EPIDEMIOLOGY AND CONTROL OF PORCINE CYSTICERCOSIS IN TANZANIA

BY

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ABSTRACT

In Study I predilection sites for cysticerci of *Taenia solium* were determined by calculating relative cyst density for different carcass sites. The psoas muscle was found to be an important site for localization of cysticerci in pig carcasses followed by muscles of *Triceps brachii*, tongue, internal masseters, external masseters, diaphragm and heart as important sites for localisation of cystcerci in pigs. Based on these findings, all of these muscle groups/organs are proposed as predilection sites of *T. solium* in Tanzanian pigs and thus their examination should be mandatory for efficient routine inspection of pig carcasses. Tongue examination survey results from Chunya and Iringa Rural Districts, (Study II), showed that the two districts are endemic for porcine cysticercosis with prevalences of 7.6% and 8.4%, respectively. Structured questionnaire interviews identified factors associated with the disease prevalence in both Chunya and Iringa Rural Districts were free-ranging of pigs, home slaughtering of pigs and pork not being inspected. While in Chunya and Iringa Rural Districts lack of latrine and barbecuing were found a risk factor, respectively. In Study III, conducted in Mgeta Division, ante mortem tongue examination of 609 pigs and post mortem pork inspection of 124 carcasses found that they were all negative. These results instigated the interview study of relevant local parties, the findings of which were, none of the respondents reported having ever seen any cysts in pork or pigs. Availability, maintenance and use of latrines was found to be very high throughout Mgeta Division (97.6%) and in every village pigs are required to be kept totally confined. Health Centre data indicated that there were no cases of taeniosis, cholera or shigellosis reported during the last five years (1998 – 2002). There is an urgent need to transfer the important lessons from Mgeta

districts such as Chunya and Iringa Rural. In Study IV sensitivity and specificity of the tongue examination and antigen ELISA [Ag-ELISA] tests were compared in local Tanzanian pigs and it was observed that Ag-ELISA was more sensitive [3.6 times] than tongue examination and therefore would be more appropriate for surveillance in Tanzanian pigs.

DECLARATION

I, MATHIAS EMMANUEL BOA, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and has not been submitted for a degree award in any other University.

Signature..

Date......27/07/2005..

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ABBREVIATIONS

Ab	Antibody
AIDS	Acquired Immune Deficiency Syndrome
Ag	Antigen
Ab-ELISA	Antibody Enzyme-Linked Immunosorbent Assay
Ag-ELISA	Antigen Enzyme-Linked Immunosorbent Assay
ASF	African Swine Fever
CNS	Central Nervous System
CSF	Cerebral Spinal Fluid
ELISA	Enzyme-Linked Immunosorbent Assay
EITB	Enzyme Immunotransfer Blot
FAO	Food and Agriculture Organization
Gp	Glycoprotein
HIV	Human Immune Deficiency Virus
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulphuric acid
IgG	Immunoglobulin G
IgE	Immunoglobulin E
IgM	Immunoglobulin M
M	Morality
MCD	Mean percent cyst density at the site
Mhl	Man hours of labour
ml	Millilitre

mm	Millimetre
MoAb	Monoclonal antibody
MRW	Mean percent pork weight at the site
n	Sample size or number examined
N	Normality
NBCS	New born calf serum
NCC	Neurocysticercosis
nm	Nanometers
No.	Number
OD	Optical density
OPD	Orthophenylene diamine
OR	Odds ratio
p	Probability
PBS	Phosphate buffer saline
PM	Post Mortem
RCD	Relative cyst density
rpm	Revolutions per minute
SAS	Statistical Analysis Software
SPSS	Statistical Programme for Social Sciences
SUA	Sokoine University of Agriculture
TCA	Trichloroacetic acid
Tshs	Tanzanian shillings
T20	Tween 20
VPHC	Village Public Health Committee

UMADEP	Uluguru Mountain Development Project
USAID	United States Agency for International Development
WHO	World Health Organization
χ^2	Chi-square
=	Equal to
>	Greater than
≥	Greater than or equal to
<	Less than
≤	Less than or equal to
µg	Microgram
µl	Micro litre
%	Percentage
95%CL	95 percent Confidence Limit

CHAPTER ONE

1.0 INTRODUCTION

The population of pigs in Tanzania is estimated to be about 821,695 heads (ASPS, 2003), this neither includes urban households nor information from the large scale farms. Small scale pig farming and consumption is on the increase in many parts of Tanzania especially the southern and northern highlands, which are known to have high agricultural potential (Boa *et al.*, 2001; Boa *et al.*, 2002; Phiri *et al.*, 2003; Ngowi, *et al.*, 2004a). Regions with high populations of pigs in descending order are Mbeya, Ruvuma and Iringa (southern highlands), Morogoro (coast) and Arusha and Kilimanjaro (northern highlands). Farmers have turned to pig farming as opposed to raising ruminants for many reasons some of which are: 1) the high density of human population and scarcity of grazing land that inhibits rearing of ruminant livestock especially cattle, 2) farmers have recognized the rapid turnover in pig farming compared to cattle rearing, 3) high return from a minimal investment, 4) cultural acceptance of pigs by the local population and 5) higher consumer demand for pork in urban areas has resulted in increased market value of pork resulting in increased production of pigs in these highland areas as well as urban and peri-urban production systems.

The increased demand for pork in urban areas of the country has resulted in the transportation of pigs from rural smallholder communities to large population centres such as Arusha, Moshi, Iringa, Mbeya, and Dar es Salaam (Boa *et al.*, 2002).

Pig management in the northern and southern highlands of Tanzania varies seasonally. During the wet season, when the fields are cultivated, pigs are confined in pigpens or tethered in the backyard. However, in the dry season after the crops are harvested, pigs are reared under an extensive free-range system whereby the pigs are allowed to roam and graze freely (Phiri *et al.*, 2003). Unfortunately this type of grazing allows them to have access to environments where human outdoor defecation occurs in the bush (Phiri *et al.*, 2003). Although this system of management minimizes input costs, leading the farmers to expect higher output returns at slaughter, it provides the ideal conditions for transmission of porcine and human cysticercosis (Phiri *et al.*, 2003; Ngowi *et al.*, 2004a).

Unfortunately, due to conditions related to poverty, such as inadequate sanitation, poor pig management practices, and lack or absence of meat inspection and control, cysticercosis caused by the zoonotic pork tapeworm *Taenia solium* has emerged as an important constraint for the nutritional and economic well-being of these smallholder farming communities as well as a serious public health risk not only in these rural communities but also in the urban areas where many infected pigs are transported and consumed (Phiri *et al.*, 2003). *Taenia solium* cysticercosis is transmitted between humans and pigs. Pigs, which are coprophagic, serve as the parasite's natural intermediate host, becoming infected by ingesting tapeworm eggs when eating human faeces. The larval cysts (cysticerci) develop in skeletal, cardiac muscles and the brain though usually not in the visceral organs (Boa *et al.*, 2002). Infection of pigs results in hundreds to thousands of cysts located throughout the muscles rendering the pork unfit for human consumption. The human being is the natural definitive host carrying the adult tapeworm in the small intestine, a condition known as taeniosis. It has been observed that an adult tapeworm in the intestine can cause mild symptoms (Pawlowski, 2002). Human beings become infected with taeniosis by ingesting the larva of the tapeworm in infected pork that is eaten raw or undercooked. Infection of humans with the larval form of the parasite (*Cysticercus cellulosae*) can also happen through ingestion of tapeworm eggs in contaminated food or water or directly from the hands of tapeworm carriers. The cysts can lodge in the brain, muscles, and sub-cutaneous tissue or in the eye. Cysts in the brain (neurocysticercosis) often lead to epileptic seizures resulting in human suffering, loss of production and costly medical treatment, while those in the eye may lead to visual loss. Neurocysticercosis has been shown to cause arachnoiditis, hydrocephalus, stroke, dementia and numerous other neurological problems (Del Bruto *et al.*, 2001).

The costs due to porcine and human cysticercosis can be enormous as shown by studies conducted in Mexico which revealed that costs due to porcine cysticercosis in that country in 1980s were over US $43 million or the equivalent of 68.5 % of the total investment in pig stock production (Acevedo-Hernandez, 1982). The costs due to human cysticercosis are related to medical care, e.g. diagnosis, hospitalisation, treatment and convalescence, as well as the associated decrease in human productivity. This was estimated in 1986 to be US $14.5 million in Mexico (Flisser, 1988).

Porcine cysticercosis was first documented in Tanzania in the mid 1980s. Cases of the disease were detected when a group of pigs exported from Arusha, Tanzania to Nairobi, Kenya was condemned due to massive cysticercosis infection in most of the pigs. The pigs were later found to have originated from Mbulu District (Nsengwa and Mbise, 1995). Subsequent epidemiological investigation indicated a prevalence of 0.24 - 0.41% in slaughtered pigs in the northern highlands District of Mbulu in Arusha Region (Nsengwa, 1995). Another abattoir survey in Mbulu District conducted in 1988 established the prevalence of 4.88% (Nsengwa and Mbise, 1995). Subsequent slaughter slab surveys conducted in the northern highland's towns of Mbulu, Arusha and Moshi in 1991-1992 indicated an overall prevalence of 13.3% [n=83] with most of the positive pigs originating from Mbulu District (Boa *et al.*, 1995). Recently, studies involving lingual examinations of pigs conducted in 21 smallholder pig raising villages in Mbulu District indicated an overall porcine cysticercosis prevalence of 17.4% [n=770] with a range of 3.2 - 46.7% among individual villages (Ngowi, *et al.*, 2004a).

In order to control or eliminate *T. solium* cysticercosis, one must first conduct baseline epidemiological studies and develop a thorough understanding of the transmission and risk factors of the disease. A purpose of this study was to further improve our understanding of porcine cysticercosis by investigating aspects of the host-parasite relationship (cyst density, intensity and distribution in the pig carcasses). The Tanzanian Meat Inspection Regulations of 1993 does not include comprehensive instructions concerning detection of porcine cysticercosis in contrast to bovine cysticercosis, which is thoroughly covered. Meat inspectors refer to the regulations for bovine cysticercosis when conducting pork inspection on the assumption that the larval cestode cysts have the same distribution, density and intensity in both cattle and pig carcasses, which may not be totally true. In order to formulate appropriate guidelines for routine post-mortem detection of porcine cysticercosis it is important to determine the predilection sites of cysticerci of *T. solium* in finished pigs. By definition these are organs or muscle groups/tissues that harbour a high proportion of cysts, have the highest cyst density and are parasitized in the vast majority of infected animals examined. Examining such organs facilitates the identification of infected pig carcasses and should provide, when combined with appropriate judgement, safer and more wholesome pork for human consumption.

Little is known about the prevalence of porcine cysticercosis in pig producing regions of Tanzania outside the northern highlands. Pig keeping is also known to be popular in the regions of the southern highlands zone (Mbeya, Ruvuma and Iringa) however, no epidemiological surveys on porcine cysticercosis have been conducted in the zone in spite of unofficial reports indicating the disease to be a widespread problem. Therefore, it was of interest to investigate the prevalence and risk factors of porcine cysticercosis in the southern highlands. Also pig keeping in Mgeta Division, Morogoro Rural District, has been on the increase for several years (Anon, 1998) and unofficial reports have claimed that Mgeta pigs are free of cysticercosis. Thus, it was interesting to investigate in Mgeta the status of disease in pigs and the possible factors responsible for the situation there.

Since ancient times tongue examination has been used to detect cases of porcine cysticercosis (Wadia and Singh, 2002). Tongue examination, although specific, is only moderately sensitive, requires highly trained personnel, is time-consuming and there is a risk of being bitten. However, it is relatively inexpensive and gives immediate results. The immunoelectrotransfer blot (EITB, Western Blot) assay is highly specific, and is more sensitive than necropsy or tongue examination. However, it is found to be expensive and not available in laboratories in eastern and southern African countries. An alternative immunodiagnostic test to the Western Blot test is an antigen ELISA test, which is currently conducted in the laboratories of the neighbouring country of Zambia, at Samora Machel School of Veterinary Medicine, University of Zambia. The sensitivity and specificity of the antigen ELISA (Ag-ELISA) was found to be 86.7% and 94.7%, respectively, much higher than tongue test (Dorny *et al.*, 2000; Dorny *et al.*, 2004). Low levels of cross-reactions have been observed in serum samples from a wide range of helminths and protozoan infections (Harrison *et al.*, 1989; Erhart *et al.*, 2002). However, the genus specificity of the test does not allow differentiation between metacesode infection of *T. solium* and *T. hydatigena* in pigs (Dorny *et al.*, 2003). Thus, Ag-ELISA and tongue examination tests need to be compared in terms of sensitivity and specificity and in detecting cases and determining risk factors for porcine cysticercosis in Tanzanian pigs.

Thus, the overall objective of this study was to contribute to the local epidemiological knowledge on *T. solium* cysticercosis/taeniosis that may be used to justify and plan future strategies for prevention and control of the disease burden in pigs and people in Tanzania.

The specific objectives of the present study were:

1. To determine the distribution, intensity and density of cysticerci of *T. solium* in distinct carcass sites of naturally infected finishing pigs from Mbulu.
2. To determine the prevalence of porcine cysticercosis and factors enhancing its transmission in the southern highlands of Tanzania.
3. To collect baseline information on the status of porcine cysticercosis in Mgeta Division, Tanzania and the possible factors responsible for its absence or presence.
4. To compare Ag-ELISA and tongue examination tests in determining cases and risk factors for porcine cysticercosis in Tanzanian pigs.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Porcine cysticercosis

2.1.1 Actiology, taxonomy and biology of *Taenia solium* Linnaeaus, 1758

Taenia solium is a member of the Family *Taeniidae* and Genus *Taenia* and is commonly called the pork tapeworm because of its close relationship with pigs. This is an obligate parasite with a life cycle involving two stages: the adult tapeworm, living in the human small intestine, and the larvae or cysticerci, usually located in the muscles of domestic pigs, humans, wild boar and dogs (Soulsby, 1982; Pawlowski, 2002).

The adult worm is flat with a tape-like shape. Its strobila (chain of segments) can measure between 2 to 4 m in length with a total of 800 to 1,000 proglottids (segments). The gravid proglottids, contain from 30,000 to 50,000 eggs, which detach from the strobila in groups of five or six and are expelled with faeces (Soulsby, 1982; Pawlowski, 2002). The adult has neither coelomic cavity nor a digestive apparatus, and nutrition occurs through the tegumental surface. The excretory system is made of two channels located laterally and run (longitudinally) anteroposterioly on the proglottids, connecting to those in the next proglottid and open to the outside in the last proglottid. The genital pores are located on the lateral edge of each proglottid, at medium height. Three sections of the tapeworm can be observed: head, neck and body or strobila. The head or scolex is globular in shape and 1 mm in diameter. It has a rostellum, with a double crown of hooks (large hooks measuring 160 to 180 mμ and small ones measuring 110 to 140 mμ), arranged alternately. It also has four muscular suckers that together with the hooks are used for attachment to the host's intestinal mucosa (Soulsby, 1982; Pawlowski, 2002). The neck is short and thin, measuring 5 to 10 mm long, and is the section with the highest biosynthetic activity because the formation of the immature progottids starts off at the neck. The body is the longest section of the parasite and is composed of hundreds of proglottids of the following kinds: -

- The immature proglottids, which have a transversal diameter longer than the longitudinal one. An incipient genital apparatus can be observed.
- The mature proglottids follow the immature ones and are square in shape, 1 cm wide, 1-2 cm long, and 2-3 mm thick. The female genital apparatus can be seen with a trilobulated ovary, as well as the male genital apparatus with 375 to 575 testicular masses.
- Gravid proglottids are rectangular in shape, with a slightly predominant longitudinal diameter. Most of the male and female genitalia are atrophic, and only the uterus can be seen with tens of thousands of eggs. The uterus is branched (arboriform) with an axis alongside the proglottid, up to 12 primary branches coming out, and smaller, dendritic ramifications arising from the primary branches (Soulsby, 1982; Pawlowski, 2002).

