-end-hosts. In patients with symptomatic neurocysticercosis, suppression of seizures or inflammation is instituted using corticosteroids. Surgical interventions may be performed depending on the number and location of cysts. Praziquantel and albendazole at doses of 50-100mg/kg/day for 15 days and 15mg/kg/day for seven days, respectively, are effective for treating intracerebral cysticerci in patients but there is a risk of developing intracranial hypertension which may result due to reaction to disintegrating cysts (Garcia *et al*., 2005).

Treatment of infected pigs

Several studies have been conducted to find drugs for the treatment of porcine cysticercosis in order to prevent human infection from pigs. Of the tried antihelmintics,

oxfendazole at a single dose of 30 mg/kg body weight has been reported to provide close to 100% effectiveness under controlled experiments (Gonzalez *et al*., 1998). It has also been reported recently that the treatment of infected pigs with oxfendazole induces protection against reinfection with *T. solium* for at least three months (Gonzalez *et al.*, 2001). These studies indicate that at least three months are needed after treatment for the the cysts to die and disappear. However, it is evident from the studies that brain cysts are not killed by the drug (Gonzalez *et al*., 1995; Gonzalez *et al*., 1997; Gonzalez *et al*., 2001). Unfortunately, oxfendazole for treatment of pigs is not yet available in Tanzania.

Vaccination of pigs

A porcine cysticercosis vaccine is indeed an attractive control measure possibility. Many trials have indicated promising progress (Sciutto *et al*., 1990; Huerta *et al*., 2001). In field trial carried by Huerta *et al*. (2001), the total number of *T. solium* cysticerci decreased by 98.7% and the prevalence of porcine cysticercosis was reduced by 52.6%. However, if a vaccine is available its cost should be quite low because the clientele for this vaccine would be rural poor communities. Also it should have long-term protection, and should be easy to administer in a mass intervention campaign. The problem with pig vaccination is that there is evidence that pigs become infected with *T. solium* early in life (Gonzalez *et al*., 2003). To protect them, immunization must be performed at an early age, an age at which the pig will not be able to mount an effective protective immune response to a vaccine due to the immaturity of their immune system (Gonzalez *et al*., 2003). Also immunisation of pigs after infection is not an effective means of combating porcine cysticercosis (Evans *et al*., 1997). Furthermore, if maternal antibodies in young pigs are present, they may inhibit an effective antibody response to *T. solium* vaccines for a

sizeable length of time depending on the duration of passive antibodies (Gonzalez *et al*., 1999; Gonzalez *et al*., 2003). To date the vaccine is not yet available for commercial use.

Health education

Health education creates an opportunity to obtain local co-operation and hence increase effectiveness and sustainability of an intervention strategy. It should focus on local perceptions, knowledge and practices related to the disease (Gonzalez *et al*, 2006). Continued educational intervention, supported by legislation and active enforcement, may succeed in reducing and perhaps ultimately eliminating transmission of the cestode (Boa, 2005). These measures were successfully used to control other animal cestodes such as *E. granulosus* and consequently proposed as a model for controlling *T. solium* cysticercosis (Gonzalez *et al*., 2006). Health education can be used alone or in combination with other strategies.

A health education intervention for *T. solium* in Tanzania increased knowledge on the parasite transmission and prevention by more than 40%, reduced consumption of infected pork by 20%, and decreased the incidence rate of porcine cysticercosis by about 43% (Ngowi *et al.,* 2008). Similar findings have been reported in Mexico, whereby the prevalences of cysticercosis in pigs at the start of the education intervention were 2.6% and 5.2% by lingual examination and antibody ELISA, respectively, and approximately one year after the intervention they were 0% and 1.2% (Sarti *et al*., 1997). It was concluded that health education, developed along with community involvement, reduced opportunities for transmission of *T. solium* in the human-pig cycle (Sarti *et al*., 1997; Ngowi *et al*, 2008). However, changes in behaviour related to parasite transmission have

been found to be less dramatic and persistent (Sarti *et al.*, 1997; Ngowi *et al.*, 2008). This calls for further studies.

Improved sanitation and pig production

Improvement in sanitary conditions and industrialisation of pig production has been recognized as effective control measures against cysticercosis (Vázquez-Flores *et al*., 2001; Garcia *et al*., 2006). Major obstacles to practical implementation of these control measures in developing countries include low socio-economic development in such a way that improvements in sanitation in poor zones are not to be expected in the near future (Garcia *et al*., 2006). High capital required in intensive pig production is another limiting factor to resource poor pig farmers (Lekule and Kyvsgaard, 2003). Control programs are needed to face this endemic disease in the short and medium term (Garcia *et al*., 2006). Because of multiple factors linked to the transmission of *T. solium*, combined interventions should be considered. For example, mass treatment in order to cure tapeworm carriers, health education towards understanding the risk factors, pig control through confinement, and environmental sanitation (Flisser et al., 2003; Suroso *et al*., 2006). However, without appropriate financial resources specifically allocated at the local and national levels as well as through international cooperation, control and prevention of this parasitic disease will not be possible (Chomel, 2008).

2.2.2 Cystic hydatidosis

2.2.2.1 Aetiologoy

Cestodes of the genus *Echinococcus* belong to the family Taeniidae, in the class Eucestoda, and the phylum Platyhelminthes (Soulsby, 1986). These are very small tapeworms with a strobila consisting of not more than seven proglottids and a metacestode

in which protoscoleces are enclosed in brood capsules (Rausch, 1994). The larval stage of the parasite is refered to as a hydatid cyst. At present, four species of the genus *Echinococcus* are accepted and regarded as valid taxonomically. These are *E. granulosus* which causes “cystic hydatidosis”, *E. multilocularis* which causes “multivesicular or alveolar hydatidosis”, *E. oligarthrus* and *E. vogeli* causing “polycystic hydatidosis” (WHO, 1979; Smyth, 1994). These four species are morphologically distinct in both adult and larval stages (Soulsby, 1982; WHO, 1981; Kenneth and Schantz, 1986).

The adult *E. granulosus* measures about 2-7 mm long and it is composed of a head with 30-36 hooklets arranged in two rows on the rostellum. It is composed of three or four proglottids (rarely up to six). The last proglottid is about equal in length to the rest of the worm. The eggs are typical taeniid eggs and measure 32-36 by 25-30 µm. (Soulsby, 1986; Gracey, 1986).

The larval stage (hydatid cyst) consists of one bladder or many completely isolated bladders, each enclosed in its own well developed pouch. The pouch has several layers, the most prominent being the laminated layer which is rich in polysacharides. The inner side of the laminated layer is the germinal membrane from which brood capsules arise. Inside the brood capsules are thousands of protoscoleces, the whole being suspended in a hydatid fluid (Smyth, 1994). Generally, the cyst generally reaches a size of about 5 to 10 cm in diameter but in humans much larger sizes may develop. The cyst of 50 cm in diameter containing 50 litres of fluid has been recorded (Pathak, 1987).

2.2.2.2 Epidemiology

Echinococcus granulosus has a worldwide distribution and is for the most part maintained in a domestic transmission cycle involving the dog as the final host and ruminants as intermediate hosts (Macpherson, 1986). The sylvatic cycle involves wild canivores and wild herbivores. Sheep and goats are the most common intermediate hosts for *E. granulosus* although other livestock including pigs may also be infected (Soulsby, 1982). Humans are accidental and usually dead-end hosts except in northern Kenya where, the high incidence and fertility of hydatid cysts in the Turkana community, together with the lack of burial customs allows dogs to have access to infected human corpses, thus involving humans in the transmission cycle of *E. granulosus* in this region (Macpherson, 1983). Certain other socio-economic and cultural factors have been found to be responsible for the high transmission rates of hydatidosis in endemic areas (WHO, 1979).

Distribution of hydatidosis in human is influenced by several factors but it usually relates most directly with the degree of association individuals have with their domestic dogs. It has been found that in many parts of the world, especially the rural areas where people live in close proximity with their dogs and the presence of customs relating to the handling of dog faeces, have a high chance of acquiring hydatidosis (Nelson, 1986). Such people do not have adequate supplies of clean water and do not understand basic principles of personal hygiene (Watson-Jones and Macpherson, 1988). For example, unusual conditions prevail in the Turkana tribe of Kenya where the highest prevalence of human hydatidosis is reported to occur. This tribe traditionally has a very close association with dogs. Most households keep dogs that they utilize to lick and clean their babies after defecation as water is very scarce in the area (Nelson, 1986).

2.2.2.3 Life cycle

The adult tapeworm is found in the small intestine of carnivores particularly dogs, wolves, coyotes, cats and dingoes (Pathak, 1987). Carnivores get infected by ingestion of a hydatid cyst, the protoscoleces attach to the host's intestinal wall and in about 40-45 days the parasites mature to adult worms and start producing eggs which pass out with the host's faeces (Gracey, 1986).