2.1.2 Morphological difference between *Taenia solium*, *T. saginata* and *T. saginata asiatica*

Several morphological abnormalities of the strobila or individual proglottids of *T. saginata,* and less frequently *T. solium* adult tapeworms have been noted, often giving rise to taxonomic confusion in the past. The taxonomic revision of genus *Taenia*, published by Vester, recognizes only two species of Taeniidae, namely, *T. solium* and *T. saginata* as capable of parasitizing the human intestines (Pawlowski, 2002). The so called Asia *Taenia*, first described in the 1980s in Taiwan, was initially proposed to be a new species but is now accepted to be a subspecies of *T. saginata,* namely *T. saginata* *asiatica* (Keeseon and Han-Jong, 2001). The differences between scolices of *T. solium* and *T. saginata* were recognized as early as the 17th century. The *T. solium* scolex is armed with small and large hooks alternately arranged around the rostellum, while *T. saginata* scolices are not armed with hooks (Keeseon and Han-Jong, 2001; Pawlowski, 2002). *Taenia solium* is morphologically similar to, but smaller than, *T. saginata* with the body length ranging between 2 and 4 m. The internal structures of *T. solium* can easily be seen owing to a thin muscular layer that is rather transparent compared to that of *T. saginata*. The structure of a mature proglottid is quite similar to that of *T. saginata* except for the following points:

- The number of testes, 375 to 575, is far less than that of *T. saginata* which has 800 to 1,200 testes, but their distribution is wider, involving the region behind the vitelline gland.
- The cirrus sac is so large that it reaches the excretory canal while that of *T. saginata* is small and doesn't reach the excretory canal.
- The ovary in *T. solium* is divided into three lobes while in *T. saginata* it is in two lobes only.
- The vagina does not have a sphincter while that of *T. saginata* does.
- The uterus has fewer lateral branches but more secondary and tertiary branches than that of *T. saginata*.
- Each *T. solium* proglottid has fewer eggs, about 40,000 on the average, while those of *T. saginata* have about 80,000 eggs (Soulsby, 1982; Sciutto *et al.*, 2000; Pawlowski, 2002) (Table 1).

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

Characteristic	*T. solium*	*T. saginata*	*T. saginata asiatica*
Intermediate host	Pig, wild boar, dog, humans	Cattle, reindeer	Pigs, cattle, goat, some wild mammals
Metacestodes			
Site	Brain, skin, muscle	Muscles, viscera	Liver (exclusively)
Size	5.6-8.5 x 3.1-6.5	7-10 x 4-6	2 x 2
Scolex	Rostellum and hooks	No rostellum	Rostellum, rudimentary hooklets (1-37)
Bladder surface	Wart-like formation	Rugae	Wart-like formations
Adult tapeworm			
Scolex			
Diameter (mm)	0.6-1.0	1.5-2.0	0.8
Number of suckers	4	4	4
Diameter of suckers (mm)	0.4-0.5	0.7-0.8	0.24-0.29
Rostellum	Present	Absent	Present
Number of hooks	22-32	Absent	Absent
Proglottids			
Length (mm)	1.5-8.0	4-12	c.3.5
Maximum breadth (mm)	7-10	12-14	c.9.5
Number of proglottids	700-1000	c.2000	260-1016
Mature proglottids			
Number of testes	375-575	800-1200	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 (16)	18-32 (15)	16-21 (32)
Branching pattern	Dendritic	Dichotomous	Dichotomous
Expulsion from host	Mainly in groups, passively	Single, spontaneously	Single, spontaneously

Note: Number in the parentheses is mean number of uterine branches.

Source: Pawlowski, 2002.

2.1.3 Physiology

Taenia solium has no digestive tract. Food is obtained from the host's intestine through the worm's body surface, which has microvilli that increase the surface area of the parasite and enhance the metabolic exchange between the tapeworm and the intestinal environment (Pawlowski, 2002). Waste products are eliminated through excretory tubes whose openings are located in the last gravid proglottids of the strobila (Pawlowski, 2002). Recently the excretory/secretory products eliminated by the tapeworm to the outside, along with the faeces, have been found useful because they contain antigenic fractions (copro-antigens) used for immunodiagnosis through the preparation of specific antibodies and their use in highly sensitive diagnostic techniques, such as ELISA (Allan *et al.*, 1990). Generally a person will harbour only one single adult *Taenia* at a time; however, there may be several, particularly in cases of habitual ingestion of raw pork meat as seen in some endemic communities (Pawlowski, 2002).

2.1.4 Life cycle

Man is the sole definitive host for the adult *T. solium*, while the pig is the usual intermediate host for the larval stage. Man can also ingest the eggs which later develop into larval stage and become a dead end host. The eggs, eliminated free or inside gravid proglottids in the faeces of the individual infected with the adult tapeworm, each contain a hexacanth embryo possessing six hooks. They are morphologically indistinguishable from those of *T. saginata*. When ingested by a pig, the eggs are exposed to digestive solutions that cause the release of the hexacanth embryos. The embryos adhere to the mucosa and then penetrate the intestinal wall reaching blood vessels. In this way, the embryos enter the general circulation and are transported to various organs and tissues where they develop as larval cysticreci (Soulsby, 1982; Schantz *et al.*, 1998; Pawlowski, 2002). From an evolutionary point of view, the location of cysticerci in pig muscle is very important since it will permit the completion of the parasite's life cycle.

The cysticercus is the larval stage of *T. solium*, called *Cysticercus cellulosae* by Rudolphi in 1803 given its predilection for conjunctive tissue. The morphology of the cysticercus is that of a vesicle, but at times, in the brain, this morphology can vary to irregular forms (racemose form) (White, 2000). The infection by cysticerci is called cysticercosis, porcine or human (Schantz *et al.*, 1998; Pawlowski, 2002). The typical cysticercus is a tiny ellipsoid bladder (0.5 to 1.5 cm diameter) with a white translucent membrane that contains a single spherical, invaginated protoscolex bathed in a small amount of clear fluid. In pigs, the cysticerci of *T. solium* localizes most frequently within lymphatic capillaries of the skeletal muscles and in the brain (Schantz *et al.*, 1998; Boa *et al.*, 2002; Pawlowski, 2002). In humans, cysticerci often occur in skeletal muscles, but the most important clinical manifestations emanate from cysticerci localized in the central nervous systems (Schantz *et al.*, 1998; White, 2000). Less frequently cysticerci may localize in the eye, subcutaneous tissues, and the heart (Schantz *et al.*, 1998; White, 2000).

The pathogenesis of human cysticercosis is related to the number and sites of localization of cysticerci and to the host immune response; cysticerci in the CNS may be apparently tolerated and survive for years or may be overwhelmed within a few days by an intense inflammatory response (Del Bruto, 1999). Consequently, neurocysticercosis (NCC) is characterized by extreme clinical polymorphism and variability in outcome, thus complicating prognostic evaluation and comparison of therapeutic regimens. Clinical NCC is diagnosed most frequently in adults; children account for fewer than 20% of clinical cases (Schantz *et al.*, 1998; Del Bruto, 1999; White, 2000). An exception to this situation occurs in South Africa whereby more children have been diagnosed with neurocysticercosis than adults (Mafojane *et al.*, 2003). NCC has been shown to be the most common cause of late-onset seizures in Mexico and many other regions where *T. solium* is endemic, accounting for 30 to 50% of all cases and recently the International League Against Epilepsy called it the main cause of preventable epilepsy worldwide (Medina *et al.*, 1990; Diop *et al.*, 2003).

2.1.5 Porcine cysticercosis

Porcine cysticercosis is usually without conspicuous signs, but intracranial involvement is not uncommon (Gonzalez *et al.* 2003). For example a pig with numerous cysts (over 400 cysts) in the brain from Mbulu District was observed to be frequently circling (Boa *et al.*, 2002). By heavily infecting the skeletal muscles porcine cysticercosis produces widespread livestock production losses due to condemnation of infected carcasses. The costs due to porcine cysticercosis can be enormous as shown by studies conducted in Mexico which found the cost due to porcine cysticercosis in that country in 1980 to be over US $43 million or the equivalent of 68.5 % of the total investment in pig stock production (Acevedo-Hernandez, 1982). The rates of the disease are variable, but in endemic regions, over 30% of pigs may be infected and an infected carcass costs only one third of the price of a healthy one (Robinson, 1978; The Cysticercosis Working Group in Peru, 1993; Gonzalez *et al.*, 1999; Gonzalez *et al.*, 2003).

2.1.5.1 *Taenia solium* taeniosis

Man acquires the adult form of *T. solium* through ingesting raw or poorly cooked pork meat containing cysts. In the intestines the cysts develop into adult worms. *Taenia solium* lives in the upper part of the small intestines and can cause local inflammation due to attachment of the scolex to the intestinal mucosa with hooks and suckers. Sometimes the lesions extend beyond the muscular layer, resulting in the adhesion of the intestine to the other organs or even its perforation followed by peritonitis. Symptoms are generally mild or lacking. If present, they are gastrointestinal disturbances, such as nausea, vomiting, increased appetite and abdominal pain (Sciutto *et al.*, 2000; Pawlowski, 2002).

2.1.5.2 Host spectrum of *Taenia solium*

Experimental infections with adult *T. solium* after ingestion of cysticerci have been successfully established in the Lar gibbon (*Hylobes lar*), chacma baboon (*Papio ursinus*) and golden hamster (*Mesocricetus auratus*). *T. solium* metacestodes are less specific than adult cestodes (Pawlowski, 2002). The list of mammals in which cysticerci armed with hooks have been found includes man, monkeys (*Ateles*, *Cercopithecus*, *Macacus* sp.), wild boar, bush pigs, bush babies, camels, rabbits, hares, rock hyraxes, brown bear, dogs, foxes, cats, polecats, rats and mice (Pawlowski, 2002). In addition, experimental infection with *T. solium* oncospheres has been successfully established in immunosuppressed mice (Wang and Ma, 1999). However, many of the reported cysticerci differed in the size of hooks and immunoelectrophoretic pattern of *T. solium* cysticerci; not all armed cysticerci are those of *T. solium* (Pawlowski, 2002). Ito *et al.* (2002) stated that although pigs are the most important intermediate hosts of economic importance, dogs are also highly susceptible and become intermediate hosts. Humans are unique in that they can harbour both adult and metacestode stages of the parasite.

2.1.6 Geographical distribution of porcine cysticercosis

Porcine cysticercosis is still a frequent condition in the developing world, especially in countries where free-range management of pigs is commonly practiced and raw or undercooked pork is consumed. Exact data on its prevalence are difficult to obtain, mainly because slaughter and meat inspection practices do not exist in many rural areas or unreliable data are reported (Gonzalez *et al.*, 1990; The Cysticercosis Working Group in Peru, 1993; Phiri *et al.*, 2003). Even then the meat inspection records can be misleading in that by simple summation of pigs slaughtered in an abattoir, positive cases from certain endemic localities could be over-diluted by the number of clean pigs from other areas within the region/district or township. Secondly, pigs, which are sent to slaughter, are in many cases bought from the farmers by traders who make visual tongue examinations of each pig for the presence of cysts. Pigs found to harbour cysts under the surface of the tongue are not bought by traders, and will, therefore, not be sent to the abattoir for slaughter (The Cysticercosis Working Group in Peru, 1993; Gonzalez *et al.*, 1990; Phiri *et al.*, 2003; Ngowi *et al.*, 2004b). Thirdly, it has been shown from cattle studies that of those animals, which are lightly infected with *T. saginata*, a close relative of *T. solium*, only 15% are detected by classical meat inspection (Kyvsgaard *et al.*, 1990). A similar, yet slighter, underestimation may be expected for *T. solium* in the pig. For example D'Souza and Hafeez (1999) observed that 33.33% [n=150] of pigs in which infection could not be detected at meat inspection were found positive by Ag-ELISA with sensitivity and specificity of 92% and 100% respectively. Geerts (1990) found that, although the official figures returned by the meat inspection services show that the number of Belgian cattle infected with cysticercosis decreased during recent years from 0.3% to 0.03%, systematic search and careful detection proved that 9.5% of cattle were infected with cysticerci of *T. saginata*. This discrepancy with the official figures was due to the inappropriate detection techniques used routinely in the slaughtering, and demonstrated that, even in Europe, official data may widely differ from reality. And lastly, most pigs raised in typical poor rural areas are slaughtered and consumed at the homestead of the pig owner and a substantial amount of pork may be sold without inspection (Ngowi *et al.*, 2004b).

2.1.7 Geographical distribution of porcine and human cysticercosis in Eastern and Southern Africa

2.1.7.1 Porcine and human cysticercosis in Tanzania

Pig production has increased significantly in the southern and northern highlands and in the urban and peri-urban centres of Tanzania. Currently pig numbers in Tanzania are estimated at 821,695 (ASPS, 2003). Of these 65% are in the rural area under traditional small scale production, while 35% are in the small and large scale commercial production systems dominant in the urban and peri-urban areas. About 60% and 25% of pigs are raised in the southern highlands and northern highlands respectively (Lekule, 1999). The lack of grazing land for ruminants and the recognition by farmers of quicker and higher returns on their investment from raising pigs have contributed to an increased interest in raising pigs. In addition, higher consumer demand for pork in urban areas has resulted in increased market value of pork. Thus, the increased demand for pork in urban areas of the country has resulted in the transportation of pigs from these rural smallholder communities to large population centres such as Arusha, Moshi, Iringa, Mbeya, and Dar es Salaam (Boa, *et al.*, 2002). For quite a long time very little information existed in the literature regarding the presence or prevalence of porcine cysticercosis in Tanzania. Documented history of the disease started unfolding in the mid 1980s when in early November, 1987, some pigs from Mbulu District exported to Kenya were observed to have massive cysticercosis during meat inspection. It was therefore decided to investigate the disease situation in northern Tanzania, with particular emphasis on Mbulu District, which was until then not known to be an endemic area.

In early December, 1987, regional and district meat inspectors were reminded by correspondence about the condition and asked to perform thorough inspections of all pigs originating from Mbulu District. They were also requested to furnish information about the past and recent inspection records indicating the number of positive cases observed in their districts and where possible, pinpoint the origin of the infected animals. Nsengwa and Mbise (1995) compiled the findings of that initial survey and the results are presented in Table 2.

From the initial information on the disease situation it is interesting to note that prior to 1985 there were no porcine cysticercosis cases reported from Mbulu, Arusha Urban, Kilimanjaro or Moshi districts (Table 2). The status of the disease prior to 1985 is questionable since positive cases suddenly appeared in all the reports in the first quarter of 1988 after correspondence with meat inspectors suggesting that it may have been overlooked previously. In any case the initially reported overall prevalence was quite low. The researchers associated the presence of porcine cysticercosis in northern Tanzania with poor hygiene and sanitation practices and low standards of pig husbandry i.e. free range management. During their visit in Mbulu district they observed that pigs were roaming and scavenging freely and toilet use by some local people was by and large unsatisfactory (Nsengwa and Mbise, 1995).

Table 2: Cases of porcine cysticercosis in Tanzania determined by post-mortem meat inspection.

Place	Year	Pigs examined	Pigs positive	Prevalence
Arusha Urban	1987	M	3	M
Arusha Urban	1988	670	9	1.34
Kilimanjaro Region	1985	13,514	5	0.04
Kilimanjaro Region	1986	13,280	15	0.11
Kilimanjaro Region	1987	13,646	18	0.13
Moshi District	1988	3,127	55	1.80
Mbulu District	1985	492	2	0.41
Mbulu District	1987	840	2	0.24
Mbulu District	1988*	225	11	4.89

KEY: M =Missing data.

*= Data is from January to March only.

Another abattoir survey in the north of the country was conducted in selected slaughter slabs from 20-31 October 1992 by Boa and others (1995) with the objective of determining the presence of *T. saginata asiatica* in cattle and pigs and also to determine the presence of porcine cysticercosis. The survey was conducted in Mbulu, Sanawari (Arusha) and Kiboroloni (Moshi). A total of 83 pigs were examined at 3 slaughter slabs and of these 11 were found positive for cysticerci of *T. solium* giving an overall crude prevalence of 13.3% ranging from 9.1% to 37.5% with most of the positive pigs originating from Mbulu District (Boa *et al.*, 1995; Phiri *et al.*, 2003).

Another interesting study in the northern highlands (Mbulu District) was that conducted by Ngowi and others (2004a). The study was aimed at determining the prevalence of porcine cysticercosis in the district right at the village and household levels by ante-mortem lingual examination. Risk factors associated with cysticercosis were assessed by the use of a structured questionnaire administered to the pig owner before the pigs were subjected to lingual examination. Examination of the tongues of pigs in 21 villages showed that out of 770 pigs examined, 134 pigs were positive giving a prevalence of 17.4%, the range being 3.2-46.7% among individual villages. Each village had at least one pig infected indicating widespread distribution of the problem. Free-range pig rearing and lack of latrines were determined to be the most important risk factors contributing to transmission and maintenance of the disease in the area (Ngowi *et al.*, 2004b; Phiri *et al.*, 2003).

Human cysticercosis has not been reported in Tanzania despite high prevalence of porcine cysticercosis. However, very recently a survey on human cysticercosis was undertaken whereby 58 epileptic patients from endemic Mbulu District were examined for the presence of circulating antigens for *T. solium* larvae using antigen ELISA. Twenty-one (36.2%) of the epileptic individuals were confirmed to have cysticercosis and two other individuals were regarded as suspected cases.