The intermediate hosts are infected through ingestion of infective ova from the faeces of the final host. The embryo is released by dissolution of the egg shell, the released oncosphere then penetrates the intestinal wall and enters blood vessels to reach the liver or lungs and sometimes other organs where it develops into the larval form (Pathak, 1987). Protoscoleces mature in about 47 days following ingestion of infective ova. Brood capsules may become detached and float free in the cystic fluid, referred to as "hydatid sand". Occasionally, daughter cysts develop within the hydatid cyst. If the cyst is ruptured, brood capsule with protoscoleces may develop into other external daughter cysts. The life cycle is completed when a dog or another definitive host ingests viable protoscoleces. Dogs may remain infective for about two years (Pathak, 1987). Fig. 2: describes the lifecycle of *E. granulosus*.

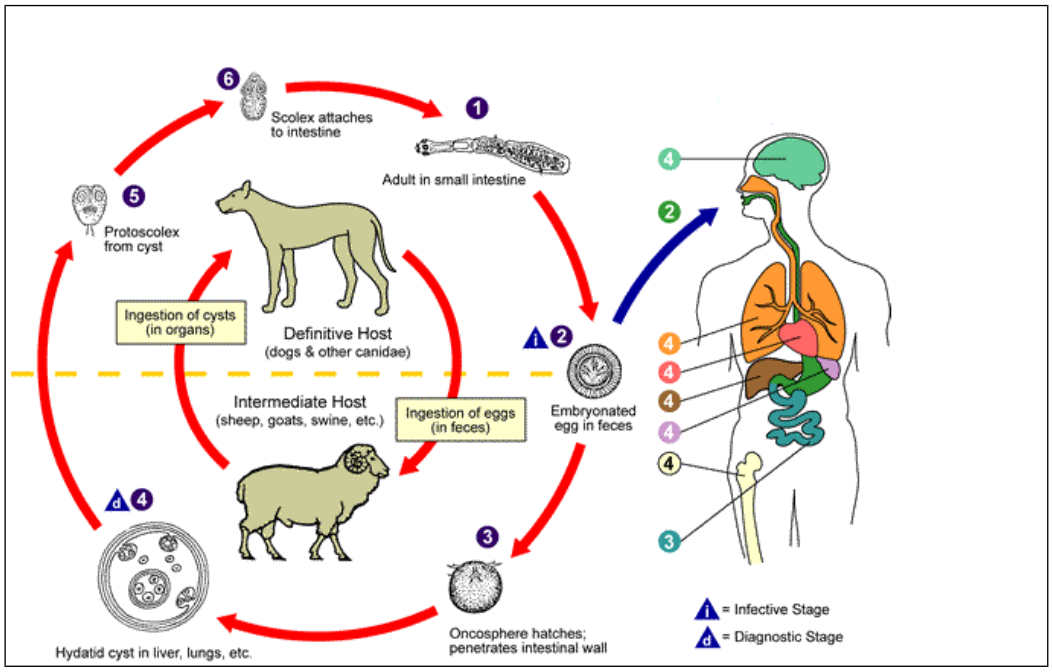

Figure 2: Life cycle of *Echinococcus granulosus*

Source: U.S. Centres for Disease Control and Prevention. [http://www.dpd.cdc.gov/dpdx]

2.2.2.4 Clinical signs

Clinical signs in the intermediate hosts

Under natural infection there is no obvious clinical signs detected in animal hydatidosis. Human hydatidosis remains silent for years before the slowly enlarging cysts cause symptoms in the infected individual. The hydatid cyst causes enlargement of some of the affected organ and clinical signs depending on the severity and organ affected, for example a distended and tender abdomen in the case of liver infection (Gracey, 1986). Hepatic involvement can result in abdominal pain and biliary duct obstruction. Pulmonary involvement can produce chest pain, cough, and haemoptysis. Rupture of the cysts can produce fever and anaphylactic shock. Apart from anaphylactic reaction, most serious sequelae may arise when cysts rupture into the abdominal or pleural cavity. In extreme cases, hundreds of cysts may develop and expand the abdomen to enormous proportions, referered to as disseminated hydatidosis (Pathak, 1987). In addition to the liver and lungs,

other organs (brain, bone, heart) can also be involved, with resulting symptoms (Soulsby, 1982). Ruptured cysts may also develop as emboli in arteries or lungs and sometimes in the brain or orbital capillary or on a heart valve resulting in fatal obstructions (Pathak, 1987).

2.2.2.5 Diagnosis

Detection of *Echinococcus* eggs involves direct identification of taeniid eggs in faecal smears from perianal swabs or in concentrated canine stool samples. This method of diagnosis, however, is less accurate because all taeniid eggs are morphologically identical (FAO, 1982). Diagnosis of *E. granulosus* infection in domestic dogs is most reliably undertaken at necropsy by careful examination of the small intestine for the presence of the minute tapeworms (Soulsby, 1982; Urquhart *et al*., 1988; Andersen *et al*., 1997). This involves collection of materials from the small intestine or the whole small intestine for total worm count. Examination of the intestinal surface (or washings) under a dissecting microscope is preferable to accomplish this. Arecoline purgation is the oldest method used to determine the prevalence of echinococcosis in domestic dogs by the use of parasympatheticomimetic action of the drug arecoline hydrobromide at the dosage rate of 2 mg/kg body weight. The material purged is collected and examined carefully under dissecting microscope for the presence of *Echinococcus* parasites (Andersen *et al*., 1997). Antibody detection is another possible diagnostic method. Smyth (1964) highlighted the intimate contact between the scolex of the adult *Echinococcus* tapeworm and the mucosal surface of the dog's small intestine leading to stimulation of immune response. Presence of *Echinococcus* specific serum antibodies in canine echinococcosis has been demonstrated by using enzyme-linked immunosobernt assay (ELISA) in an experimental study with helminth-free reared dogs (Jenkins and Rickards, 1985). Crude antigens prepared from

excretory-secretary or somatic extracts of *E. granulosus* protoscolices were able to detect serum antibody by the second week post-infection and readily thereafter (Jenkins and Rickard, 1985). However, this method is still not very reliable because of its instability when used for dogs with natural echinococcosis infection (Andersen *et al*., 1997).

Coproantigen detection is a diagnostic test for canine echinococcosis which is more sensitive in reflecting current infection and therefore has potential for replacing other methods as a method for antemortem diagnosis of canine echinococcosis (Andersen *et al.*, 1997). This method involves the detection of the specific parasite antigens present in faeces. Detection of specific antigen(s) (coproantigens) in faecal samples has the advantage of high probability of correlation with current infection, as tapeworm-derived antigens should not be present in the absence of infection (Allan and Craig, 1989).

The source of parasitic antigens in faeces could be scolex and proglottids, excretory-secretory products, tegumental turnover and/or degradation products from detached proglottids and possibly from egg-derived antigens, though the latter appears not to be the case (Allan *et al.*, 1992; Allan and Craig, 1994). To be detected in the faeces, antigens need to survive the proteolytic stool environment (Andersen *et al*., 1997). The techniques for antigen detection usually rely on the use of the specific polyclonal or monoclonal antibody in a sensitive solid phase assay like ELISA, where a known catching antibody is used. This test therefore, is reliable and can be employed as a test of choice in the diagnosis of canine echinococcosis.

DNA detection techniques can be employed in the diagnosis of canine echinococcosis. DNA diagnosis is either based on hybridization profiles of parasite DNA following restriction enzyme digestion and electrophoresis (Southern Blotting) or polymerase chain

reaction (PCR) technology. Differential diagnosis of *E. granulosus* and *E. multilocularis* infection in definitive hosts could be achieved by specific DNA hybridization of PCR-amplified worm products in faeces. PCR is now becoming the method of choice in diagnostic parasitology as it provides rapid amplification of target DNA, however, the disadvantages include the cost, requirement of trained personnel and the need for a specialized facility to conduct the assay. Moreover, DNA based techniques do not usually distinguish between dead and live parasites (Andersen *et al*., 1997).

For the diagnosis of hydatidosis in an animal intermediate host, a postmortem examination and identification of a mature hydatid cyst is the only available method that can be relied on (Andersen *et al*., 1997). However, small lesions especially in the liver require histological confirmation to differentiate them from *Taenia hydatigena* metacestode and other migratory parasite helminths such as *A. suum* infection in pig liver (Slais and Vanek, 1980; Trees *et al*., 1985). Microscopically, fluid aspirated from hydatid cyst may show multiple protoscolices (hydatid sand), each of which has typical hooklets (Bowman, 1999). There are as yet no satisfactory serological tests available for the diagnosis of echinococcosis in herbivore intermediate host species (Lightowlers, 1990), although they have been used experimentally in sheep (Andersen *et al*., 1997). Other diagnostic techniques like radiology and ultrasound have been used for the purpose (Wyn-Jones and Clarkson, 1984), but their practical application is limited in developing countries due to high cost. Despite the recent advances, diagnosis of hydatid disease in man is often difficult. Improved diagnostic methods are used such as ultrasonography and/or other imaging techniques supported by positive serologic tests. In seronegative patients with hepatic image findings compatible with echinococcosis, ultrasound guided fine needle biopsy may be useful for confirmation of diagnosis; during such procedures precautions must be taken to control or prevent allergic reactions (Soulsby, 1982).

Cystic echinococcosis (CE) is among the few parasitic infections where the basis for laboratory diagnosis is primarily serology (Craig *et al*., 1995). Immunodiagnosis of human CE is basically based on the detection of humoral and cellular immune responses of the host against the parasite. The indirect haemagglutination test (IHT) and ELISA are the most widely used methods for the detection of anti-echinococcus antibodies (IgG). Imaging methods for detection of space occupying masses [i.e. X-ray, Ultrasound, Computed tomography (CT) scan and Magnetic-resonance-imaging (MRI)] are the primary approaches for clinical diagnosis of CE in humans (Schantz and Gottstein, 1986; Sinner, 1991), however, confirmation by serology is still frequently used. X-ray and ultrasound techniques are very useful in longitudinal studies and in massive surveys to assess the prevalence of the human CE (Andersen *et al*., 1997). CT scan and MRI are used for further characterization of the lesions. They are mainly used for the pre-operative evaluation in follow-up examinations at longer intervals. Parasitological examination of the materials obtained after surgical operations can give the confirmatory diagnosis of echinococcosis whereby the protoscolices can be seen under the microscope in the aspirated cyst fluid (WHO, 1984; Bowman, 1999).

2.2.2.6 Prevention and control

A number of anthelmintic drugs have proven to be effective against adult stages of *E. granulosus* in the final host. The best drug currently available is praziquantel at a dose rate of 3-5 mg/kg body weight administered orally or subcutaneously as a single dose (Schantz, 1982), which eliminates all juvenile and adult *Echinococcus* worms from dogs.

In human hydatidosis, surgery is the treatment of choice at present though several benzimidazole compounds have been shown to have efficacy against the hydatid cysts. Long-term treatment with albendazole has a particular marked effect on the cysts (McManus and Smyth, 1986; Morris *et al*., 1990), while long-term treatment with praziquantel only has a limited effect with few changes in the germinal layer of the cyst.

The control of hydatidosis/echinococcosis is often considered to be a veterinary matter since the disease can be regulated by controlling the parasites in animals. However, collaboration between veterinarians and public health workers is essential for the successful control of hydatidosis. Echinococcosis can be controlled through preventive measures that break the life cycle between the definitive and the intermediate hosts. These measures include good dog management including regular diagnosis and deworming, proper meat inspection and educating the public on the risk to humans and avoiding feeding offal to dogs, as well as introducing hygiene legislation to the community.

2.2.3 Porcine ascariosis

2.2.3.1 Aetiology

The genus *Ascaris* belongs to the family Ascarididae, in the class Nematoda, and in the phylum Nemathelminthes (Soulsby, 1986). These worms have separate sexes, laying unembryonated eggs, which require external stimulation to hatch. As opposed to cestodes, these nematodes have a body cavity (Soulsby, 1986).

The adult *Ascaris suum* is found in the small intestine of the pig. The worm is very large and round with both anterior and posterior ends pointed. The size of the male parasite is 15 - 25 cm long by about 3 mm wide while the female measures up to 41 cm by 5 mm (Soulsby, 1982). The parasite produces characteristic eggs, which are oval, measuring 50-

75 by 40-50 µm. The eggs have thick shells, the albuminous layer bears prominent projections, and the eggs are brownish-yellow in colour (Soulsby, 1986).

2.2.3.2 Epidemiology

Ascaris suum is distributed world wide. In pigs, the parasite affects all age groups, but, the condition is more serious in piglets especially those that are under poor nutrition. Pigs acquire infection from food or water contaminated with infective eggs that contain the second stage larvae (L2). The development of eggs into the infective stage takes place in the soil. Favourable conditions for development of eggs include high environmental temperature (preferably, 22-33^{o}C), high relative humidity (60% or more), and presence of oxygen (Smyth, 1994). The larvae mature in three to four days under optimum conditions. The second stage larvae are extremely resistant to environmental hazards and, in a cold dry atmosphere, they may remain viable for up to six years in the soil (Smyth, 1994).

The number of adult worms that develop in the intestine is known to be inversely egg-dose dependent, and immunity to re-infection is directly related to frequency of egg exposure (Murrel *et al*., 1997). When given a high dose of eggs, pigs have a chance of developing a self-cure (worm expulsion) response to the intestinal larva stage four (L4) during the prepatent period. Epidemiological studies have revealed that constant exposure of pigs to eggs induces a pre-hepatic immune barrier, presumably in the intestine and against the invading L2.

Therefore, very few migrating larvae could be recovered in repeatedly inoculated pigs harbouring an existing population of adult worms.

Ascaris suum was formally considered to be a parasite of the pig only but recent studies have reported occurance of cross-infectection to humans (Nejsum *et al*., 2005; Nejsum *et*

al., 2006) whereby evidence suggests the possibility of *A. lumbricoides* of humans infecting pigs and *A. suum* of pigs infecting humans. Nevertheless, more studies in this area are required.

2.2.3.3 Life cycle

On ingestion of infective eggs (containing unsheathed second stage larvae, L2), the eggs hatch in the gut releasing second stage larvae (L2). The L2 penetrate the intestinal mucosa, reach the liver via the portal system, and develop into third stage larvae (L3). The L3 migrate through the liver of affected pigs causing hepatic necrotic lesions, which later become fibrotic lesions referred to as “milk spots”. The L3 move to the lungs and trachea and are swallowed into the gut where they undergo further development into the fourth stage (L4) and then to adult nematode. The prepatent period of the parasite is 40-53 days (Smyth, 1994).

2.2.3.4 Clinical signs

Light infections with *A. suum* are often asymptomatic and go unnoticed. However, heavy infections are associated with clinical signs. The passage of *Ascaris* larvae through the lungs causes considerable systemic disturbance, which is an allergic reaction manifested by exudation with fever, cough, accelerated respiration and symptoms of pneumonia. Heavy infestations with the adult worms are mostly apparent in piglets. It may be characterized by passage of adult worms in faeces and often loss of weight in long standing heavy infestations. This may lead into clinical signs such as loss of appetite and distended abdomen (Soulsby, 1982). Moreover, heavy burdens of worms in the intestine may cause rupture of the intestine leading to peritonitis and death.

2.2.3.5 Diagnosis and control

Ascariosis in pigs may be diagnosed by the isolation of the characteristic eggs in the faeces of pigs. Sometimes adult worms may be found in faecal material. Milkspots that are observed on the liver surface during meat inspection is a common diagnostic feature used to indicate chronic infection with *A. suum* (Soulsby, 1982). The parasite is well controlled by good management and routine deworming (Gerwert *et al*., 2004).

2.3 Status of Cysticercosis, Hydatidosis and Ascariosis in Tanzania

Porcine cysticercosis was first documented in Tanzania in the mid 1980s when meat inspection indicated a prevalence of 0.24-0.41% in slaughtered pigs in the northern highlands of Tanzania (Nsengwa, 1995). The situation became alarming in 1988 when another abattoir survey in the area indicated a higher prevalence of 4.88% (Nsengwa and Mbise, 1995). A subsequent slaughter-slab survey conducted in Moshi, Arusha and Mbulu indicated an overall prevalence of 13.3% (Boa *et al*., 1995), revealing further increase in the prevalence. Studies conducted in 21 villages in Mbulu, a district where most infected slaughter pigs originated, indicated an overall prevalence of 17.4% (village range 3.2-46.7%) based on lingual examination of live pigs (Ngowi *et al*., 2004a). A resent study in Mbulu district established an incidence rate of 68.6 per 100 pig – years in sentinel pigs (Ngowi *et al*., 2008). In southern regions of the country, prevalences ranging from 5.5-16.9% have been reported (Boa *et al*., 2001; Boa *et al*., 2006).

Prevalence of hydatidosis of 4.3% in pigs has been reported by Ngowi *et al*. (2004b) in the northern highlands. Esrony *et al*. (1997) reported a prevalence of 12% of ascariosis in pigs in Morogoro region through coprological examination while Ngowi *et al*. (2004b) reported a prevalence of 44.3% of liver milkspots in pigs slaughtered in northern Tanzania.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was conducted in Dar es Salaam city of Tanzania, which is located between latitude 6º46` and 6º51` S and longitude 39º14 and 39°18' E.(Fig. 3). It is bordered by the Indian Ocean to the east. It occupies an area of 162.5 km^2 with a population of about 2,497,940 people (NBS, 2002). Administratively, Dar es Salaam city is divided into three municipals: Ilala, Kinondoni, and Temeke. Being situated close to the equator and the warm Indian Ocean, the city experiences generally tropical climatic conditions, typified by hot and humid weather throughout the year. Annual rainfall is approximately 1100 mm per annum and in a normal year there are two distinct rainy seasons: the long rain season, which fall between April and May, and the short rain season between October and November.

The city contains unusually high concentrations of trade and other services and manufacturing industries compared to other parts of the country. It has a population of mixed social ethnicity creating good market for pork as for other goods. The present study was carried out between November 2007 and January 2008. Laboratory examination of samples was carried out at Sokoine University of Agriculture (SUA) in Morogoro region, located approximately 200 km west of Dar es Salaam city.