2.1.7.2 Porcine and human cysticercosis in Kenya

The history of porcine cysticercosis in Kenya dates back to the 1960s when the Kenyan Ministry of Agriculture reported several cases. A government ban on free-range pigs led to a decrease in reported cases in the urban and export slaughterhouses around Nairobi (Phiri *et al.*, 2003). However, it is questionable whether at the smaller slaughter slabs, which are common in the rural areas, cases of porcine cysticercosis could have gone unnoticed or were detected but not recorded. Home slaughter of pigs with no inspection is common in rural areas of Kenya (Githigia *et al.*, 2002; Phiri *et al.*, 2003). In mid-2000 several cases of porcine cysticercosis were detected at slaughter slabs near Nairobi and a subsequent investigation led to the findings that these infected pigs were imported from Uganda (Phiri *et al.*, 2003). Smallholder pig keeping has very recently become popular in south-western Kenya in areas bordering Uganda. In many of these areas pigs are being kept under extensive, free-range conditions in spite of legislation requiring confinement of pigs (Githigia *et al.*, 2002; Phiri *et al.*, 2003).

In the years 2000 and 2002 a team of researchers from the Kabete campus, University of Nairobi conducted an investigative study on porcine cysticercosis in south western Kenya involving Busia and Nyanza Districts. Pigs raised by smallholder farmers were examined lingually and a structured questionnaire which probed on the issues of pig management, presence and use of toilet and knowledge of taeniosis/cysticercosis was administered to relevant local inhabitants with the findings presented in Table 3.

Table 3: Prevalence of porcine cysticercosis determined by ante-mortem lingual examination and information on associated risk factors in Busia and Nyanza Districts, Kenya.

District	No. examined	No. positive	Prevalence rate	% roaming	Toilet coverage	Authors
Busia	107	15	14.0	98 [n=48]	Missing information	Githigia *et al.*, 2002
Nyanza	300	30	10.0	Most pigs freely forage	Most homesteads lack latrines	Githigia *et al.*, 2002
Total	**407**	**45**	**11.1**			

In Busia District 14.0% of the pigs were positive while 10.0% were positive in Nyanza District. These observations indicate that the disease is present in the two districts in significant proportions. A total of 407 pigs were examined in the two districts giving an overall prevalence of 11.1% which was lower than the 17.4% prevalence observed by Ngowi (2004a) in Mbulu District, Tanzania. Factors associated with transmission of the disease in the two districts of Kenya were free ranging of pigs and lack of latrines in most households (Table 3), which were also implicated as the main risk factors responsible for the transmission and maintenance of the disease in northern Tanzania (Ngowi, 2004a).

Two cases of neurocysticercosis in humans were recorded in 1986, one was a patient at Nairobi hospital while the other was a resident of Kakamega District in the south-western part of the country. Both cases had cerebral cysts with one case also having an ocular cyst (Mafojane *et al.*, 2003).

2.1.7.3 Porcine and human cysticercosis in Uganda

No extensive or structured studies on porcine cysticerocosis have been conducted in Uganda despite it having the largest population of pigs in East Africa. The latest estimated number of pigs in the country is about 1.4 million with the pig population growing at about 10% annually (Phiri *et al.*, 2003).

Limited abattoir surveys for porcine cysticercosis in Kampala conducted in 1998 and 1999 indicated a prevalence of 1.2 and 0.12%, respectively, with most of the pigs whose carcasses were condemned because of cysticercosis originating from the northern rural areas such as Lira, Apac, and Nakasongola Districts (Phiri *et al.*, 2003).
The rather low reported prevalence in pigs being slaughtered in Kampala is probably due to the screening process instituted by the pig traders and other factors as already discussed in the preceding paragraphs. This hypothesis is supported by the observation from a limited rural survey conducted in 1999 in Moyo (extreme north of Uganda) in which 34% of the pigs slaughtered in selected villages were found to be infected (Phiri *et al.*, 2003).

Recently, Kisakye and Masaba (2002) and Phiri and others (2003), reported on a post-mortem cysticercosis survey of 297 pigs slaughtered during a two month period in Kampala. Most of the pigs surveyed (214) came from the central region of Uganda from the districts of Kampala, Masaka, Mpigi and Mubende while 83 pigs came from the rural, northern district of Lira. None of the pigs originating from central region districts were found to be positive whereas 28 of the pigs coming from Lira were infected with *T. solium* cysts. Thus, overall 9.4% of the pigs surveyed were found positive with 33.7% of pigs coming from Lira infected. Only 6 of the positive pig carcasses were condemned while the others were released for consumption as they were deemed to have low intensities of infection though the authors note that if national meat inspection regulations had been strictly followed (i.e. condemnation if more than 7 cysts found at inspection sites), then 20 carcasses should actually have been condemned (Phiri *et al.*, 2003). Interestingly, one of the positive sows was found to be pregnant with 8 foetuses at slaughter (Kisakye and Masaba, 2002; Phiri *et al.*, 2003). Examination of these foetuses revealed that all 8 were infected with cysts of *T. solium* with 32 cysts recovered from one foetus providing initial evidence of the possibility of congenital transmission of porcine cysticercosis (Kisakye and Masaba, 2002; Phiri *et al.*, 2003).

Given the high porcine cysticercosis prevalence rate in areas of Kenya and Tanzania bordering Uganda and its large rural pig population, it may be anticipated that Uganda has one of the highest prevalence rates of cysticercosis in East Africa (Phiri *et al.*, 2003). Human cysticercosis has not been noted as a problem in Uganda, however, recent reports indicate that porcine cysticercosis is a serious, emerging problem particularly in rural areas such as Lira, Apac and Nakasongola Districts (Mafojane *et al.*, 2003; Phiri *et al.*, 2003).

2.1.7.4 Porcine and human cysticercosis in Zambia

Pig farming in Zambia is practiced mainly in Eastern and Southern Provinces which together harbour 70% (54% and 16%, respectively) of the country's total number of pigs (Phiri *et al.*, 2002). As in many other parts of the developing world pigs in Zambia are raised by resource poor smallholder farmers with few commercial piggeries existing. In Eastern Province, pigs are raised mainly for home consumption, while most of the pigs raised in Southern Province are transported to Lusaka where many of them are sold and slaughtered at an illegal market (Phiri *et al.*, 2003). Pigs raised in Eastern Province are barred from export to other parts of the country due to concerns about the spread of Africa Swine Fever (ASF) found to be endemic in the area. Slaughterhouse records indicated that 6 of Zambia's 9 provinces have reported cases of porcine cysticercosis implying that this is a widespread problem (Phiri *et al.*, 2003). Routine meat inspection of 1,316 pigs originating from Southern Province at a slaughter slab in Lusaka indicated that 20.6% of the slaughtered pigs had cysticercosis (Phiri *et al.*, 2002) (Table 4). An enzyme-linked immunosorbent assay (ELISA) for the detection of circulating antigen (Ag-ELISA) performed on 874 pigs from the same slaughter slab indicated that 56.6% were sero-positive (Phiri *et al.*, 2002) suggesting that Ag-ELISA may be more than twice as sensitive as post mortem examination for detecting cysticercosis cases (Table 4).

Preliminary field surveys revealed that eight (8.2%) out of 98 pigs from Southern Province (Kalomo District) and eight (5.3%) out of 151 pigs from Eastern Province (Sindi District) were positive by tongue palpation. In the same survey, using the Ag-ELISA, 20 (20.8%) and 14 (9.3%) pigs tested positive in Kalomo and Sindi Districts, respectively (Phiri *et al.*, 2002) (Table 4).

Community surveys have recently been conducted in Eastern and Southern Provinces of Zambia aimed at determining the prevalence of porcine cysticercosis and collecting information on potential risk factors. The surveys included the districts of Gwembe, Petauke and Katete. At the district level, Gwembe District in Southern Province had a prevalence of 25.4 % (n = 291) while Petauke and Katete Districts of Eastern Province had prevalences of 9.3% (n = 150) and 8.8% (n = 260), respectively. The Ag-ELISA results for Gwembe, Petauke and Katete were 39.2%, 14.0% and 23.5%, respectively (Sikasunge *et al*., 2003) (Table 4).

Potential risk factors were assessed by the use of a structured questionnaire to interview 386 pig farmers which showed that 53.4% lacked latrines, 74.9% kept pigs on free range, 92.4% consumed pork, 96.6% slaughtered pigs at home without inspection, 85.2% have observed cysts in pork, 32.1% admitted eating pork containing cysticerci and 57.5% were ignorant about the mode of transmission of cysticerci of *T. solium* they observed in pork. The high prevalence in the surveyed districts suggests widespread distribution and high endemicity of *T. solium* taeniosis/cysticercosis in these areas of Zambia.

There are no official reports on human cysticercosis in Zambia despite high prevalences of porcine cysticercosis in rural areas. This suggests the presence of human tapeworm carriers and a high risk of human cysticercosis in the surveyed areas as well as in urban centres where pigs from rural areas are increasingly sold, slaughtered and consumed (Mafojane *et al*., 2003).

Table 4: Prevalence of porcine cysticercosis determined by different diagnostic methods of pigs coming from different areas of Zambia.

Study area	Year	Pigs observed	Prevalence by:			Author
			Tongue	Ag-ELISA	PM	
Lusaka city	2001	1,316		56.6 [n=874]	20.6	Phiri *et al.*, 2002
Kalomo	2002	98	8.2	20.8		Phiri *et al.*. 2002
Sindi	2002	151	5.3	9.3		Phiri *et al.*, 2002
Gwembe	2002	291	25.4	39.2		Sikasunge *et al.*, 2003
Petauke	2002	150	9.3	14.0		Sikasunge *et al.*, 2003
Katete	2002	260	8.8	23.5		Sikasunge *et al.*, 20003
Total		**2,266**	**11.4**	**21.4**		

In total 2,266 pigs have now been examined in Zambia giving an overall crude prevalence of 11.4% by tongue examination which is similar to the 11.1% prevalence detected by Githigia and others (2002) in Kenya. However, it is lower than the 17.4% prevalence of porcine cysticercosis observed in the northern highlands of Tanzania by Ngowi and others (2004a).

2.1.7.5 Porcine and human cysticercosis in Zimbabwe

The documented history of porcine cysticercosis in Zimbabwe dates back to the 1960s and 1970s when Robinson (1978) found the prevalence with decreasing trend from 1.2% in 1968 to 0.48% in 1975. He also found that the level of infection was higher in free ranging pigs (4.26%) than in confined pigs (0.03%). Recent reports of cysticercosis cases from slaughter houses in the western region around Bulawayo (Matabele-land) revealed the problem to be serious in pigs coming from non-commercial sources in rural, communal areas. In 1995, the prevalence of porcine cysticercosis in this region was 2.7%, whereas in the first half of 1999 it had increased to 28.6% (Phiri *et al.*, 2003). Suspected risk factors associated with disease transmission are free ranging of pigs, poor sanitation (lack of latrines/toilets) and nonexistent pork inspection (Phiri *et al.*, 2003).

Taenia solium has been reported in Zimbabwe 45 years ago (Merle, 1958; Mafojane *et al.*, 2003). In humans, calcified cysticerci are not uncommon incidental findings on chest or limb X-rays and neurocysticercosis is an occasional diagnosis at surgery for intra-cranial or spinal lesions (Rachman, 1970; Mafojane *et al.*, 2003). A study in Bulawayo reported calcified cysticerci in 11% of patients who presented with seizures and in whom thigh X-rays were taken (Rachman, 1970). In one hospital survey in Harare, 12% of epileptic patients were found to be positive for *T. solium* on serological testing (Mason *et al.*, 1992; Mafojane *et al.*, 2003). The prevalence was higher in men (18%) than in women (7%). Ndhlovu (1997) reported an uncommon presentation of cysticercosis that manifested as sudden death. Recent evidence suggests that *T. solium* is an emerging problem in smallholder communities where the prevalence of porcine cysticercosis in these communities has increased from 2.7 to 28.6% during the period 1995-2002 (Mafojane *et al.*, 2003).

2.1.7.6 Porcine and human cysticercosis in Mozambique

In Mozambique data on porcine cysticercosis is rather scanty, however; abattoir records indicate that the disease is present in all provinces of the country. A sero-prevalence study in 11 districts of rural Tete Province showed that 15% of 387 pigs were sero-positive with a district range of 6.5 to 33.3% using an antibody-detecting ELISA based on purified cysts fluid antigen (fraction 17A) (Phiri *et al.*, 2003).

Serra (1968) reported the first post-mortem case of neuorocysticercosis (NCC) in Mozambique while the first clinical case of NCC was reported at Maputo Central Hospital in 1999 (Mafojane *et al.*, 2003). In a cross-sectional sero-epidemiological study on humans conducted in Tete City, 32 out of 157 sera (20%) presumably from epileptic cases, were found positive by ELISA (Mafojane *et al.*, 2003). Another study on epileptic patients conducted in northwest Tete Province found that 14 out of 80 (17.8%) were positive for cysticercosis by ELISA testing (Mafojane *et al.*, 2003). A similar serological survey conducted at Maputo's Central Hospital found sero-positivity rate of 12.1% (59 out of 489 patients) (Mafojane *et al.*, 2003).

2.1.7.7 Porcine and human cysticercosis in South Africa

South Africa has the largest number of pigs (most being raised under commercial conditions) in southern Africa, and human cysticercosis has been recognized as a problem in the country for many decades. An extensive survey conducted in 1931 in 67 slaughterhouses in different areas of the country indicated a prevalence of porcine cysticercosis of 0.5 % to 25.07% (Viljoen, 1937). In 1965, Heinz and MacNab reported that the average percentage of incidence of porcine cysticercosis reported at slaughterhouses around the country managed by the South African Meat Board ranged from 0 to 9.1% with a total of 1.7% of 28,242 inspected pigs infected whereas the non controlled slaughter facilities in Umtata, Eastern Cape Province, reported an incidence greater than 10%. Surprisingly there have apparently not been further epidemiological studies conducted on porcine cysticercosis in spite of strong evidence indicating that *T. solium* is an important pathogen of poor, black South Africans for a long time (Phiri *et al.*, 2003). However, currently there is an on going project funded by United States Agency for International Development (USAID) geared to determine prevalence and risk factors of porcine cysticercosis in Eastern Cape Province [Prof. Krecek, R. C. personal communication, 2003].

The little information gathered in Eastern and Southern Africa clearly shows that porcine cysticercosis is widely distributed in the region. Since most of these studies have used lingual examination, a technique of low sensitivity (not more than 70% and probably less than 50%), one could assume that the prevalence figures obtained are probably an underestimation of the actual prevalence. The risk factors associated with disease transmission so far identified include lack of latrines, free range pig husbandry, consumption of improperly cooked pork, domestic slaughtering of pigs and lack of pork inspection and ignorance (Phiri *et al.*, 2003).

In South Africa human cysticercosis was recognised as a problem many decades ago. During the past 3 decades several hospital surveys utilising serological and/or radiological diagnostic techniques have indicated that 28-50% of epileptics, predominantly black and including many children, were positive for cysticercosis (Mafojane *et al.*, 2003; Phiri *et al.*, 2003). Human cysticercosis appears to be most prevalent in Eastern Cape Province particularly in poor, former black homeland, rural areas of Ciskei and Transkei, where pigs are allowed to roam freely and sanitation facilities are inadequate or nonexistent. The community based epidemiological studies conducted in these areas have involved children where surveys have indicated a prevalence of 2.5-5.5% of Transkei children (n=2,088) were serologically positive for cysticercosis (Shasha and Pammenter, 1991; Pammenter *et al.*, 1987; Mafojane *et al.*, 2003; Phiri *et al.*, 2003). In addition to the surveys of rural inhabitants, a small hospital survey of urban black South Africans (n=230) indicated a prevalence of 7.4% suggesting that urban dwellers are also at risk of infection with cysticercosis (Sacks and Berkowitz, 1990; Mafojane *et al.*, 2003). An interesting and potentially life-threatening source of cysticercosis infections is from concoctions prepared by traditional healers to which are added tapeworm segments (Joubert and Evans, 1997; Mafojane *et al.*, 2003; Phiri *et al.*, 2003). Besides this practice, the malevolent use of *T. solium* segments by women to punish their unfaithful husbands or lovers is also common, whereby the contents of *T. solium* segments are added to beer as punishment (Mafojane *et al.*, 2003).

2.1.8 Geographical distribution of porcine and human cysticercosis in central and West Africa

The meat inspection data colleted in Nigeria in the years 1977 – 1978 indicated the prevalence of porcine cysticercosis to be 0.33% (Table 5). The authors of the report noted that up to that time meat inspection was still largely conducted by non-qualified veterinarians, and abattoir facilities were not in a state enabling efficient meat inspection thus the reported low prevalence rates.