3.2 Study Design

3.2.1 Sample size

The sample size to estimate prevalence of the zoonotic endoparasites was calculated using the formula developed by Martin *et al.* (1987) as follows:

$n=Z^2PQ/L^2$, where;

n = required sample size,

Z = Z value for a given confidence level,

P = known or estimated prevalence,

Q = (1-P), and

L = allowable error of estimation.

For the purpose of this study, confidence level was assumed at 95% with an allowable error of estimation of 5%. Reference was made to porcine cysticercosis because of its known economic and public health effects. In Tanzania, the highest prevalence so far reported in slaughter slabs was 13.3% (Boa *et al*., 1995), thus, it was used as P in the calculation. Therefore,

$n = 1.96^2 \times 0.133 \times 0.867/0.05^2 \approx 177$ pigs.

Because sampling was done in slaughter slabs of three different municipals, the sample size was raised four times to improve the precesion of estimation of the prevalence of the infections.

Therefore,

$n_{adjusted} = 708$ pigs. A total of 731 pigs were examined.

3.2.2 Mapping of the distribution of pig slaughter slabs

A hand held geographical positioning system (GPS), made in Taiwan, was used to locate all official slaughter places visited during the study. The information recorded were the altitudes, latitudes and longitudes.

3.2.3 Collection of primary data

All official slaughter places in all municipalities were included in the study. All animals slaughtered in the dates of visit were inspected and important information was collected for each pig, including the place of origin and inspection findings.

3.2.4 Postmortem examination of pig carcasses and laboratory confirmation of *Taenias solium* cysts

After the pig carcass was dressed, inspection of the carcass was done **v**isually and following incisions made according to the Tanzania general guidelines for inspection of pig carcasses, which recommended incision of the following muscles; the tongue, masseter, heart and triceps brachii to search for *C. Cellulosae*. A few pieces of infected muscles were collected, refrigerated at 4-8^{o}C and transported to the Faculty of Veterinary Medicine of SUA for microscopic confirmation of *T. solium* cysts. In the laboratory, the cysts were immersed in Berlese mounting medium (Den kgl. Veterinaer-og Landbohøjskoles apotek) for 24 hrs, and then each pressed between two glass slides and examined under the microscope (Olympus-Taiwan) at 4x, 10x and 40x magnification.

3.2.5 Postmortem examination of pig carcasses and laboratory confirmation of hydatid cyst

Visual examination and palpation of visceral organs: livers, lungs, spleens and kidneys were performed. Two of the suspected hydatid cysts were collected and preserved in 70% alcohol for laboratory examination. In the laboratory a small amount of cyst fluid was drawn using a syringe. One to two drops of the fluid sample was placed on a glass slide and covered with a drop of lactophenol solution (BDH chemicals Ltd Poole England) to clear the surrounding materials. A cover slip was applied and the sample examined for presence of hydatid protoscoleces under the microscope at 10x and 40x magnification.

3.2.6 Carcass examination for *Ascaris suum*.

The entire liver was visually examined for presence of milk spots, which were used as an indicator of *A. suum* infection.

3.2.7 Assessment of the state of pig slaughter places

Using the checklist prepared (Appendix 2), important elements necessary for a standard slaughter place for food animals, each slaughter place was directly observed and the parameters recorded. The parameters observed included; location, presence of a fence, source and availability of water, slaughter place layout, waste disposal pit, presence of toilet and bathroom, protective gears and hygiene of workers and the surroundings.

3.2.8 Secondary data collection

Records of pig carcass inspection regarding to porcine cysticercosis, hydatid cysts and ascariosis were collected from relevant offices in the three municipalities of Dar es Salaam city.

3.3 Data Analysis

Data were entered and cleaned in Microsoft Exel. Statistical package for social sciences (SPSS) version 11.5 was used for the statistical analysis of the data. Descriptive statistics were computed to determine the prevalence of porcine cysticercosis, hydatidosis and ascariosis infections in examined pigs. Cross tabulation was performed to assess the association between infected pigs and important variables such as the region of origin. Data from the retrospective study were analysed in Microsoft Excel to determine the prevalence of the conditions. Locations of the slaughter places were mapped using ArchView 3.2 mapping software.

CHAPTER FOUR

4.0 RESULTS

4.1 General Results

A total of 731 carcases of pigs were examined in the three municipalities of Dar es Salaam city namely, Kinondoni (578), Ilala (111), and Temeke (42) between November 2007 and

January 2008. Out of these, 309 were from male pigs and 422 were from female pigs. There was no great age variation because most were finished pigs. The origin of pigs is presented in Table 4.

4.2 The Number and Distribution of Authorized Pig Slaughter Slabs in Dar es Salaam City

There were a total of 24 pig slaughter slabs officially operating in Kinondoni (13), Ilala (7), and Temeke (4) municipalities. All the slaughter slabs were privately owned. Figure 3 and 4 show the study area and the distribution of the slaughter slabs in the area. As shown in Figures 4 and 5, most of the slaughter places were located in Kinondoni and Ilala, with very few in Temeke. Unfortunately, there is overlapping of the locations of some slaughter slabs on the map because such slabs were in close proximity to each other. In addition, to the slaughter slabs being clustered in two of the three municipals, there was an overall clustering of the slabs in Ubungo area, near the central bus terminal.

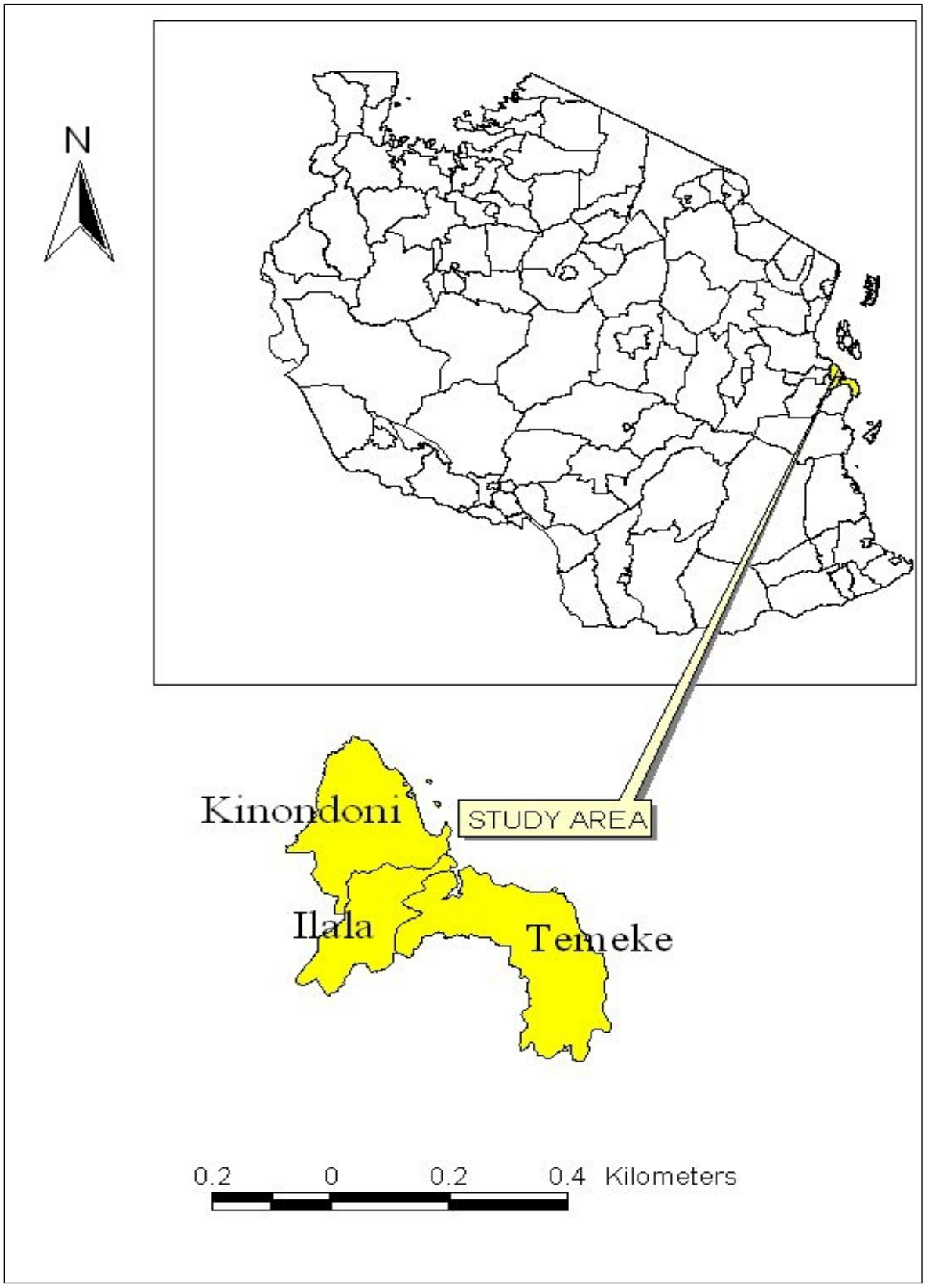

Figure 3: Map of Tanzania showing Dar es Salaam city, the study area

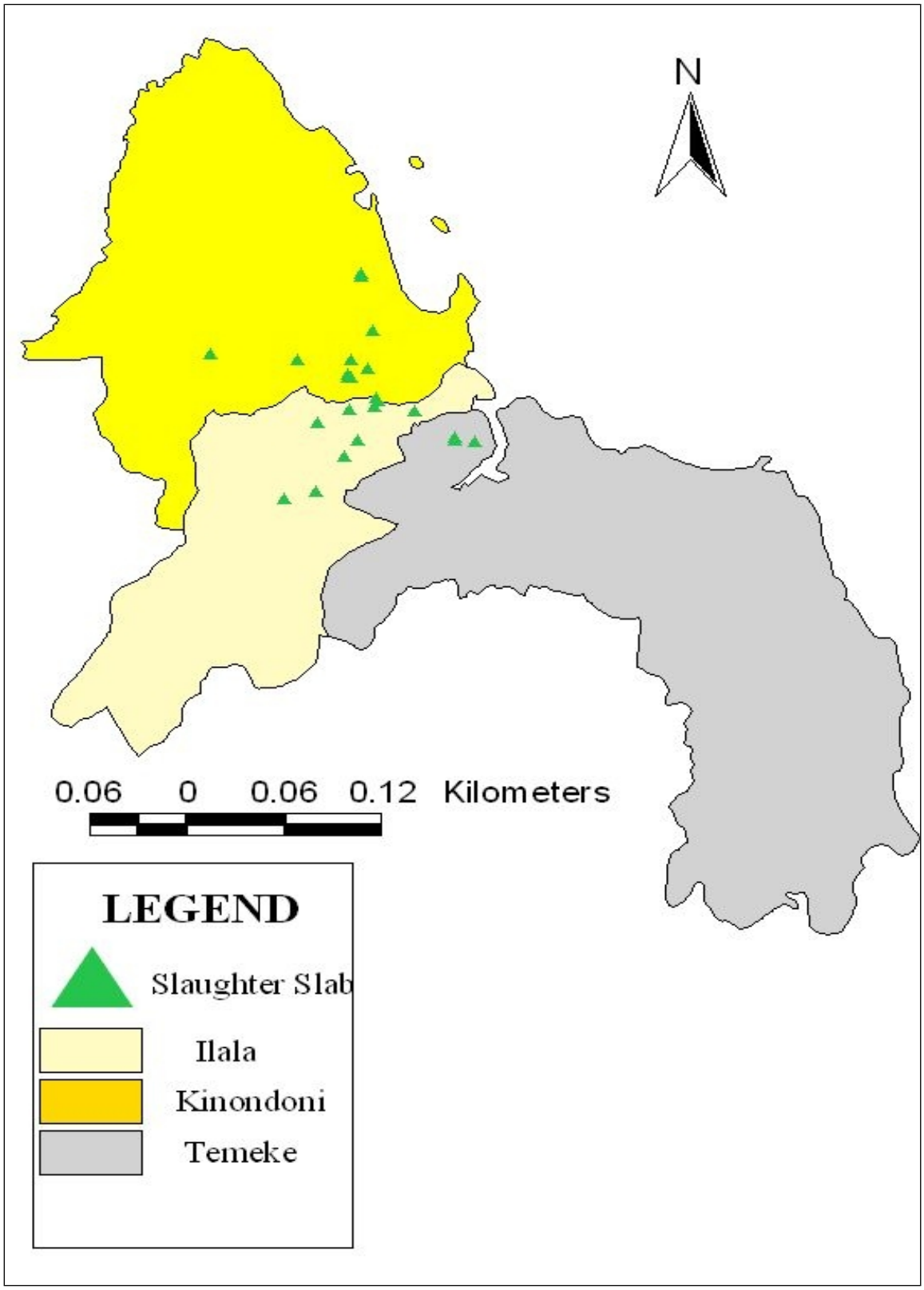

Figure 4: Map of Dar es Salaam city showing the distribution of pig slaughter slabs in its three municipalities, November 2007 – January 2008

4.3 The Situation of the Slaughter Slabs / Places

All but one of the slaughter places were found to be of poor standard according to the assessment made. All the slaughter places were located very close to human settlements or buildings used for other businesses. All had very small structures lacking necessary infrastructure such as potable water supply. Workers lacked necessary working gear and their personal hygiene as well as sanitary condition of the surroundings was poor. In addition, some slaughter places were inaccessible because of lack of roads. Plate 1 and 2 show some of the slaughter slabs found in the study area. Additional information can be found in the appendix 5.

Plate 1: A pig slaughter slab in Dar es Salaam city where all operations are done in this small room

Plate 2: Slaughter slab in close proximity to people's residences and without a fence, where dogs (not in picture) were found roaming around searching for offals.

4.4 Prevalence of Porcine Cysticercosis, Hydatidosis and Ascariosis as Determined by Slaughter-Slab Survey in Dar es Salaam City

Table 2 summarises overall prevalence of the various zoonotic endoparasites in Dar es Salaam city. Table 3 presents the prevalence of porcine cysticercosis in the three different municipalities of Dar es Salaam city, and Figure 5 shows the distribution of porcine cysticercosis by slaughter slabs. Laboratory examination of porcine cysticerci confirmed that the observed cysts were due to *T. solium* because of the presence of double rows of hooks on the protoscoleces (Plate: 6).

No any protoscoleces that were observed by microscopy upon examination of the fluid sample from the two of the four suspected hydatid cysts suggesting that the cysts were possibly sterile. Plates 3, 4, 5 and 7 show some of the conditions observed at meat inspection during the study.

Table 2: Prevalence of porcine cysticercosis, hydatidosis and ascariosis in slaughtered pigs in Dar es Salaam city, Tanzania, November 2007 – January 2008.

Condition	Total number of pigs examined	Number of positive pigs	Percentage
Porcine cysticercosis	731	43	5.9
Hydatidosis	731	4	0.5
Ascaris suum	731	59	8.1

Table 3: Prevalence of porcine cysticercosis in different municipalities of Dar es Salaam city, Tanzania, November 2007 – January 2008.

Municipality	Pigs examined	Positive pigs	Percentage
Kinondoni	578	33	5.72
Ilala	111	10	9.01
Temeke	42	0	0.00