Dada, (1980) studied the prevalence of porcine and bovine cysticercosis infection. A survey was performed in the abattoirs in Kano (Sudan Zone), Kaduna and Zaria (Northern Guinea Zone) and Jos (Bauchi Plateau zone) to access the actual prevalence of bovine and porcine cysticercosis. Cysticerci of *T. solium* were detected in 18.4% and

1.76% of slaughtered pigs examined in the northern Guinea and Bauchi plateau zones, respectively (Table 5). Cysts were observed in the tongue, skeletal muscles, heart, diaphragm, thigh and forelimbs.

Pandey, and Mbemba, (1976) studied porcine cysticercosis in the Republic of Zaire and its relation to human taeniosis. Pig carcasses were examined in 14 regions of Zaire. The average prevalence of infection was 0.1% in Shaba, 0.4% in Baszaire, 4.7% in Kivu and 8.1% in Haut Zaire. There were variations in the percentage of infestation in different zones of the same region. The high prevalence of cysticercosis in the north East (Kivu and Haut Zaire) is attributed to the lack of sanitary installations, absence of suitable meat control facilities, free ranging method of pig husbandry and eating undercooked pork (Pandey and Mbemba, 1976) (Table 5).

In Burkina Faso there has been yearly diagnosis of porcine cysticercosis especially in animals coming from the Savannah and Kara regions. Reports state that the number of carcasses and parts condemned due to cysticercosis has declined over the past 10 years (Coulibaly and Yameogo, 2000). However, the decline in the prevalence has to be taken with caution for the obvious reason that infected pigs are not brought to the abattoir for slaughter because if brought they are likely to be condemned.

In Togo porcine cysticercosis was found significantly responsible for carcass condemnation at abattoirs and in the reported 5 year study period 568 pigs were condemned however, the data on the total number of pigs examined was not available in the report and cysticercosis was the main (84%) cause of carcass condemnation (Domingo, 2000) (Table 5).

Table 5: Prevalence of porcine cysticercosis as determined by different diagnostic techniques in pigs coming from different countries of Central and West Africa.

Country	Year	Pigs observed	Prevalence by:			Author & Year of Publication
			PM	Tongue	Ag-ELISA/ Ab-ELISA	
Nigeria	1971-1977	23,830	0.33			Dada, 1980
Nigeria	1977-1978	317	9.5			Dada., 1980
Nigeria, Guinea zone	1980	147	18.4			Dada, 1980
Nigeria, Bauchi plateau	1980	170	1.76			Dada, 1980
Nigeria	1993	2,358	20.0			Onah and Chiejina, 1995
Zaire- (Shaba)	1976		0.1			Pandey and Mbemba (1976)
Zaire –Baszaire	1976		0.4			Pandey and Mbemba (1976)
Zaire-Kivu	1976		4.7			Pandey and Mbemba (1976)
Zaire-Haut	1976		8.1			Pandey and Mbemba (1976)
Burkina Faso	1997		0.57			Coulibaly and Yameogo, 2000.
Togo	1993-1997	568				Domingo, 2000
West Cameroon	2000	707		6.1	11.0 (Ag-ELISA) 21.8 (Ab-ELISA)	Pouedet *et al*., 2002
Ghana	1998	60	11.7			Permin *et al*., 1999

The survey in Cameroon by Pouedet and others (2002) involved 290 families living in two rural settings of Bafou and Bamendou, Menoua Division situated in the western highlands of Cameroon. Of the 707 pigs examined, 577 (81.6%) were usually kept in confinement and 130 (18.4%) were free roaming. Among the 290 pig-owning households visited (174 in Bafou and 116 in Bamendou), 33 (11.4%) did not have latrines, and in 154 (53.1%) of the households pigs had access to human faecal material. Of the 707 pigs examined lingually 43 (6.1%) were found positive, 78 (11.0%) were found positive in the Ag-ELISA and 154 (21.8%) in the Ab-ELISA (Table 5). In terms of risk factors interesting findings in this study were that pigs that were reported by their owners to be usually confined were significantly less infected (9.9%) than those that were allowed to roam freely (16.2%) and animals that had access to human faeces were significantly more infected (13.8%) than those that did not (9.1%). Adult pigs showed a significantly higher sero-prevalence (15%) than young ones (8.4%) (Pouedet *et al.*, 2002).

In the West Province of Cameroon the prevalence of human cysticercosis has been reported to range between 0.7 and 2.4% (Zoli *et al.*, 1987; Nguekam *et al.*, 2003; Zoli *et al.*, 2003). A recent survey among Cameroonian epileptic patients revealed a very high cysticercosis prevalence rate (44.6%) using antibody detection ELISA (Zoli *et al.*, 2003).

In the Upper East Region of Ghana, Permin and others (1999) conducted a post-mortem examination of 60 pigs from a population of free range animals from 10 villages and reported 11.7% of them were infected with cysticercosis (Table 5).

The most recent estimates shows that 6 central and west African countries are endemic for porcine cysticercosis with an estimated average prevalence of infection of 6.9% by post mortem meat inspection (Table 5). This figure is considered to be a real underestimation of actual data for the reasons already explained in relation to inefficiency of meat inspection in the preceding paragraphs above.

In West Africa, *T. solium* cysticercosis in man was first recorded in Ivory Coast (Bowesman, 1952). Later, Proctor *et al.* (1965) identified spinal cysticercosis as a major cause of paraplegia in Ghana. More recently, extensive studies were carried out in Togo and Benin in order to study the prevalence of the cysticercosis. Dumas and others (1989) reported 2.4 and 29.5% sero-positives for cysticercosis in the adult population and in epileptics of northern Togo, respectively. A prevalence of 10.8% was reported in hospitalised epileptic patients in the capital Lome (Grunitzky *et al.*, 1995). In Benin, nation wide surveys revealed that the overall sero-prevalence of cysticercosis in the general population was 1.3% with a significantly higher prevalence in men (1.9%) than in women (0.8%), and that the prevalence increased with increasing age (Houinato *et al.*, 1998). Obviously, higher sero-prevalence rates were found in non-muslim regions (up to 3.3%) than in muslim regions (up to 0.8%). The prevalence rate of epilepsy in Benin was 15.2 per 1000 which is comparable to the rate in Togo (16.7 per 1000) (Dumas *et al.*, 1989; Avodé *et al.*, 1998; Zoli *et al.*, 2003).

In Central Africa, Rwanda, has for along time been considered hyperendemic for taeniosis-cysticercosis (Brandt, 1997). The prevalence of *T. solium* cysticercosis in the human population is even higher than in some hyperendemic regions of Latin America. Cysticercosis was present in 7% of 300 autopsies carried out in regions of Butare (Vanderick and Mboroyingabo, 1972); this contrasts with 2.4% in a similar study in Mexico (Sarti *et al.*, 1992). Unfortunately, no recent figures are available for Rwanda, except the high percentage (21%) of sero-positives for cysticercosis among epileptics (Tsang and Wilson, 1995). In Burundi the sero-prevalence of human cysticercosis was determined to be 2.8% in the general population and 11.7% in the epileptics (Zoli *et al.*, 2003).

2.1.9 Porcine and human cysticercosis in South America

2.1.9.1 Porcine and human cysticercosis in Peru

Peru is a country in South America with a population of 24 million people (Garcia *et al.*, 2002). Cysticercosis was believed to be endemic in the highlands, and certain zones of the coast and jungle (Garcia *et al.*, 2002). The Cysticercosis Working Group in Peru conducted sero-surveys of people and pigs in 12 and 10 pig rearing communities, respectively, over the past 10 years (1988-1998). In Maceda by use of EITB test human seroprevalence was 8% and porcine seroprevalence 43% (Table 6). The survey found that very few houses had latrines. Furthermore, pigs and other domestic animals were raised free range and had access to human dwellings (Garcia *et al.*, 2002; Bern *et al.*, 1999).

In Haparquilla, the highland area, the survey found that pigs were mostly confined in the backyards. Human seroprevalence was found to be 13% and was comparatively higher than in the jungle communities. Porcine sero-prevalence was similarly higher (46%) (Garcia *et al.*, 2002; Bern *et al.*, 1999).

A survey in Salya, another community in the highlands, with the help of the local Mothers Club in the village, found that human and porcine seroprevalence were 24% and 36%, respectively. The risk factors associated with the presence of cysticercosis are free ranging pigs and backyard disposal of human faeces (Garcia *et al.*, 2002).

Table 6: Studies of cysticercosis sero- prevalence in pigs and humans among communities in Peru (1988-1998) as determined by EITB assays.

Area	Department	Proportions (%) seropositive		Prevalence ratio
		Humans	**Pigs**	**Human:Pig**
Large scale surveys				
Andahuaylas				
Urban	Apurimac	198/1529 (12.9)	Missing	
Rural	Apurimac	418/3443 (12.0)	36/1345 (27.0)	1:2
Huancayo				
Quilcas	Junin	275/1631 (16.9)	364/538 (67.7)	1:4
San Pedro	Junin	45/446 (10.1)	45/94 (47.9)	1:5
Canchayllo	Junin	33/468 (7.1)	30/71 (42.3)	1:6
Coto coto market	Junin	Missing	40/77 (51.9)	Missing
Community surveys				
Monteredondo	Piura	78/489 (16.0)	13/98 (13.0)	1:0.8
Pomabamba	Ancash	15/112 (13.4)	Missing	Missing
Central highland	Vichaycocha	72/334 (21.0)	Missing	Missing
Northern coast	Tumbes	(22.0)		
Haparquilla	Cuzco	14/108 (13.0)	51/110 (46.4)	1:4
Saylla	Cuzco	24/99 (24.0)	19/53 (36.0)	1:1.5
Haparquilla	Cuzco	14/108 (12.9)	38/98 (43%)	1:3.3
Maceda	San Martin	30/421 (8.0)	57/133 (43.0)	1:5
Churusapa	San Martin	9/134 (6.7)	43/87 (49.0)	1:7
La Matanza	Piura	Missing	6/20 (30.0)	Missing
Tupac Amaru	Junin	2/309 (0.6)	Missing	Missing
Urban shantytown1	Lima	1/98 (1)	Missing	Missing
Urban shanty town	Lima	0/250	Missing	Missing
Villages	Iquitos	0/200	Missing	Missing
Slaughterhouse	Lima	Missing	0/42 (0)	Missing

Source: Bern *et al.*, 1999 ; Garcia *et al.*, 1999 and Garcia *et al.*, 2002.

Another study was conducted in the endemic community, Monteredondo, situated in the coastal zone which established a seroprevalence of 13% and 16% cysticercosis in pigs and humans, respectively (Table 6). However, interestingly this time the seroprevalence in pigs (13%) was considerably less than human seroprevalence in the community and was also less than prevalence figures in porcine populations in other areas of the country (Table 6). The low prevalence in pigs was somewhat unexpected and the reason considered most likely behind the low prevalence was that the community began to grow rice 3 years before the survey. This led the villagers to tether pigs in order to protect the rice crop. The introduction of rice meant that for the first time the benefit accrued by tethering pigs outweighed the cost of feeding them. Therefore, at the time of the survey, all pigs were less than 3 years of age and were tethered; accordingly the sero-positivity proportion was low. Serological status of humans remained high since it represented the cumulative effects of exposure over a much longer period of time (Bern *et al.*, 1999; Garcia *et al.*, 2002).

Other community surveys have similarly described high seroprevalence rates in endemic communities within Peru. In Pomabamba, Ancash, the prevalence of 13.4% in humans was established, while in Vichaycocha, central highlands, 21% of examined persons were sero-positive (Garcia *et al.*, 2002).

Two large-scale surveys in Quilcas, Huancayo, and Andhuaylas (Apurimac, southern highlands) established sero-prevalence proportions of 27.0% and 67.7% in pigs, respectively. While the human seroprevalences for the two communities were 12.0% and 16.9%, respectively (Table 6) (Bern *et al.*, 1999; Garcia *et al.*, 2002).

In another study a serological survey was performed using the enzyme – linked immunoelectrotransfer blot assay [EITB] in a village in the highlands of Peru where there are three district but close neighbourhoods, to determine if there is a direct relationship between human and porcine *T. solium* infection. One hundred-eight out of 365 individuals were sampled, and 13% were seropositive. Most seropositive individuals were neurologically asymptomatic. Thirty-eight out of 89 sample pigs (43%) were seropositive (Garcia *et al.*, 1999) [Table 6]. The investigators observed that there was a clear geographical clustering of cases, and positive correlation between human and porcine seroprevalence was found when comparing the three neighbourhoods (Garcia *et al.*, 1999). In addition, a recent survey in Tumbes in the northern Coast, found 22% of individuals sampled to be seropositive (Garcia *et al.*, 2002). However, the total number of sampled persons was not stated.

It has been shown that the majority of pigs in *T. solium* endemic areas of Peru are marketed outside the official regulated system, which is supposed to remove infected carcasses from the human food chain. Pork vendors have been found to purposely bypass formal slaughterhouses and sell cysticercosis infected meat. Such meat, if improperly handled, can cause human infection (The Cysticercosis Working Group in Peru, 1993).

2.1.9.2 Porcine and human cysticercosis in other Latin American Countries

In the rural community of Cuentepec, Mexico tongue examination of 1,087 pigs revealed cysticercosis in 354 pigs making the overall prevalence of 33% which is very high considering that tongue inspection underestimates the real prevalence (Gonzalez *et al.*, 1990; Morales *et al.*, 2002; Sato *et al.* 2003; Dorny *et al.*, 2004). The most striking finding in this study was castrated males had significantly a higher prevalence than their counterparts (castration more than doubled the prevalence from 22 to 47%) and pregnant sows had a higher prevalence than non-pregnant ones (pregnancy more than doubled the prevalence: from 28 to 59%). The investigators were of the opinion that sexual hormones had a role in susceptibility of pigs to *T. solium*. As castration and pregnancy are accompanied with profound changes of androgens (in males) and progesterone and prolactin (in females) these hormones may be involved in susceptibility and resistance of pigs to *T. solium* infections, or perhaps through an, as yet, undefined requirement of cysticercus physiology (Morales *et al.*, 2002) (Table 7).

A serological prevalence survey in pigs in Bahia State, northeast Brazil, using an enzyme linked immuno-electrotransfer blot assay (EITB), found the seroprevalence of 4.4% (2 of 45) in Salvador, 3.2% (3 of 93) in Santo Amaro, and 23.5% in Jaque township (24 of 102) (Table 7). [Sakai *et al.*, 2001].

A significant high seroprevalence in Jaquie, Brazil was associated with poor sanitary conditions, such as an open sewer system and no inspection process of pork before marketing (Sakai *et al.*, 2001). This study showed that the transmission of cysticercosis is not restricted to rural areas where poor sanitary conditions, such as no toilets or latrines, are present. The authors reported that in Bahia, poor sanitary conditions and pig husbandry are commonly observed not only in rural areas, but also in urban areas, even in the capital. Residents who do not have latrines defecate outdoors, and water contaminated with filth from a dumping ground and/or a house latrine contaminates the environment heavily. Consequently, pigs roaming in these areas have access to human faeces and contaminated water because of their coprophagic and bathing behaviour (Sakai *et al.*, 2001).

Table 7: Frequency of porcine cysticercosis determined by ante mortem inspection, serology, or post-mortem meat inspection in South American countries apart from Peru.