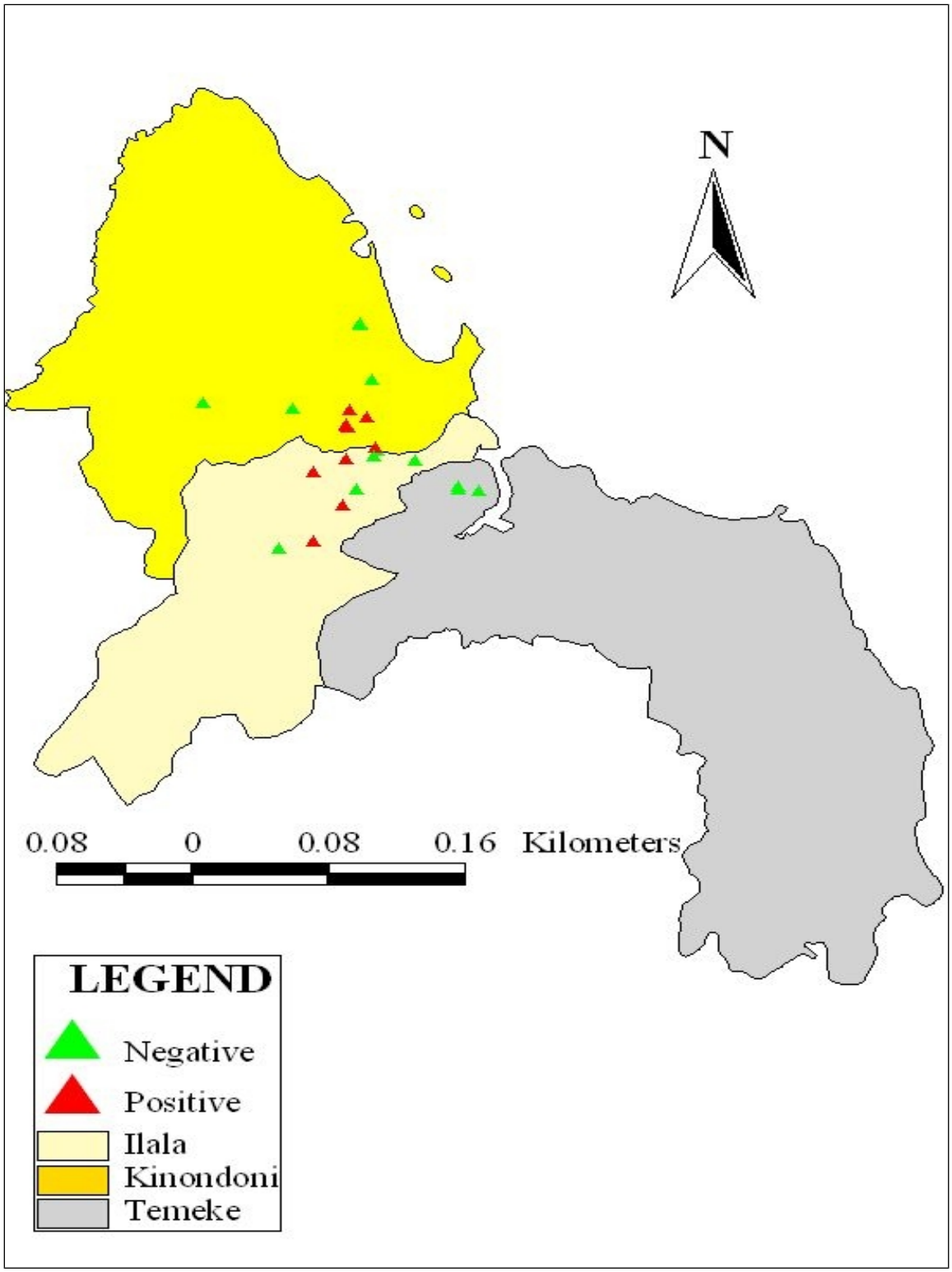

Figure 5: Map of Dar es Salaam city indicating slaughter slabs that had at least one positive case (red triangle) and those that did not have any positive cases (green triangle) of porcine cysticercosis, November 2007 – January 2008

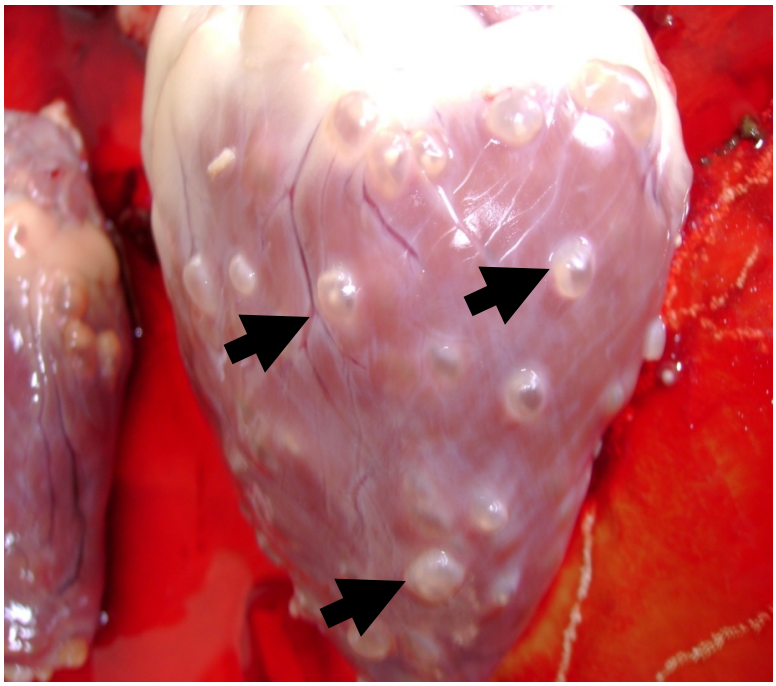

Plate 3: Cysts on the surface of heart muscles (arrows)

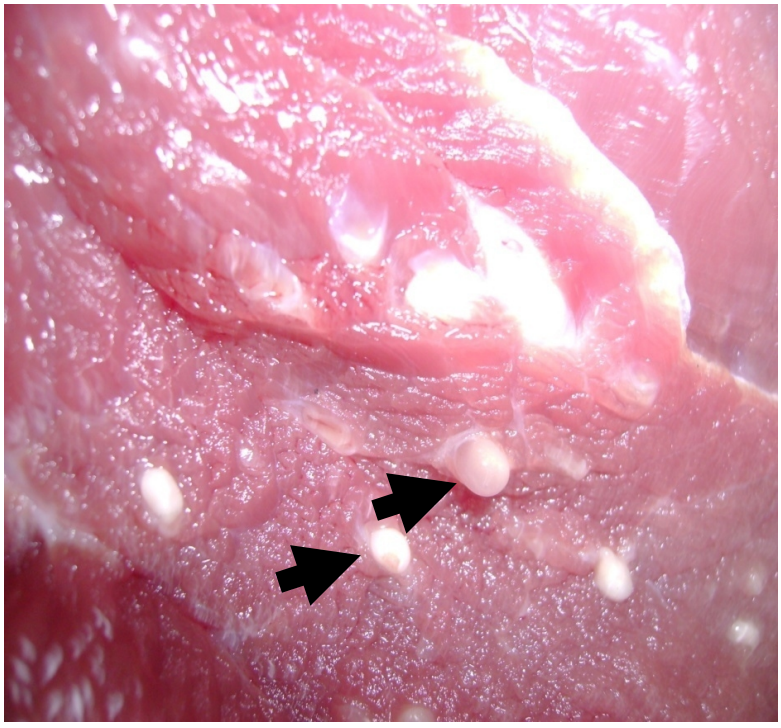

Plate 4: Cysts on cut surface of thigh muscles (arrows)

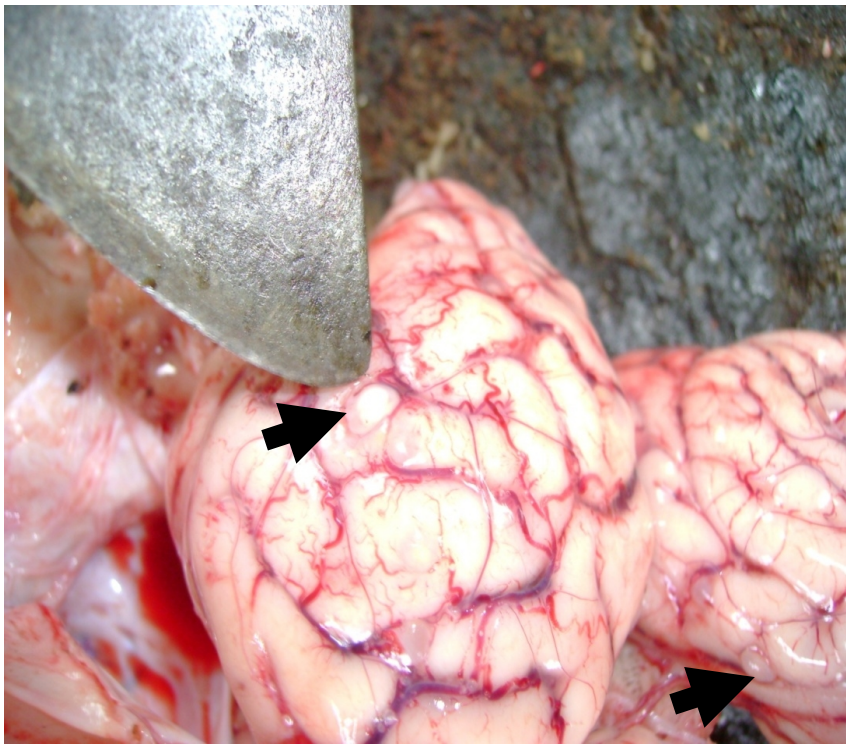

Plate 5: Cysts on the surface of brain tissue (arrows)

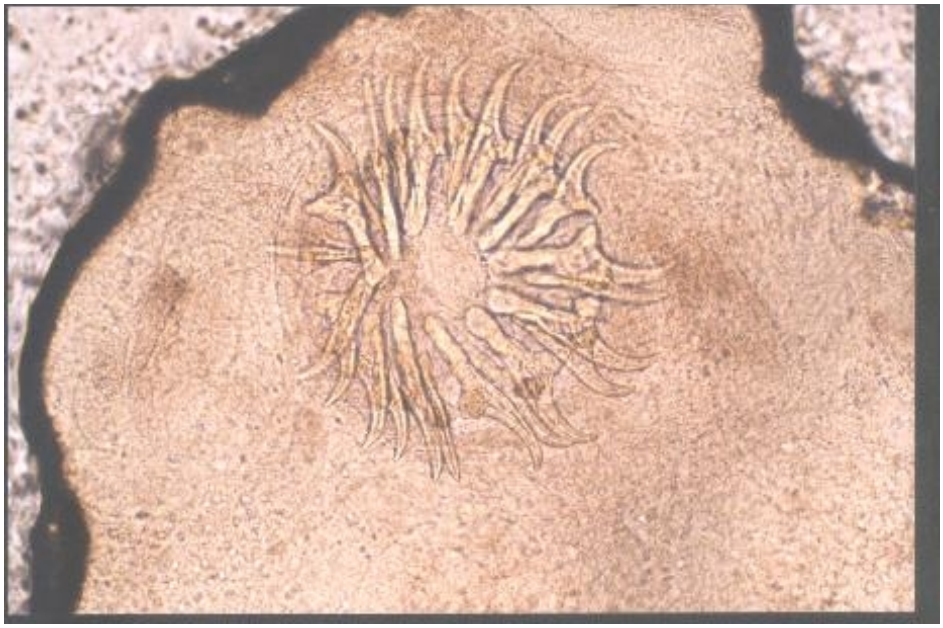

Plate 6: Hooks of *Taenia solium* protoscoleces (40x magnification)