Country/Study location	Survey population	No. observed	% positive	Reference
Mexico, Morelos	Rural village	571	4.0 (Tongue)	Sarti *et al.*, 1992
Mexico, Ixtlahuaca market	Pigs for sale in a market	269	9.66 (1.09, PM)	Flisser *et al.*, 1982
Mexico, Ixtlahuaca farms	Two farms	20	20.0 (Tongue)	Flisser *et al.*, 1982
Mexico, Almoloya farms	Seven farms	142	7.75 (1.38, PM)	Flisser *et al.*, 1982
Mexico, Atlacomulco farms	Three farms	26	30.8 (0.32, PM)	Flisser *et al.*, 1982
Mexico, San Felipe	Three farms	47	6.38 (Tongue)	Flisser *et al.*, 1982
Mexico, San Felipe	Isolated hamlets (n=7)	128	15.62 (Tongue)	Flisser *et al.*, 1982
Mexico, Yucan state	Rural community	75	23 (35%, EITB)	Rodriguez-Canul *et al.*, 1999
Mexico, Michoacan State	Rural community	216	6.5 (Tongue)	Sarti *et al.*, 1992
Mexico, Cuentepec	Rural community	1087	33 (Tongue)	Morales *et al.*, 2002
Mexico, Guerrero state	Tianquizolco village	151	13.0 (Tongue)	Flisser *et al.*, 2003
Guatemala , ElJocote (Rural)	Rural community	354	14.0 (Tongue)	Garcia-Noval *et al.*, 1996
Guatemala , Quesada, (Rural)	Rural community	117	4.0 (Tongue)	Garcia-Noval *et al.*, 1996
Guatemala	Santa Gertrudis	193	40.0 (EITB)	Allan *et al.*, 1997
Guatemala	El Tule	214	64.0 (EITB)	Allan *et al.*, 1997
Honduras, Promdeca	Promdeca abattoir (1981-1996)	366712	4.8 (PM)	Kaminsky, 1991
Hondurus, Olancho	Rural community, Salama	192	27.1(EITB)	Sakai *et al.*, 1998
Ecuador, Loja & El Oro	Loja and El Oro rural	1117	3.0 and 0.9% respectively	Cruiz *et al.*, 1989
Ecuador, Loja & El Oro	Gonzanama Canton	70	11.4, (PM)	Cruiz *et al.*, 1989
Bolivia,	Pigs from rural areas	193	38.9 (Tongue)	Tsang and Garcia, 1999
Bolivia, Chaco Region	Rural population	273	37 (Ag-ELISA)	Carrique-Mas *et al.*, 2001
Brazil, Bahia state	Salvador, capital state	45	4.4 (EITB)	Sakai *et al.*, 2001
Brazil, Bahia state	Santo Amaro town	93	3.2 (EITB)	Sakai *et al.*, 2001
Honduras	Agua Caliente	179	7.0 (Tongue)	Sanchez, 1991 unpublished data
Honduras	Salama county	192	27.0 (EITB)	Sanchez, 1999
Brazil, Bahia state	Jaque town	102	23.5 (EITB)	Sakai *et al.*, 2001

A survey of 100 rural households in a village in the Chaco of Bolivia revealed a serious problem of *T. solium* cysticercosis, with a seroprevalence of 99/447 [22%] in humans and 102/273 [37%] in pigs [Table 7]. Risk factors for humans were being in older age groups, absence of sanitary facilities, poor formal education and inability to recognise infected pork. Significant risk indicators were a history of seizures and the reported elimination of worms in the faeces (Carriques-Mas, 2001). Risk factors for pigs were being in older age groups and absence of sanitary facilities in the owner's house. The proportion of households with evidence of human cysticercosis was similar for those who owned pigs [48%] and those that did not [55%]. This unexpected findings was attributed to the high overall prevalence of cysticercosis in pigs and probability that everyone, regardless of pig-ownership, had ample opportunity to become infected in such communities (Carriques-Mas, 2001).

An interesting study conducted recently in Mexico is that by Morales and others (2002) in a rural setting of Cuentepec located in the state of Morelos. Noteworthy findings were that there is no public sewage in the community of 3000 inhabitants (Morales *et al.*, 2002). Most (95%) houses lack latrines and humans defecate around the household, on the streets, and nearby garbage dumps. Pigs are the primary source of meat. Pigs spend the night in their corrals but in the daytime, they are left to roam freely around the households, in the village streets and neighbouring fields, in search of food and 33.0% of observed pigs were found infected by tongue examination (Morales *et al.*, 2002). A study in Honduras by Sakai and others (1998) established a prevalence of 27.1% by the use of EITB test in 192 pigs though sero-positivity did not correlate with age or sex of pigs. The authors further said most of the pigs were kept under free range conditions in the community whereby they have access to human faeces. However, possible risk factors associated with disease presence in pigs were not established by the study.

The prevalence studies in other South American countries indicated that by using the EITB test significant numbers of pigs were infected (prevalence range 4.4 to 64.0%) (Table 7). In most of these countries pork consumed in the rural communities is from pigs raised locally and most pigs are slaughtered and eaten without any formal type of meat inspection to eliminate infected carcass. Based on information obtained from pig owners, the principal risk factors associated with infection in at least one pig in the household were histories of using the pig pen as a toilet and allowing pigs to run loose (Sarti *et al.*, 1992).

2.1.9.3 Porcine and human cysticercosis in Asia

2.1.9.3.1 Porcine and human cysticercosis in China

Current livestock statistics show that over 500 million domesticated pigs are kept in China. Among minority rural communities in Yunnan, Sichuan, Guizhou, Qinghai, and many other provinces, pigs are allowed to roam around the villages with free access to human faeces (Rajshekhar *et al.*, 2003). Recent national investigations in China have revealed that *T. solium* cysticercosis has been reported from 671 counties in 29 Provinces in China (Rajshekhar *et al.*, 2003). Five zones of high endemicity are as follows:

- First zone: Northeast China including Helongjiang, Jili, and Liaoning Provinces.
- Second zone: North China including Hebei, Neimonggol, and Shanxi Provinces.
- Third zone: Northwest China including Gansu, Ningxia, and Qinghai Provinces.
- Fourth zone: comprising Shandong, Henan, Anhui, Hubei, and Shaanxi Provinces.
- Fifth zone: comprising Guandong, Guangxi, Hainan, Yunnan and Sichuan Provinces.

Sporadic cases have also been reported from Jiangsu, Shanghai, Zhejiang, Fujian, Guizhou, Xinjiang, and Tibet. Among the factors associated with *T. solium* taeniosis/cysticercosis prevalence are preference for raw pork especially among the Bai, Yi and Pumi people and free foraging of pigs (Rajshekhar *et al.*, 2003). The infection rates of pigs in China is highly variable ranging from 0.84 to 15% and in some areas was found to be as high as 40% (Rajshekhar *et al.*, 2003).

Most epidemiological studies on human cysticercosis have, however, focused on the prevailing situation in Shandong Province of China. A sero-prevalence of 2.2% was noted using ELISA and in another study using the indirect fluorescent antibody assay, a sero-prevalence of 3.2% was found (Cao *et al.*, 1996). The sero-prevalence was found to be low in other provinces ranging from 0.02 to 4.3%. However, higher rates have been reported from the Pumi national area of Yunnan Province

(11.2%) and Guxi (9.5%). Recently it was estimated that there were at least 3 million patients with cysticercosis in China (Rajshekhar *et al.*, 2003).

2.1.9.3.2 Porcine and human cysticercosis in Nepal

Poudyal, (1998) did a survey of porcine cysticercosis in Metropolitan Kathmandu and Dharan Municipality by post-mortem meat inspection. Of the 250 pigs examined, 34 were found positive (13.6 % prevalence). Twenty-two samples (14.9%) were from Khichapokahri, six (12.5%) samples were from Koteshwor and six (11.1%) were from Dharan. The author associates the prevalence of disease with the close relationship of pigs with humans in rural areas where the pigs live practically in the house of the owner and feed on kitchen wastes and human excreta. Others risk factors were eating inadequately cooked pork, ignorance and use of sewer water for irrigation.

Data from the Christian Medical College Hospital, Vellore showed that 14 Nepalese patients were diagnosed with the Solitary Cysticercosis Granuloma (SCG) form of NCC in the five years between 1991 to 1995 (Rajshekhar and Chandy, 2002; Rajshekhar *et al.*, 2003). However, a diagnosis of cysticercosis was made in only 0.01 % (4/25033) of pathological specimens examined at Bir Hospital, Kathmandu between 1995 and 1997. In Patan Hospital, Lalitpur District, 62 of 23402 pathological specimens were diagnosed as cysticercosis (Rajshekhar *et al.*, 2003). These low figures are thought to be due to the fact that most patients with cysticercosis do not need surgical confirmation. The fact that seven of eight epileptic Gurkha soldiers (Nepalese) serving with the British Army in Hong Kong were diagnosed to have NCC provides evidence of the prevalence of the disease in parts of Nepal (Heap, 1990; Rajshekhar *et al.*, 2003).

2.1.9.3.3 Porcine and human cysticercosis in Indonesia

Major endemic areas for *T. solium* taeniasis/cysticercosis in Indonesia are North Sumatra, Bali and Irian Jaya. Endemic areas are also found in other islands, such as Timor, Flores, north Sulwesi, west Kalimatan, and south Sumatra (Simanjuntak *et al.*, 1997). In Irian Jaya, *T. solium* is endemic. In the early 1970s, health workers in west Irian Jaya noticed an increase of cases of burns in humans living in the Paniai Highlands resulting from epileptic seizures, possibly caused by neurocysticerosis (Simanjuntak *et al.*, 1997; Rajshekhar *et al.*, 2003). Based on a positive serological test using ELISA, 10 of 74 (13.5%) patients with epilepsy in Bali were diagnosed to have NCC (Margono *et al.*, 2001; Rajshekhar *et al.*, 2003). The sero-prevalence of cysticercosis has been reported to range from 2% in northern Sumatra to 48% in Irian Jaya (Simanjuntak *et al.*, 1997). However, a more recent survey performed in three villages of Bali, using the immunoblot, has revealed a sero-prevalence of 1.65% (6/363) (Rajshekhar *et al.*, 2003).

Another survey of 746 residents in four ecological groups of Bali found that 94 (13.0%) persons were positive by immunoblot (Rajshekhar *et al.*, 2003). In a survey of 160 human sera samples from 18 villages in Jaywijaya District of Irian Jaya, 81 (50.6%) were found to be positive by immunoblot (Subahar *et al.*, 2001;

Rajshekhar *et al.*, 2003). Thus, there seems to be considerable variability in the sero-prevalence of the disease in different parts of Indonesia (Rajshekhar *et al.*, 2003).

The risk factors associated with *T. solium* taeniosis are eating infected raw or rare roasted pork (Fan *et al.*, 1997) while that of cysticercosis in children around the age of 3 years is due to consumption of raw sweet potatoes contaminated with eggs of *T. solium* (Simanjuntak *et al.*, 1997). Others are defecation of local people in the environment in the process contaminating water and soils with eggs/proglottids of *T. solium.*

2.1.9.3.4 Porcine and human cysticercosis in Vietnam

A survey of porcine cysticercosis in Hanoi slaughterhouses by looking at secondary data found out that of 2,091,000 pigs examined 836 were infected making the overall prevalence 0.04%. The common localization sites for the cysts were: eye: 31%, jaw: 14.2%, throat: 12.2%, tongue: 9.3%, shoulders: 8.3%, back: 6.0%, neck: 6.3%, chest: 5.3%, rump: 4.6%, and diaphragm: 2.3% (with 1,067 cysts per 10.11 kg pork).

The local people have the habit of eating raw pork and allowing pigs to freely roam about to feed around the house where hygienic conditions are below the normal standard (Ito *et al.*, 2003; Willingham *et al.*, 2003).

In a study of patients attending the National Institute of Malariology, Parasitology and Entomology (NIMPE) in Hanoi, Vietnam, 633 cases of NCC were diagnosed out of 4017 patients (15.8%) managed there between 1996 and 1997 (Simanjuntak *et al.*, 1997). These cases were diagnosed with CT scanning of the brain. A number of patients with NCC had live cysts in the brain and 30% patients with NCC were found to have taeniosis. Several patients were reported to have subcutaneous cysts (Rajshekhar *et al.*, 2003).

2.1.9.3.5 Porcine and human cysticercosis in India

In a study performed in the northern Indian state of Uttar Pradesh between 1980 and 1985, 3,550 pig carcasses were screened for cysticercosis and 9.3% were found to be positive for infection (Pathak and Gaur, 1989).

Human cysicercosis is widely distributed in India. The disease is prevalent in virtually all states of the country although it varies significantly between different states (Rajshekhar and Chandy, 2002). There are few reports of patients with cysticercosis from Jammu and Kashmir, a predominantly Muslim state, and Kerala where educational levels and hygienic standards are probably the highest in the country (Simanjuntak *et al.*, 1997).

There are certain unique features of the disease in India. The solitary form of the disease (solitary cysticercus granuloma, SCG) is the commonest presentation of the disease and is seen in nearly 2/3 of all the patients with NCC. Anywhere between

26 and 50% of all Indian patients presenting with partial seizures are diagnosed with a SCG on the CT scan (Simanjuntak *et al.*, 1997). The other unusual feature of the disease is the low proportion of pork eaters amongst Indian patients with NCC. Less than 1-2% of patients with NCC admit to eating pork (Simanjuntak *et al.*, 1997). More than 95% of Indian patients with NCC are vegetarians or do not consume pork (Simanjuntak *et al.*, 1997). Serological assays using the enzyme linked immunotransfer blot (EITB) revealed exposure to the disease in 21.5% of 107 neurological patients attending a hospital in Mumbai (Tsang and Garcia, 1999). Data on the prevalence of porcine cysticercosis in India are not easily available (Rajshekhar *et al.*, 2003).

2.1.9.3.6 Porcine and human cysticercosis in South Korea

A serological assay of 2.667 randomly selected patients with epilepsy was performed using enzyme linked immunosorbent assay (ELISA) (Kong *et al.*, 1993). Overall a positive rate of 4% was noted with patients from Cheju Do having the highest rate of 8.4%. Furthermore, 2.1% of normal people who were undergoing a routine medical check up were found to be serologically positive for exposure to cysticercosis. This study performed between 1987 and 1990 and published in 1993 revealed for the first time the prevalence of the disease both in the epileptic and normal population of South Korea (Rajshekhar *et al.*, 2003). Data on the prevalence of porcine cysticercosis in South Korea are not available (Rajshekhar *et al.*, 2003).

2.1.9.3.7 Other countries in Asia

The presence of cysticercosis in Hong Kong is well recognized in clinical articles (Rajshekhar *et al.*, 2003). In Thailand one report on CT scan findings in 132 patients with NCC in 1989, among which 45 (34.1%) were found to have a SCG (Bhoopat *et al.*, 1989; Rajshekhar *et al.*, 2003). More recently Yodnopaklow and Mahuntussangapong (2000) found a SCG in 20 of 972 (2.1%) patients presenting with epilepsy in Thailand. Reports of patients with NCC have been presented from other countries in Asia such as Japan and Oman (Rajshekhar *et al.*, 2003). But most of these patients are expatriates or have had a history of travel to endemic regions (Rajshekhar *et al.*, 2003).

2.2 Diagnostic techniques in porcine cysticercosis and human taeniosis

2.2.1 Antemortem tongue examination, post-mortem and serological techniques for porcine cysticercosis

In endemic countries, porcine cysticercosis is commonly diagnosed by tongue examination, which is very specific but has low sensitivity (Gonzalez *et al.*, 1990; Sato *et al.*, 2003; Dorny *et al.*, 2004). In Peru Gonzalez and others (1990) studied 77 pigs from Huancayo an endemic area for cysticercosis. By the use of tongue examination 23.4% of the pigs were found positive while by necropsy 31.2% were positive and 51.9% by EITB test. Calculated sensitivity for lingual examination, Ab-ELISA and EITB were 70.8%, 79.2% and 100% respectively. While the specificities were 100% for lingual examination, 76.2% for Ab-ELISA and 100% for EITB. All the 42 animals from Lima, a non-endemic area, were negative by both tongue and EITB tests however. 23.8% were positive by ELISA technique (Gonzalez *et al.*, 1990). Porcine serology does not correlate perfectly with necropsy, and often returns positive results when necropsy is negative (Gonzalez *et al.*, 1990). The EITB assay, however, is highly specific since pigs from *T. solium* non-endemic areas are serologically negative. A positive result in the face of a negative necropsy could result from either exposure to *T. solium* infection, such as a past infection that has cleared, or from a very light infection missed at necropsy or due to improperly conducted post-mortem inspection (Gonzalez *et al.*, 1990).

In Tanzania, Sato and others (2003) studied 100 pigs from endemic Mbulu District in 1998. Of 100 pigs 50 were tongue negative and 50 tongue positive for cysticercosis. The study revealed that 76% of tongue inspection positive pigs and 34% of tongue inspection negative pigs were seropositive by ELISA using glycoproteins (GPs). The sensitivity of serology from tongue positive pigs was found similar to that found by Gonzalez and others (1990) in Peru. The most important finding from the study was approximately 34% of tongue negative pigs were seropositive and consequently are suspected to have been infected with cysticerci of *T. solium* even though no post-mortem inspection were conducted. In addition approximately 76 and 78% of tongue positive pigs and 34 and 18% of tongue negative pigs were serologically confirmed to be infected with cysticerci of *T. solium* by ELISA and immunoblot using GPs, respectively. Similarly, approximately 64 and 68% of tongue positive pigs and 36 and 28% of tongue negative pigs were confirmed to be infected with cysticerci of *T. solium* by ELISA and immunoblot using recombinant chimeric antigens (RecTs).