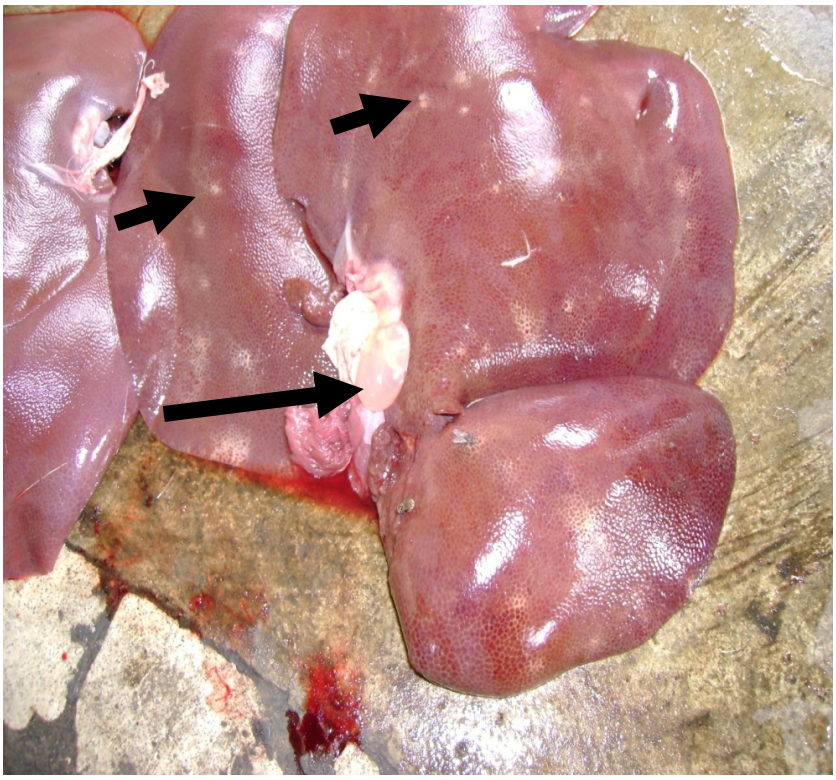

Plate 7: Pig liver with suspected hydatid cyst (long arrow) and liver milk spots (short arrows)

4.5 Origins of Pigs Examined and their Infection Statuses

The pigs slaughtered in Dar es Salaam city during the study period originated from nine regions of Tanzania which are Manyara, Mbeya, Rukwa, Kilimanjaro, Dodoma, Morogoro, Singida, Dar es salaam and Tanga as shown in Table 4. Most of the pigs originated from Manyara, a region of high endemicity for porcine cysticercosis (Nsengwa, 1995; Nsengwa and Mbise, 1995; Boa *et al*., 1995; Ngowi *et al*., 2004a). This was further confirmed in this study by the fact that the region was among the two with the highest proportion of pigs with cysticercosis. The four hydatidosis cases originated from Manyara, Mbeya, Dar es Salaam and Singida regions. Ascariosis was found to be widely spread, being reported in all regions with exception of Rukwa, Kilimanjaro and Tanga.

Table 4: Origin of pigs slaughtered in Dar es Salaam city and their infection statuses

Region of origin	Number of pigs examined	Percent with cysticercosis	Percent with hydatidosis	Percent with ascariosis
Manyara	328	8.2	0.3	8.8
Mbeya	116	6.9	0.9	6.9
Rukwa	8	0.0	0.0	0.0
Kilimanjaro	12	0.0	0.0	0.0
Dodoma	98	8.2	0.0	8.2
Morogoro	14	0.0	0.0	14.3
Singida	57	0.0	1.8	10.5
Dar es salaam	90	0.0	1.1	6.7
Tanga	8	0.0	0.0	0.0

4.6 Meat Inspection Records

The retrospective data for pork inspection were only available for the previous two years (2006 and 2007). Prevalences of the endoparasite infections are summarised in Table 5. It was noted that porcine cysticercosis prevalence was higher in the prospective study (5.9%) than in the retrospective survey for the two years (0.64%). Similar trends were observed for the other parasitic diseases.

Table 5: Prevalence of porcine cysticercosis, hydatidosis and ascariosis in Dar es Salaam city between January 2006 and September 2007 based on restrospective record survey

Year	Municipality	Total number examined	Prev of PC (quarterly range)	Prev of HC (quarterly range)	Prev of AS (quarterly range)
2006	Ilala	383	0.0 - 3.5	0	2.8 - 15.8
	Kinondoni	11 196	0.0 - 1.1	0	0.0 - 2.6
	Temeke	1 580	0.6 - 1.9	0	0.0 - 14.7
2007	Ilala	1 385	0.0 - 3.6	0	1.5 - 6.2
	Kinondoni	7 481	0.0 - 2.5	0-6	0.0 - 5.9
	Temeke	1 187	0.3 - 2.7	0	1.0 - 7.3

Source: Municipalitiess of Ilala, Kinondoni and Temeke meat inspection records

Key:

PC = porcine cysticercosis

HC = hydatidosis

AS = ascariosis

CHAPTER FIVE

5.0 DISCUSSION

This is the first extensive study to determine the prevalence of cysticercosis and other endoparasite zoonoses in pigs slaughtered in Dar es Salaam city. Previous studies in the country examined the cysticercosis situation mostly in the main pig farming areas, which are normally in the rural areas. Nevertheless, a good proportion of pigs are transported to and consumed in urban centres, like in this study 87.7% of inspected pigs originated from outside Dar es Salaam city, which also need to be investigated.

Post-mortem meat inspection has been employed widely as a routine method for judging the fitness of meat for human consumption. Despite some variations on the procedure between countries, it primarily involves visual observation combined with incisions made in a few areas of the pig carcass. Despite its low sensitivity in detecting some pathological conditions including cysticercosis, it is still the method of choice to enable a decision regarding the safety of meat for the consumer. This has been due to the availability of the method and its easeness to perform, requiring little skill. If carefully performed, postmortem inspection of pork can reduce the risk to pork consumers of acquiring taeniosis caused by *T. solium*, because the majority of infected pig will have heavy *T. solium* cyst burden which can be easily detected by meat inspection.

This study has revealed difficulties in the monitoring and control of slaughter pigs because of the scattered nature and large number of slaughter places. This has been partly due to the fact that identification of sites for slaughtering pigs was done by pig traders based on their convenience without considering other necessary requirements. As a result most of

the slaughter places are inadequate, which could also partly be due to little investments to their establishment. Due to these limitations, it was observed that some pork was sold without being inspected because of the difficulties the few available meat inspectors encounter that often prevent them from being present at each slaughter site. Consequently, this creates opportunities for some pork traders to sell infected pork or hide it and sell it after the meat inspector has gone. This study also revealed that antemortem inspection was rarely done for the same reason. Difficulties in monitoring slaughter pigs hinder efforts to control meat-borne zoonoses as also reported elsewhere (Phiri *et al*., 2003; Zoli *et al*., 2003).

Results from this study have indicated that an important proportion of pigs slaughtered in Dar es Salaam city were infected with cysticercosis caused by *T. solium.* Nevertheless, infected pigs originated from rural areas of the country, some of which have been previously shown to be endemic for the parasite. However, this study could not confirm the actual absence of the infection in the other regions, including Dar es Salaam, because of the small number of pigs from these regions that were slaughtered during the study. The observed prevalence of porcine cysticercosis in slaughter pigs in Dar es Salaam city, despite the serious screening of pigs by pig traders using lingual examination at the farm level, indicate a high risk to public health and economic losses to the pig traders. Considering the low sensitivity of the meat inspection method, the observed prevalence should be regarded as a gross underestimation of the actual prevalence.

One of the important findings from this study is the observed high prevalence of porcine cysticercosis in pigs originating from Dodoma, the central region of Tanzania. This region had not previously been investigated for porcine cysticercosis. This initial evidence

suggests another area in the country to consider for more epidemiological studies and later institution of control measures. In addition, it suggests that porcine cysticercosis might be a nation-wide problem.

Recently, a health-education intervention was evaluated in Mbulu district of northern Tanzania indicating promising progress towards reducing the incidence of porcine cysticercosis (Ngowi *et al*., 2008). Nevertheless, combined and preferably repeated interventions are necessary for the sustainable control of the parasite. The feasibility of a wider dissemination of the intervention messages should be investigated. Targeting slaughterhouses as the primary intervention point may be ineffective in developing countries because inspection and condemnation measures fail to compensate the farmer or trader with the infected pig to be condemned. As a result, such pigs often pass through clandestine markets to the consumers.