Tongue examination, although specific, is only moderately sensitive, requires highly trained personnel, is time-consuming and there is a risk of being bitten. However, it is relatively inexpensive and gives immediate results. The immunoelectrotransfer blot (EITB, Western Blot) assay is highly specific, and is more sensitive than necropsy or tongue examination. Therefore, it is most suited for use in field surveys. Pigs can be bled rapidly from the jugular vein, a task which requires less training, and involves less danger for the operator than does the examination of tongue. Post-mortem pork inspection is of limited use for epidemiological studies, because in endemic countries most pigs are killed at unofficial slabs/places on a pre-purchase order basis (The Cysticercosis Working Group in Peru, 1993).

2.2.2 Diagnosis of *T. solium* taeniosis/cysticercosis

2.2.2.1 Parasitological diagnosis of taeniosis

The parasitological diagnosis of human taeniosis is made by finding eggs or segments in the stools, and can be demonstrated by direct microscopic examination. Techniques include: demonstration and counting of primary uterine branches in gravid proglottids and microscopic demonstration of eggs in faeces. However, direct microscopy is known to be relatively insensitive as eggs usually appear in small numbers in faeces or may be irregularly distributed in the sample, within portions of the detached proglottids, which, if partially digested could be easily overlooked (Pawlowski, 2002). Also, eggs can be periodically absent from faeces during infection. If a gravid proglottid is found in faeces then the standard method for differentiating between *T. solium* and *T. saginata* is to count the number of primary uterine branches and the differences between the two species are as shown in Table 1 (Pawlowski, 2002).

If one is lucky and can obtain the scolex then the two tapeworms can be differentiated by *T. solium* having a scolex armed with suckers and hooks, while that of *T. saginata* has suckers and no rostellum and no hooks (Pawlowski, 2002). However, this can be of little diagnostic value as intact scolices can rarely be found after treatment with modern anthelmintics, which can cause considerable damage to the worm (Pawlowski, 2002).

Microscopy is used whereby visual demonstration of *Taenia* eggs in faeces is performed; however the method is not specific because *T. solium* and *T. saginata* eggs appear identical. Another disadvantage of microscopy is that it has a very low sensitivity for example a study conducted in Vietnam has shown that only 10% of cases can be detected (Willingham *et al.*, 2003). Examination of several faecal samples collected during an interval of 2 or 3 days, as well as the use of an egg concentration technique, increases the sensitivity of the parasitological examination. The egg concentration technique developed by Ritchie (1948) is generally considered the most sensitive concentration method for this diagnosis.

2.2.2.2 Immunodiagnosis of taeniosis

To overcome the low sensitivity of coproparasitological techniques which depend on the presence of eggs in faeces, immunological and molecular techniques to demonstrate cestode intestinal infections in the definitive host have been attempted for many years (Chapman *et al.*, 1995; Flisser *et al.*, 1988; McManus *et al.*, 1989; Dorny *et al.*, 2003). Detection of *Taenia*-specific antigens in human host faeces is currently the most sensitive diagnostic technique for taeniosis. Coproantigen (CoAg) assays are based on capture-type enzyme-linked immunosorbent assays (ELISAs) with polyclonal antisera raised against either worm somatic or excretory-secretory products (Allan *et al.*, 1990; Allan *et al.*, 1992; Dorny *et al.*, 2003). The specificity of the coproantigen test for *Taenia* infection is above 99% which should make it applicable in most endemic areas (Allan *et al.*, 1996a), though the test can not distinguish between *T. solium* and *T. saginata*. Extensive field studies in Mexico, Guatemala, and China have shown that the coproantigen test detects up to 2.5 times as many cases of taeniosis as microscopy (Allan *et al.*, 1996b; Garcia-Noval *et al.*, 1996; Schantz *et al.*, 1995; Dorny *et al.*, 2003).

Wilkins and others (1999) developed a serological assay to identify adult *T. solium* tapeworm carriers using excretory/secretory (TSES) antigens collected from *in vitro* cultured *T. solium* tapeworms. Using serum samples collected from persons with confirmed *T. solium* tapeworm infections, the test was determined to be 95% [69 of 73] sensitive. Serum samples [n=193] from persons with other parasitic infection, including *T. saginata* tapeworm infections, do not contain cross-reacting antibodies to TSES, indicating that the assay is 100% specific. The report suggests that the immunoblot assay using TSES antigens can be used to identify persons with current or recent *T. solium* tapeworm infections and provides a new, important tool for epidemiological purposes, including control and prevention strategies.

2.2.2.3 Immunodiagnosis of cysticercosis

The development of improved immunodiagnostic tools has contributed to our knowledge on the importance of taeniosis/cysticercosis by enabling sero-epidemiological surveys and community-based studies to be carried out (Dorny *et al.*, 2003). Immunodiagnostic techniques include detection methods for specific antibodies and for circulating parasite antigens in serum or cerebrospinal fluid (CSF) (Harrison *et al.*, 1989; Dorny *et al.*, 2003). Serological tools may be applied on humans and pigs in epidemiological studies and for diagnosis of NCC in humans.

2.2.2.4 Antibody detection methods

Infection with *T. solium* results in a specific antibody response, mainly of the IgG class (Dorny *et al.*, 2003). Some patients have IgM, IgA and IgE classes (Goodman *et al.*, 1999), however, these subclass responses are less common than IgG (Carpio *et al.*, 1998). It is possible that most infected hosts produce multiple antibodies of different specificities, which appear at different intervals after infection, apparently in response to the quantitative and qualitative changes in excretory, secretory and somatic antigens released during various phases of parasitic development (Schantz, 1996; Dorny *et al.*, 2003).

Antibody detection techniques for *T. solium* in man and pigs include the complement fixation test, hemagglutination, radio immunoassay, enzyme-linked immunosorbent assay (ELISA), dipstick-ELISA, latex agglutination and immunoblot technique (Dorny *et al.*, 2003). Antigens used in these tests are either cyst fluid or crude homogenates of *T. solium* cysticerci or crude preparations of the related parasite *T. crassiceps*, which can be maintained in laboratory rodents (Dorny *et al.*, 2003). These unpurified antigens have sensitivities and relatively poor specificities (Schantz and Sarti, 1989; Dorny *et al.*, 2003). Research on the antigenic properties of cyst fluid and surface associated glycoproteins, and improved protein purification techniques have resulted in much more reliable serological tools (Gottstein *et al.*, 1986; Harrison *et al.*, 1989; Parkhouse and Harrison, 1987; Tsang *et al.*, 1989; Ito *et al.*, 1998; Dorny *et al.*, 2003).

The most specific test developed is the enzyme-linked immunoelectrotranfer blot (EITB), an immunoblot of seven cysticercus glycoproteins, purified by lentil lectin-purified chromatography, which gives close to 100% specificity and sensitivity varying from 70 to 90% (Tsang *et al.*, 1989). However, a sensitivity of only 28% has been found in cases with single cysts in the brain (Wilson *et al.*, 1991). This EITB has been widely used for the diagnosis of cysticercosis in human and pig serum samples (Tsang *et al.*, 1991). In developing countries, ELISA is preferred because of its better availability, simplicity and lower cost compared with immunoblot (Rosas *et al.*, 1986; Dorny *et al.*, 2003).

Recently, purification of glycoproteins from cyst fluid by single–step preparative isoelectric focusing was shown to produce very specific antigens, which are applicable both in immunoblot and ELISA (Ito, 2002). With this ELISA, antibody responses were detectable in experimentally infected pigs harbouring 16 or more cysts (confirmed at necropsy) from 30 days after experimental infection. The assay appears to be species- specific since pigs naturally infected with the metacestode stages of *T. hydatigena* were negative by ELISA (Sato *et al.*, 2003).

Since the preparation of purified antigens relies on the availability of parasitic material and may be subject to the quality of this material, attempts were made to produce recombinant antigens (Dorny *et al.*, 2003). Different authors synthesised 10, 7-10 and 14 kDa recombinant polypeptides that can be used in immunoblot and ELISA (Chung *et al.*, 1999; Sako *et al.*, 2000). While the specificity of these antigens is reported to be high, the sensitivity is generally lower than with the native antigens (Dorny *et al.*, 2003).

2.2.2.5 Antigen detection methods

Antibody detection has two important drawbacks in clinical settings:

- It may indicate exposure to infection and not necessarily the presence of an established, viable infection, resulting in transient antibodies (Gonzalez *et al.*, 1999; Garcia *et al.*, 2001).

- Antibody may persist long after the parasite has been eliminated by immune mechanisms and/or drug therapy (Harrison *et al.*, 1989; Garcia *et al.*, 1997; Gonzalez *et al.*, 2001).

In endemic villages, up to 10% or more of the general population may have antibodies to *T. solium*, not necessarily reflecting the true prevalence of cysticercosis, and leading to misdiagnosis in a proportion of neurological cases (Bern *et al.*, 1999). Detection of anti-parasite antibodies in a patient may lead to unnecessary use of antiparasitic therapy in cases where the parasites are not viable (Garcia *et al.*, 2000).

Antigen detection may provide a suitable alternative. It may also provide a tool for serological monitoring of anti-parasitic therapy. Several assays have been developed to detect parasite antigens, but only the monoclonal antibody-based tests directed at defined parasite antigens may ensure reproducibility and specificity (Correa *et al.*, 1989; Harrison *et al.*, 1989; Brandt *et al.*, 1992; Choromanski *et al.*, 1990; Wang *et al.*, 1992; Erhart *et al.*, 2002; Dorny *et al.*, 2003).

Antigen detection may be done on serum as well as on CSF (Choromanski *et al.*, 1990; Garcia *et al.*, 1998, 2000; Dorny *et al.*, 2003). Because of the localisation of the cysts in the brain, antigen detection in CSF may be more appropriate for diagnosis than in serum; however, sampling of CSF is more cumbersome than blood sampling (Dorny *et al.*, 2003).

The sensitivity and specificity of antigen detecting ELISA is found to be high with reported values of 86.7% and 94.7%, respectively (Dorny *et al.*, 2000; Dorny *et al.*, 2004). Garcia and others (2000) found a sensitivity of 85%, which is the second highest from that recorded at present by Dorny and others (2004), however, in their data set only patients who were seropositive on EITB were selected. The sensitivity in patients with a single viable cyst or only enhancing lesions was 65% (Garcia *et al.*, 2000). Erhart and others (2002) found a very high agreement between an ELISA for detecting circulating antigens, computerised tomography scanning and biopsy examination of subcutaneous cysticerci. Remarkably low levels of cross-reactions were observed in serum samples from a wide range of helminths and protozoan infections (Harrison *et al.*, 1989; Erhart *et al.*, 2002). However, the genus specificity of the test does not allow differentiation between metacesode infection of *T. solium* and *T. hydatigena* in pigs (Dorny *et al.*, 2003).

2.2.2.6 Immunodiagnostic tools in epidemiological studies

In man, no clinical features are specific for cysticercosis, even asymptomatic brain lesions are not uncommon, and imaging methods are not available for epidemiological studies; therefore, definition of cases is based solely on immunodiagnostic methods (Flisser, 2002). In surveys on cysticercosis, immunodiagnostic tools applied on human and pig serum samples are useful in estimating the prevalence and identifying the risk factors associated with transmission of *T. solium*, a high sero-prevalence in a community indicating a 'hot spot' where preventive and control measures should be applied (Garcia-Novel *et al.*, 1996; Subahar *et al.*, 2001; Dorny *et al.*, 2003). Immunodiagnostic tools also offer the possibility of surveillance of the infection during and after control programmes (Garcia *et al.*, 2000; Sarti and Rajshekhar, 2003; Varquez-Flores *et al.*, 2001; Dorny *et al.*, 2003).

In pigs, the benefits of immunodiagnosis are:

- tests offer diagnosis on live animals;
- blood sampling followed by serological testing is more sensitive than the classical tongue examination; and
- the tests are relatively inexpensive and easy to perform on large numbers of serum samples.

However, there are some problems related to serodiagnosis in pigs:

- it has been reported that the sensitivity of the available technique [EITB] is low in pigs with low levels of cyst burdens (Sciutto *et al.*, 1998), although other authors (Nguekam *et al.*, 2003) were able to detect pigs harbouring single cysts using an Ag-ELISA;
- when measuring antibodies, antigen exposure is measured rather than actual infection;
- interpretation of sero-positive results in young pigs may be complicated by the fact that maternal antibodies transferred by colostrum from a seropositive sow to its piglets may persist for up to seven months. This has to be considered in studies that examine the prevalence of cysticercosis in pigs (Gonzalez *et al.*, 1999; Dorny *et al.*, 2003).

- as in humans, the problem of transient antibodies may have to be considered also in pigs, *i.e.* a transient antibody response to a *T. solium* infection without the establishment of a patent infection; and
- cross-reactions with *T. hydatigena* are rather the rule than the exception in most antibody and antigen detecting tests (Dorny, 2003).

In man, the occurrence of a transient antibody response to *T. solium* infection in field conditions was found to be a major contributor to the overestimation of the prevalence of cysticercosis in endemic areas. Review of longitudinal serologic data from serological surveys in endemic areas of Peru and Columbia demonstrated that about 40% of seropositive people were seronegative when resampled after one year. This may also be the case in pigs (Garcia *et al.*, 2001; Dorny *et al.*, 2003).

2.3 *Taenia solium* environmental contamination evaluation

Several epidemiological studies conducted so far have failed to recover *T. solium* eggs from the environment using standard laboratory methods. In Peru, Diaz and others (1992) took 5 samples of river water obtained at different points which were pumped through a 0.10 micron nylon filter. The water quantity varied between 50-100 gallons depending on the amount of sediment present in water. In addition, five soil samples were taken near the edge of stool pits or latrines and examined for the presence of *Taenia* species eggs using sedimentation techniques. None were found positive for *T. solium* eggs (Diaz *et al.*, 1992). The authors of the paper were of the opinion that direct detection of eggs in the environment is extremely difficult because *Taenia* eggs are scarce and large amounts of soil have to be processed and examined microscopically to find a single egg (Keilbach *et al.*, 1989; Sarti *et al.*, 1988).

In Mexico, Martinez and others (2000) caught 1,187 flies using entomological nets in the kitchens of different homes located in the village of Tianquizolco, Gurrero State and examined all the guts of 1,187 flies and 1,080 legs for the presence of *Taenia* sp. eggs. Of the total 1,187 flies caught, 1,174 (98.9%) were *Musca domestica* (house fly). The rest belonged to other genera. The findings were that no *Taenia* and other parasite eggs were found in any of the 1,187 guts or on the 1,080 legs examined from the 1,187 flies. The study failed to demonstrate that flies are mechanical vectors of *T. solium* eggs, disagreeing with the findings of Lawson and Gemmell (1985) who demonstrated the importance of these insects in the transmission of eggs of *T. ovis* and *T. hydatigena*. The behaviour of pigs in the rural community of Huancayo, Peru, were studied and results showed that the time between defecation by human beings and ingestion of faecal material by pigs is very short (Prof. Gonzalez, A.E. personal communication, 2002). For this reason, flies may have only a limited time available to feed on human faeces. On the other hand pigs do not feed on faeces produced by other domestic animals, which gives the flies greater access to this material. However, the situation is quite different in the case of *T. ovis* and *T. hydatigena*, because dogs defecate in fields in the absence of immediate coprophagic animals like pigs. For this reason the surroundings are contaminated with parasites eggs with the subsequent possibility of their distribution by insects and wind (Lawson and Gemmell, 1989).

In Michoaca, Mexico a search of *Taenia* spp eggs in non-washed strawberries from Irapuato, Guanajuato and Zamora was conducted by Felix and others (1996). In total 168 samples collected over one year were analysed and the results were negative for *Taenia* spp eggs. The study suggested that strawberries and other vegetables irrigated possibly with sewage are not main risk factors for acquiring cysticercosis (Flisser, 1994; Felix *et al.*, 1996).

A recent study on environmental contamination in Bac Ninh Province of Vietnam found that two out of 100 soil samples examined contained *Taenia* eggs (De *et al*, 2001).

From the above sited literature on environmental evaluation for *T. solium* eggs using different methods we have realised that direct detection of eggs in the environment is extremely difficult because *Taenia* species eggs are scarce because large amount of soil must be processed and examined microscopically to find a single egg.

Since pigs become infected only by ingesting eggs from human faeces, pig infection rates must, therefore, reflect the relative amount of *T. solium* eggs in the environment. A team of researchers from Peru picked on this idea and used sentinel piglets to determine environmental contamination with *T. solium* eggs in a disease endemic zone in Peru. Twelve sentinel piglets from an area where the disease is not present were tested using the EITB test at two months of age, moved to an area where the disease is endemic, and retested at the age of nine months. Sentinel piglets native from this *T. solium* – endemic area were also tested concurrently at two and nine months of age. Of the non – native pigs, 33% [4 of 12] acquired new infection. Of the 28 native pigs tested, 64% [18 of 28] acquired the infection. In a subset of native piglets from sero-negative sows, 44% [4 of 9] were infected at five months of age. The researchers concluded that sero-diagnosis of sentinel piglets is a practical method to detect *T. solium* eggs in the environment (Gonzalez *et al.*, 1994).