Abattoir surveys elsewhere have also reported the prevalence of cysticercosis in slaughtered pigs. In Uganda, Kisakye and Masaba (2002) and Phiri, *et al*. (2003), reported a prevalence ranging from 0.12-34% in different abattoirs, with most of the slaughtered pigs originating from rural areas. In Zambia, Phiri *et al*. (2002) reported a prevalence of 20.6-56.6%. Pig production and marketing systems in developing countries are very complex, calling for an intergrated intervention initially targeted at those areas with the highest prevalence of porcine cysticercosis as suggested by Morales *et al*. (2006). The prevalence of hydatidosis in the slaughtered pigs in this study, though low, is an indication of its endemicity in pigs. This may result in the possibility of transmission of infections to dogs if proper disposal of infected organs is not practiced as it has been the case in the study area. However, it was surprising in this study that both cysts that were confirmed

microscopically did not show any protoscoleces, suggesting sterility or misdiagnosis. Further studies are needed in this aspect. The prevalence of porcine hydatidosis in this study is lower than that obtained by Ngowi *et al.* (2004b) of 4.3% in slaughter slabs in northern Tanzania, where most pigs slaughtered were from Mbulu district. Mixed origins of pigs in this study might have contributed to the observed difference.

The prevalence of *A. suum* as indicated by liver milk spots was lower in this study (8.1%) than that of 44.3% reported in northern Tanzania (Ngowi *et al*., 2004b) and 40% in Burkina Faso (Tamboura *et al*., 2006). Again, mixed origins of the pigs in the present study may partly explain these differences. Nevertheless, the observed prevalence is of economic and public health importance. The lower prevalence of the endoparasite infections recorded in Dar es Salaam previously than those observed in the current prospective study may be due to the fact that meat inspectors were not aware of the infections, were not inspecting the carcasses adequately or were not keeping records properly. It could also be an indication of an increase in the prevalence of the infections in the rural areas, or an increase in the numbers of pigs being brought from rural areas to Dar es Salaam city for slaughter.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

Statistics indicate that pig production and pork consumption are growing dramatically in many developing countries, including Tanzania, creating a valuable source of income to smallholder farmers and pig traders and providing a valuable source of animal protein to pork consumers. The present study, like other studies elsewhere, clearly shows that porcine cysticercosis is widely prevalent, becoming an obstacle to the development of the pig industry thus impacting on smallholder farmers and pig traders, and posing a serious health risk to the public in endemic countries.

In order to monitor and control the pig production chain, local governments should review and implement existing national policies and regulations pertaining to pig production, marketing, pork inspection, as well as hygiene practices that are necessary for the control of *T. solium* infections. If any deficiencies are noted, establishing local by-laws to fill existing gaps should be considered. This could help in the short run towards the control of the parasite. Efforts to motivate regions and districts should be implemented in developing the strategic plan to control the infections, considering the greater diversity in ethinicity, levels of education, and socio-economic conditions to make sure that control strategies are relevant to a particular local situation. National level strategies should in the long run be established for the control and finally elimination of the parasite. Collaboration between relevant ministries is a key to the control of any zoonotic disease. Resource support could be obtained from international agencies, several of which are currently paying greater attention to this problem. It has been noted that there is no clear programmes for the control of these zoonotic endoparasites in the country because of low priority given by

relevant stakeholders to helminth zoonoses. This could be due to lack of knowledge on their magnitude and impact to the society especially from the medical point of view i.e no record in Tanzania on prevalence of *T. solium* infection in human though pigs are infected. Researchers are urged to fill this knowledge gap by informing relevant stakeholders through evidence based research findings. Presence of porcine cysticercosis is an indication of the presence of human tapeworm carriers, the sole source of porcine and human cysticercosis.

Therefore, studies should be conducted to establish the status of infections in people especially in areas endemic for porcine cysticercosis. This aspect is still lacking, with the exception of only one study that has recently established the prevalence of human neurocysticercosis and its close association with epilepsy in Mbulu district (Winkler *et al*., 2008). The government should support communities to build standard abattoirs, preferably one for each municipality in order to improve inspection and control of pork to safeguard the health of consumers.

The prevalence of hydatidosis in this study, though low, is of great public health importance as pigs may transmit the infection to dogs and dogs are the source of infection of human hydatidosis. Therefore, slaughter slabs should be fenced and proper disposal of offals should be practiced to prevent dogs from accessing them.

In this study, the observed high prevalence of *ascariosis* is of economic and public health importance. Further epidemiological studies are needed to establish factors responsible for the prevalence and transmission of ascariosis in the country, evaluate the economic losses caused by the parasite and to carryout molecular studies to confirm the possible cross infection to human in Tanzania.

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APPENDICES

Appendix 1: Post-mortem inspection recording form used during the study of porcine endoparasite survey in Dar es Salaam city, Tanzania, November, 2007 to January, 2008.

Date…….....

Name of Municipal …….....

Name of slaugher slab/place……....

Ownership of the slaughter slab/place…….....

Origin of pig…….....

Sex of the pig……...…

Age of the pig……..

Inspection findings..…..…….....

…… …….

Name of inspector Signature of inspector

Appendix 2: Checklist of the status of the pig slaughter slab/place during the study of porcine endoparasite survey in Dar es Salaam city, Tanzania, between November, 2007 and January, 2008.

1. Name of municipal.....

2. Name of slaughter place…….....

3. Ownership (1-Private, 2-Government).....

4. Location; (1-≤50M, 2-100M, 3-200M, 4-500M, 5-≥1000M from residents).....

5. Fenced (1-Yes, 2-No).....

6. Source of water (1-Tap water, 2-Well, 3-River, 4-Rainy water 5-Others).....

7. Availability of water (1-plenty, 2-Scarse, 3- Very scarce).....

8. Availability of basic facilities for the slaughter slab/place

Availability of water (1-plenty, 2- Scarse, Very scarce .....

Place for pig resting (1-present, 2-absent).....

Walls and floor (1-cemented, 2-Muddy).....

Roof (1-Iron, 2-Grass, 3-Not roofed).....

Separation between dirty and clean operation (1-Yes, 2-No)....

Display room (1-present, 2-Absent).....

Cold storage facility (1-Present, 2-Absent).....

Toilet and bathroom (1-Present, 2-absent).....

Decomposition pit (1-Present, 2-absent).....

9. Working/protective gears (1-Present, 2-absent).....

10. Workers hygiene (1-Good, 2-Fair, 3-Poor).....

11. Hygiene of the surrounding (1-Good, 2-Fair, 3-Poor).....

Appendix 3: Geometric locations of slaughter slabs in Dar es Salaam city

Name of slaughter slab	Elevation (m.a.s.l)	Latitude	Longitude
KINONDONI			
Riverside 1	51	-06.79919	039.20817
Riverside 2	78	-06.80119	039.20945
Riverside 3	33	-06.80041	039.20827
Ubungo darajani	46	-06.78865	039.21014
Makongo	55	-06.84481	039.21433
Materu	32	-06.76800	039.22323
Tangibovu 1	36	-06.72807	039.21631
Tangibovu 2	33	-06.72967	039.21621
Shekilango	50	-06.79436	039.22018
Mabibo 1	28	-06.81687	039.22624
Mabibo 2	34	-06.81569	039.22498
Korogwe-Kimara	116	-06.78828	039.17676
Mbezi	112	-06.78434	039.12419
ILALA			
Maruma	38	-06.82348	039.20857
Tabata relini	28	-06.82138	039.22396
Karakata	53	-06.85613	039.20601
Kisukulu	54	-06.83220	039.18943
Ukonga madizini	74	-06.88589	039.16852
Kipunguni	54	-06.88110	039.18884
Sukita	18	-06.82491	039.24905
TEMEKE			
Keko 1	25	-06.84508	039.27370
Keko 2	9	-06.84481	039.27387
Keko juu	28	-06.84279	039.27398
Kurasini	33	-06.84602	039.28573

Appendix 4: Slaughter slabs showing pigs examined and infection statuses

Name of slaughter slab	Pigs examined	Positive for PCC	Positive for Hydatidosis	Positive for Ascariosis
KINONDONI				
Riverside 1	176	13	3	18
Riverside 2	87	6	0	6
Riverside 3	117	7	0	7
Ubungo darajani	117	5	0	12
Makongo	12	0	0	2
Materu	7	0	0	0
Tangibovu 1	6	0	0	0
Tangibovu 2	5	5	0	0
Shekilango	9	1	0	0
Mabibo 1	8	0	0	1
Mabibo 2	9	1	0	1
Korogwe-Kimara	8	0	0	0
Mbezi	17	0	0	0
ILALA				
Maruma	16	2	0	2
Tabata relini	4	0	0	0
Karakata	35	4	1	1
Kisukulu	7	1	0	3
Ukonga madizini	14	0	0	0
Kipunguni	30	3	0	2
Sukita	5	0	0	1
TEMEKE				
Keko 1	19	0	0	3
Keko 2	8	0	0	1
Keko juu	6	0	0	0
Kurasini	9	0	0	1

Appendix 5: Some other photos taken during the study of porcine endoparasite survey in Dar es Salaam city, Tanzania, November, 2007 – January, 2008.

Investigator inspecting the pig carcass

Kinondoni inspector, putting official stamp on pig carcasses passed for human consumption

Butcherman slaughtering a pig without protective gears.

Slaughter slab (Back view) in Mbezi Kinondoni, Dar es Salaam