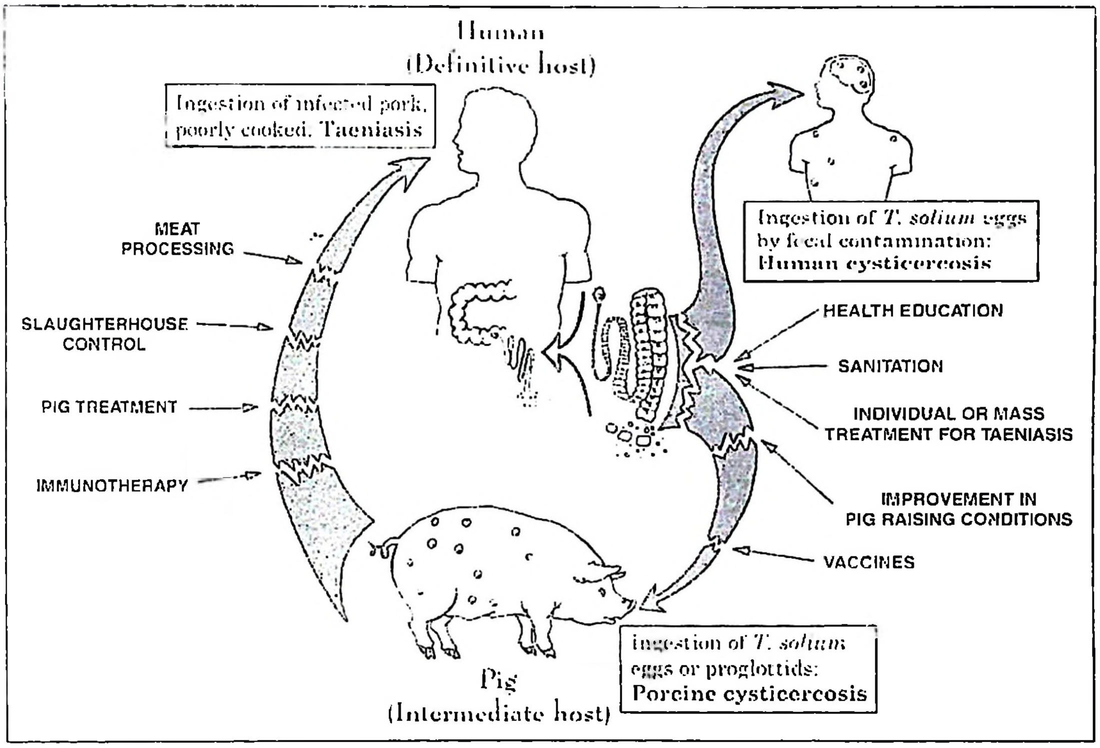
Drinking from water streams carrying the effluent from sewage treatment plants was found to be an important risk factor for bovine cysticercosis (Kyvsgaard *et al.*, 1991). The authors also observed that a small risk was associated with cattle drinking from streams with sewage outlets from single households. However, herds with cattle grazing next to these streams but without the possibility of drinking were not found to have an elevated infection risk. Similarly, Pawlowski (1982) found that the frequency of cysticercosis was higher downstream from a sewage outlet than upstream.

The observed risk was interpreted as increased transmission of *T. saginata* eggs (Kyvsgaard *et al.*, 1991). There is evidence that retention times in sewage treatment plants are insufficient for sedimentation of *T. saginata* eggs (Arundel and Adolph, 1980) and these will consequently pass with the effluent to the streams. The concentration of eggs in the stream depends on the distance from the effluent outlet. Investigations where sewage effluent possibly had caused massive outbreaks discovered that cattle were drinking close to the sewage outlet (Holt, 1985; Ilsøe *et al.*, 1990). When the effluent is diluted the eggs from even a single tapeworm can be spread to a large number of cattle resulting in geographically widespread but usually low-grade infections (Kyvsgaard *et al.*, 1991). Massive bovine cysticercosis outbreaks have been observed after sewage contractors have emptied septic tanks immediately before the spreading of liquid manure with the same machinery on to pastures (Nansen and Henriksen, 1986; Ilsøe *et al.*, 1990).

A small but significant risk was associated with harvest of fresh grass for feeding cattle in the stable. This explanation, proposed by the authors with scepticism, suggests that the risk is associated with the mechanical harvest preventing the cattle from their normal selective grazing behaviour (Kyvsgaard *et al.*, 1991).

2.4 Prevention and control of taeniosis and cysticercosis

For the life cycle of *T. solium* to be completed, pigs must be exposed to human faecal material containing *T. solium* viable eggs, and undercooked infected pork ingested by humans (Fig.1). Cysticercosis and taeniosis are diseases of poverty and social under-development. Human cysticercosis may be prevented by the provision of sanitation, treatment of tapeworm carriers, enforcing meat inspection and properly cooking pork.



Biologic cycle of Taenia solium and alternatives for its control.

Figure 1: Biological cycle of *T. solium* and alternatives for its control such as adequate cooking of pork, total confinement of pigs in pig sties and improved sanitation.

Source: Schantz, 1999.

Such improvements in public health and animal husbandry have led to the virtual eradication of human and porcine cysticercosis in wealthy countries (Shandara *et al.*, 1994; Anonymous, 2000) but these measures are difficult to implement in less developed rural areas (Evans *et al.*, 1995). Most of the pigs raised in these rural settings in endemic areas are slaughtered and the pork consumed without inspection. This makes control measures to prevent human consumption of infected pork impractical and currently inadequate in endemic areas (Boa, personal observations; The Cysticercosis Working Group in Peru, 1993; Phiri *et al.*, 2003). In Peru, it has been demonstrated that in slaughterhouses where control and confiscation are not conducted, rates of infection among pigs may be as high as 23% (The Cysticercosis Working Group in Peru, 1993).

A series of specific control measures, in addition to slaughterhouse inspection, must be considered to avoid human and swine infection with *T. solium*. One possibility is to purchase infected pork at a normal price and treat it by boiling it adequately, over 77 ^{0}C for two and a half hours, so that it can be sold to public institutions for consumption. In this way farmers will be encouraged to take even infected pigs to the formal markets because there is no risk of confiscation (Robinson, 1978).

2.4.1 Control by health education and mass chemotherapy in humans

Other proposed strategies for control emphasize eliminating egg dissemination in the environment by using community health education (Schantz *et al.*, 1993; Sarti *et al.*, 1997) and mass human chemotherapy (Diaz-Camacho *et al.*, 1991; Bryan, 1992 and Pawlowski, 1987). However, sustainable control has not yet been achieved. This strategy is based on the assumption that if egg dispersion is stopped, then the disease cycle will be broken. These measures were successfully used with other animal cestodes such as *Echinococcus granulosus*. Consequently, this approach was proposed and used as a model for controlling *T. solium* cysticercosis (Cruiz *et al.*, 1989; Gemmell *et al.*, 1983). However, as pointed out by Lawson and Gemmell (1989), field trials and control programmes demonstrate that ovine echinococcosis (*E. granulosus*) and cysticercosis (*T. hydatigena* and *T. ovis*) have different stabilities and do not respond in the same way to control. In the endemic state *T. hydatigena* is readily transformed by dog-dosing programmes to an extinction status. In contrast, *T. solium* cysticercosis, which is usually in the hyperendemic state, may only be transformed to the endemic state. Furthermore, other crucial aspects were neglected in the mass treatment strategy. Human taeniosis is not easy to treat (Gilman *et al.*, 1999).

There is also a theoretical risk of a temporary increase in human and porcine cysticercosis infection during taeniosis treatment campaigns if disposal of stools is not carefully controlled; a study performed in Mexico found that swine cysticercosis prevalence increased from 6.6% to 11% one year after mass chemotherapy (Keilbach *et al.*, 1989). That means human treatment led to heavy environmental contamination with *Taenia* eggs due to improper disposal of faeces and consequently free ranging pigs frequently had more access to faeces/environments with *Taenia* eggs thus the increased prevalence of porcine cysticercosis after mass treatment of human for taeniosis.

2.4.2 Control by treatment of infected pigs

Effective treatment of infected pigs is the next logical step for controlling this disease, and should, therefore, be considered an important cost-effective addition to control programmes. As humans can only become infected with the adult stages of this parasite when they eat contaminated pork, treatment of pigs prior to slaughter may block a key step in the transmission cycle of cysticercosis. Several drugs have been tested for the treatment of porcine cysticercosis. Early efforts with flubendazole (Tellez-Giron *et al.*, 1981) were followed by testing different dosages of praziquantel in therapies lasting 15 days, with variable efficacy (Flisser *et al.*, 1990). A single dose of praziquantel was later reported to kill all cysts in 10 out of 17 pigs (Torres *et al.*, 1992).

A group in Peru demonstrated that albendazole therapy is effective for porcine cysticercosis when given as a three-day scheme but the need for multiple does makes this regime impractical for use in the field control programme. Furthermore, although the cysts were not viable, the meat was measly and unattractive as a food product. The Peru group considered that if the pigs could be treated a few months before slaughter the cysts would disappear and the meat would be aesthetically acceptable. The group later introduced a trial with oxfendazole as the first effective, cheap, single-dose treatment for swine cysticercosis given at 30 mg/kg (Gonzalez *et al.*, 1996; Gonzalez *et al.*, 1997). The meat after oxfendazole treatment was clean and only minute scars were observed in all treated pigs 8 to 10 weeks post treatment. The appearance of the meat was found suitable for marketing, and no apparent differences in taste were found compared to pork sold in Lima markets, as tested by organoleptic trials in an expert panel (Gonzalez *et al.*, 1996).

Further trials with oxfendazole have demonstrated that pigs with cysticercosis, once treated with oxfendazole, are protected from new infections for at least 3 months. In field conditions, most pigs live approximately nine months (Gonzalez *et al.*, 2003). Cysts take about two months to develop, so it is reasonable to assume that pigs will be infective only after 3-4 months of age. Thus, if positive pigs are treated at 3-4 months of age, cured pigs will not be re-infected until at least seven months of age, and it is very probable that this protection will extend for longer periods and thus cover the remaining lifetime of the pig (Gonzalez *et al.*, 2003). In *T. saginata* cysticercosis, successfully treated cattle remained immune to re-infection for at least 6 months and presumably this might also be the case in *T. solium* infection in pigs (Gonzalez *et al.*, 2001).

Humans can only become infected with the adult stage of *T. solium* when they ingest contaminated pork. Thus, treatment of pigs prior to slaughter may block a key step in the transmission cycle of cysticercosis. Better market prices for treated pork and access to the formal marketing system will be strong incentives for farmers to treat their animals, and community cooperation will be ensured. Until a vaccine for porcine cysticercosis is available, treatment of infected pigs is a logical approach for controlling the disease, and should therefore be considered an important, cost-effective addition to control of cysticercosis.

2.4.3 Control by pork inspection

Human infection can be avoided by preventing the sale and consumption of *T. solium* infected meat (Gemmell *et al.*, 1983). In the past, the World Health Organization (WHO) suggested that control programms would be successful if inspection of pig carcasses in slaughterhouses was rigourously enforced (Gemmell *et al.*, 1983). This strategy has failed miserably in most developing countries, for two interrelated reasons: First, instituting a policy in which pigs that are detected to have cysticercosis are confiscated without payment to the pig's owner leads to the establishment of a clandestine market for pigs that may be infected with cysticercosis. In most countries, if porcine cysticercosis is detected, the carcass is confiscated without payment to the peasant or in Tanzania the farmer is expected to cover the cost of making the meat harmless to people by burning or burying the infected carcass. In Peru, it is estimated that 55% of all pigs are illegally slaughtered, and this figure is close to 100% in many rural areas (The Cysticercosis Working Group in Peru, 1993). For instance, in Huancayo, Peru, only 30 pigs of an estimated 35,000 pigs were killed at the slaughterhouse even though nearly all pigs were killed within their first year of life (The Cysticercosis Working Group in Peru, 1993). Secondly, targeting slaughterhouses as the primary intervention fails to influence the animal husbandry practices which occur before the pigs are brought to market. The policy of slaughterhouse inspection is effective only in non-endemic areas or with commercial piggeries both situations where the vast majority of pigs are free of cysticerci of *T. solium*. Farmers will most likely use the slaughterhouse under these conditions since there is low risk of infection and thus confiscation. Again in Peru, it has been shown that small slaughterhouses in outlying regions are not likely to practice control and confiscation in order to attract business from the areas' piggeries. The rates of infection among pigs killed at these slaughterhouses may be as high as 30% (The Cysticercosis Working Group in Peru, 1993).

Thus, the inspection and condemnation measures supported by present policy in most of the countries encourage high rates of infection with *T. solium* by targeting the slaughterhouse only and failing to provide financial market incentives to reimburse the farmers and or slaughterhouse for infected pigs that are taken out of circulation or made safe for consumption by processing the meat through boiling. Even then, some of the lightly infected pigs might enter the food chain because the technique of meat inspection using visual inspection of key carcass sites is not 100% effective. This has been demonstrated in cattle in that those animals which are lightly infected with *T. saginata*, a close relative of *T. solium*, only 15% are detected by classical meat inspection (Kyvsgaard *et al.*, 1990). Geerts (1990) found that, although the official figures returned by the meat inspection services show that the number of Belgian cattle infected with cysticercosis decreased during recent years from 0.3% to 0.03%, systematic search and careful detection proved that 9.5% of cattle were infected with cysticerci of *T. saginata*. This discrepancy with the official figures was due to the inappropriate detection techniques used routinely in the slaughtering, and demonstrated that, even in Europe, official data may widely differ from reality.

Postmortem meat inspection of slaughtered pigs with respect to cysticerci of *T. solium* generally relies on visual examination of different sites in the carcass considered to be predilection sites for the parasite including the heart, diaphragm, masseters, tongue, neck, shoulder, intercostal and abdominal muscles (Gracey, 1986). Mendez and others (1986) examined ten heavily infected carcasses in order to establish which muscular region has the highest number of cysticerci. The masseters, followed by the pterygoid and the triceps muscles, were found to have the highest number of cysticerci per 100 g and were thus determined to be predilection sites.

A survey of predilection sites done by Viljoen (1937) in Bloemfontein abattoir in South Africa involving 10 heavily and 30 lightly infected pigs with the primary concern of finding the most reliable routines for detecting cysts in naturally infected carcasses by direct visual inspection cutting specific sites demonstrated the following organs/muscles to be predilection sites based on their frequency of infection 1) fore-quarters above the elbows (pork shoulder), 2) hind limbs above the hocks (pork leg), 3) psoas muscles on the ventral surface of the vertebrae, 4) cervical muscles and intercostals, 5) the tongue muscles, 6) heart and perineal region, 7) oesophagus and the diaphragm, 8) facial muscles and abdominal muscles, 9) brain, 10) liver, fat and superficial fascia, 11) eyeball, conjunctiva, etc. 12) sexual organs, internal organs, and lymphatic glands. However, the study did not investigate the infection intensity (cyst density) which is probably the most important factor in determining whether cysts are visible by visual inspection of the organs/incision sites during meat inspection.

2.4.4 Control by physical (heating, refrigeration and freezing) and chemical treatments of pork

In developing countries, the possibility of commercialisation of infected pork is high. Therefore, to prevent development of the intestinal tapeworm, all pork meat should be thoroughly cooked prior to consumption. Robinson (1978) in his heating trials of dissected cysts found that *T. solium* cysticerci will survive a temperature of 45^0 C for more than 25 minutes; they will survive 46^0 C for 15 but not 20 minutes and they will survive 50^0C for 6 but not 8 minutes. Cooking at 65 ^{0}C or higher will kill the cysticerci (Robinson, 1978). Freezing pork meat to -5 ^{0}C for four days, -15 ^{0}C for 3 days, or -24^{0}C for one day prevent the survival of cysticerci (Viljoen, 1937; Robinson, 1978; Sotelo *et al.*, 1986). Freezing the meat at -20 ^{0}C for several days will also inactivate cysticerci (Robinson, 1978). Robinson (1978) further investigated the required time to inactivate pork with cysticerci of *T. solium* under blast freezing temperature of -15 and -18 ^{0}C and found out that no cysts survived a temperature of -15 ^{0}C for 75 minutes, whether naked or situated in muscles, and all cysts were dead in less than 30 minutes at -18 ^{0}C.

The limiting factor in the lethal freezing of cysticerci of *T. solium* in a pig carcass is consequently the time taken for the depths of the muscle to reach a sufficiently low temperature for deep-seated cysts to be exposed to lethal temperatures. Under modern blast-freezing conditions Robinson (1978) observed that the temperature in the deep hind quarter after 24 hour treatment with air temperatures of -40 ^{0}C and air velocity of 5 m per second was -15 ^{0}C.

In a recent study, it was demonstrated that cysticerci in carcasses of pigs remained viable for up to 30 days at 4 ^{0}C refrigeration temperature (Fan *et al.*, 1998). These findings indicate that taeniosis due to *T. solium* can be transmitted through eating raw or undercooked pork or viscera of pigs following refrigeration at 4 ^{0}C for up to 30 days.

Pickling and smoking pork have been observed not to destroy cysticerci, because some cysticerci were found alive 22 days after being pickled in 20% brine (Viljoen, 1937). Keittivuti and others (1986) investigated the survival of cysticerci of *T. solium* in Nham, a Thai native food, consisting of chopped-up raw pork thoroughly mixed with salt, garlic, potassium nitrate, cooked rice, chilly and pork skin which is placed in a plastic bag and wrapped up with banana leaves. They observed that under room temperature (27-30 ^{0} C), the intact *T. solium* cysts in Nham could survive for as long as 12-18 hours after preparation while isolated cysticerci and cysticerci in a 2 x 9 cm portion of pork in 0.85% saline could survive for as long as 60 and 66 hours, respectively. The cysticerci in other ingredients of Nham and in saline solution (6%) could remain viable for 48-96 and 12-18 hours, respectively. Under the temperature of 4^{0} C, cysticerci in various recipes could survive for 96 hours while in controls, it could survive as long as 20-30 days. However, *T. solium* cysticerci in various compositions of Nham could remain viable for 11-20 days which was longer than those in potassium nitrate or salt alone.

2.4.5 Control by vaccination of pigs

There are several reports of acquired immunity to *T. solium* in pigs by the use of recombinant proteins, DNA, synthetic peptides and single proteins (Pathak and Gaur, 1995; Molinari *et al.*, 1993; Lightowlers, 2003). Pathak and Gaur (1995) demonstrated a significant decrease in the number of cysts by about 94%, by vaccinating pigs with *T. solium* oncosphere excretory-secretory antigens. In another study in Mexico, there was a six-fold reduction in the mean number of cysts from 80 to 12 in five control versus six pigs immunized with crude cysts antigens (Molinari *et al.*, 1993). In most studies, crude antigens obtained from oncospheres, cysticerci or tapeworms were used (Lightowlers, 2003). Various degrees of protection were reported and living oncospheres and oncospheral antigens were the most effective for generating immunity (Lightowlers, 2003).

In common with all other taeniid cestodes which have been investigated, oncosphere antigens of *T. solium* have been found to be a rich source of host-protective antigens (Verastigui *et al.*, 2002). The rapid success which has been achieved with identifying host-protective recombinant antigens for *T. saginata*, encouraged the adoption of a similar approach for development of a vaccine against *T. solium* cysticercosis in pigs (Lightowlers, 2003).

Investigations using Southern blotting with *T. solium* genomic DNA probed with cDNA's encoding host-protective antigens of *T. ovis* or *T. saginata*, identified close homologues to each of the tree target genes in *T. solium* (Lightowlers, 2003). Two of the associated mRNAs from *T. solium* oncospheres have been cloned and expressed in *Escherichia coli* and recombinant proteins used in vaccination trial against oral challenge infection with *T. solium* in pigs (Lightowlers, 2003). In this trial, one antigen (TSOL18) achieved complete protection against the development of any cysticerci in any of the vaccinated pigs, compared with the presence of any cysticerci developing in the musculature of all control pigs. This experiment demonstrated the potential for application of recombinant oncosphere antigens for development of a practical vaccine against porcine cysticercosis (Lightowlers, 2003).

A porcine vaccine is indeed an attractive control measure possibility. If a vaccine is available its cost would have to be quite low. Porcine cysticercosis is a disease uncommon to commercial piggeries, suggesting the clientele for this vaccine would be rural endemic villages. A high priced vaccine would undoubtedly be an effective obstacle to the use of a vaccine strategy. Also it has to have long-term protection, and should be easy to administer in a mass intervention campaign. Governments will have to subsidize, either completely or partially. Other factors to consider include the logistics of distribution of the vaccine and the trained personnel needed to run a mass intervention campaign. One must also decide if such an intervention should be implemented over the entire country or only in places and communities where transmission of the disease has been demonstrated ('hot spots').

Another problem with a vaccine is that there is evidence that pigs become infected with *T. solium* early in life (Gonzalez *et al.*, 2003). If this is true, immunisation must be performed at an early age. However, pigs immunised at an early age may 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). Alternatively, vaccinating pigs later in life may not be effective. If pigs are infected early in life and vaccinated, the ability of vaccine to eliminate an already established infection is poor (Gonzalez *et al.*, 2003). It has previously been shown that immunisation of pigs after infection is not an effective means of combating porcine cysticercosis (Evans *et al.*, 1997). Also in young pigs, if maternal antibody is present it may inhibit an effective antibody response to *T. solium* vaccines for a sizeable length of time, according to duration of passive antibodies (Gonzalez *et al.*, 1999; Gonzalez *et al.*, 2003).

2.5 The immunology of the host-parasite relationship in *Taenia solium* cysticercosis: Implications for prevention and therapy

2.5.1 The immunology of asymptomatic cysticercosis

The pig is the intermediate host for *T. solium* larvae and multiple cysticerci may survive within the pig's tissues. In some endemic regions, examination of pigs' tongues for palpable living larvae before being purchased has been routine practice since biblical times because this reliably diagnoses cysticercosis (Gonzalez *et al.*, 1990). The usual absence of apparent illness in infected pigs is remarkable considering that thousands of cysticerci are found at necropsy, scattered throughout muscular, neurological and other tissues (Boa *et al.*, 2002).

In humans, autopsies of victims of warfare and road traffic accidents have revealed that a large proportion (typically 80%) of neurocysticercosis infections are asymptomatic, discovered incidentally at necropsy (Gemmell *et al.*, 1983). Living cysticerci may occasionally cause disease through local pressure effects or by obstructing the flow of cerebrospinal fluid, despite the absence of a host inflammatory response. In contrast, symptomatic cysticercosis is usually associated with inflammation around one or more degenerating cysticerci. *Taenia solium* cysts therefore usually survive within pig and human tissues without symptomatic inflammation, despite the presence of circulating antibodies (Evans and The Cysticercosis Working Group in Peru, 1999).

2.5.2 Immunology of taeniosis

There is no protective immunity in the adult stage and multiple infections and re-infections are common. Serum antibodies have been detected in tapeworm carriers using the ELISA, or the immunoelectrotransfer blot (EITB) assay. The role of these antibodies remains unclear (Sanchez, 1999).

2.6 Mechanisms of immune modulation by cysticerci

2.6.1 Sequestration

After a brief period of migration, *T. solium* larvae lodge in host tissues and form cysticerci. The site where they settle and nature of the relationship with the encapsulating host may contribute to sequestration of the parasites from immune attack. The unequal distribution of cysticerci throughout body tissues does not mirror regional blood flow but may result from selective invasion by the parasite or differential survival and encystment of larvae in different tissues (Evans and The Cysticercosis Working Group in Peru , 1999).

In humans, cysticerci occur frequently within the brain, spinal cord and eye, all of which may be considered to be immunologically privileged sites. Distinct immunological characteristics of the central nervous system compared with other tissues include: the presence of the "blood brain barrier", which prevents conventional lymphocyte re-circulation; the inducible rather than constitutive expression of major histo-compatibility complex class one and two molecules; and the presence of specialized cells that execute immunological effector functions. These features may explain the unique interaction between the central nervous and immune systems (Fabry *et al.*, 1994) and the resistance of the brain parenchyma to leukocyte diapedesis (Anderson *et al.*, 1992). Recent evidence also suggests that inflammatory cell apoptosis is up-regulated in these sites (Streilen, 1995). Although we are not aware of systematic studies of the number of cysticerci in the human brain compared with non-neurological tissues, in their experience the medical researchers have observed that peripheral, mainly muscular located cysticerci are far more numerous than those in the central nervous system (Evans and The Cysticercosis Working Group in Peru , 1999). The apparent predilection of cysticerci for the brain may, therefore, simply reflect the severe symptoms which results from lesions in this organ (Evans and The Cysticercosis Working Group in Peru, 1999).

The form, fibrous encapsulation which surrounds some cysticerci, particularly in non-neurological tissues, is unlikely to form a physical barrier to immunity since humoral factors do gain access to the internal fluids of cysticerci (Willms and Arcos, 1977) and chemotherapeutic challenge or death of cysticerci is rapidly followed by intense inflammatory cell infiltration (Rickard and Williams, 1982).

2.6.2 Antigenic shifts

Concomitant immunity describes protection against newly invading larvae in hosts harbouring an established worm infection. This may result from changes or shifts in the antigens expressed by parasites as they develop through different stages of their life-cycle. Hence, adult larvae may be able to counteract those immune effector mechanisms that kill immature forms. Concomitant immunity has not been demonstrated in *T. solium* cysticercosis. However, animals may harbour vaccine-derived *T. saginata* and *T. hydatigena* larvae despite having acquired resistance to further egg challenge. This mechanism may explain the lack of overwhelming cysticercosis in hyperendemic regions since animals may only be able to acquire cysticercosis for 1 or 2 weeks after primary exposure to the parasite. Thereafter, the animal may be resistant to re-infection despite the survival of viable cysticerci resulting from the primary infection (Gemmell *et al.*, 1983).

2.6.3 Molecular mimicry

Parasites may evade immune recognition by synthesizing host-like antigen determinants (Evans and The Cysticercosis Working Group in Peru. 1999). Willms and others (1980) detected immunoglobulin G (IgG) on the surface of *T. solium* cysticerci by immuno-electron microscopy, but after purification this IgG showed no specificity for antigens on the cysticercus. The possibility that it was synthesized by the parasite was tested *in vitro* by translation of parasite-derived messenger-RNA. One of the protein products was found precipitable with rabbit anti –pig IgG, providing evidence that the cysticercus itself synthesized host-mimicking antigens. The occurrence of homologous genome sequences in host and parasite may explain the selectivity of cestodes for particular hosts, for example *T. solium* for pigs and humans (Evans and The Cysticercosis Working Group in Peru, 1999).

2.6.4 Masking of cysticercal antigens by host immunoglobulins

The presence of host antibodies in fresh cysticerci obtained from human surgery has been compared with the antibodies present in patients' serum and cerebrospinal fluid (CSF). Although circulating human IgG was present with the same frequency as IgG on the surface of the parasite, IgM, IgA and IgE were present only on the surface of the parasite and could not be detected in the serum or CSF. Furthermore, *T. solium* cysticerci have recently been shown to express an Fc receptor for IgG.

These results, reviewed by Flisser (1994), are consistent with the hypothesis that cysticerci are masked by host immunoglobulins, although the importance of these possible mechanisms of immune evasion has not been established.

2.6.5 Modulation of host immunity

Some evidence suggests that *T. solium* cysticerci may not only hide from the host immune system, but they may also actively suppress host immunity. A secretion product of living cysticerci, antigen B, has been shown to bind to and inhibit Clq, the first component of the complement cascade (Laclette *et al.*, 1992). As yet unidentified secretory products of cysticerci also have a suppressive effect on cultured human lymphocytes stimulated with phytohaemagglutinnin (Molinari *et al.*, 1990). Similarly, viable cysticerci implanted into the peritoneal cavity of mice release factors that depress rather than enhance lymphocyte reactivity (Willms *et al.*, 1980). Mice infected with *T. crassiceps* larvae also had suppressed cell-mediated immunity. Furthermore, there was evidence of up-regulated Th2 and down-regulated Th1 type T-lymphocytes in the vicinity of infecting larvae (Villa and Kuhn, 1996). Further elucidation of the mechanisms by which living larvae suppress local immune responses may allow more specific and effective anti-inflammatory therapy to be administered during cestocidal therapy.

2.6.6 Immunotherapy for porcine cysticercosis

It has been shown that cysticerci may be destroyed by immunological reactions. Herbert and Oberg (1974) infected nine pigs with cysticercosis at the age of two months and re-infected four of these pigs two months later. Autopsy revealed significantly fewer cysticerci in the pigs that had been infected twice, suggesting that re-infection accelerated cysticercus degeneration and absorption. Similarly, re-infection of cows infected with *T. saginata* and sheep infected with *T. hydatigena* caused degeneration of established cysticerci (Gemmell, 1970; Gallie and Sewell, 1972). Molinari and others (1983) reported that immunotherapy caused the resolution of cysticercosis in two pigs and this immuno therapy was then evaluated in a field trial (Molinari *et al.*, 1993) and the results of the trial were that the prevalence of porcine cystcicercosis fell significantly in two villages where pigs were vaccinated repeatedly. However, there was no control group and cysticercosis was diagnosed by tongue palpation only. Seven cysticercotic pigs given immunotherapy were studied in more detail and 73% of cysts excised from them failed to evaginate compared with 5% in seven untreated cysticercotic pigs.

Evans and others (1997) further investigated the effect of immunotherapy on porcine cysticercosis in a prospective, randomised, controlled and blind study. They observed that when pigs naturally infected with cysticerci of *T. solium* were inoculated with cysticercal antigen, the viability of cysticerci was significantly reduced. The percentage of cysticerci that showed no evidence of viability was more than double in the group of pigs given crude antigen and most of these animals developed new electro-immunotransfer blot bands suggesting an antibody response to the immunotherapy. However, all of the pigs remained macroscopically heavily infected and most of the cysticerci in the majority of the treated animals appeared viable for causing human disease.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study I: Determination of the distribution and density of cysticerci of *Taenia solium* by muscle groups and organs in naturally infected local finished pigs in Mbulu

3.1.1 Study area, human population and agricultural activities

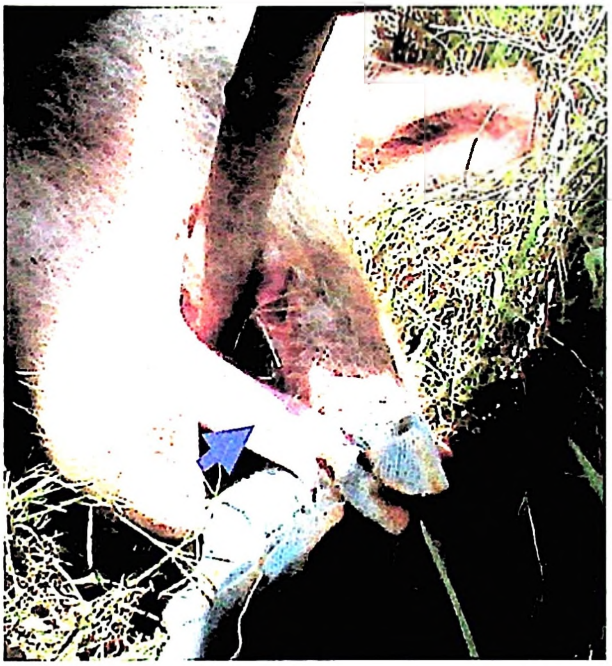
Mbulu District is located in north-eastern Tanzania, between latitude 3.80^{0}-4.50^{0}S and longitude 35.00^{0}-36.00^{0}E [Appendix 1]. The altitude varies from 1,000-2,400 meters above sea level. The District contains areas having semi-arid and sub-humid climates that receive an annual rainfall of less than 400 mm and over 1.200 mm, respectively. The long rainy season extends from about March to mid-May and the short rainy period extends from November to December. Relative humidity ranges from 55%-75% and mean annual temperature ranges from 15^{o}C-24^{o}C. The District has 59 villages and the 1997 district census showed that it had a population of 200,000 people and 32,883 pigs (Mbulu District Veterinary Officer, unpublished data). Crop and livestock production are by far the most important economic activities, employing over 90% of the total district labour force. Most of the district inhabitants, who belong to the Iraqw tribe, occupy mostly highland areas and are agro-pastrolists. Pigs are raised by many homesteads as a source of income and animal protein for the household. Besides pig farming, villagers raise other livestock including cattle, sheep, goats, and chickens, and many keep dogs, cats, and donkeys.

3.1.2 Study animals, ante-mortem lingual examination, slaughtering and organ separation

The study used twenty-four (twelve males and twelve females) naturally infected finished pigs with ages in the range of one to three years, all of the local pig breed purchased from villages in Mbulu District near the town of Mbulu. Pigs that were suspected to be positive for cysticerci of *T. solium* by the farmer or pig trader were subjected to ante-mortem lingual examination. A pig was restrained in lateral recumbence or in a standing position and the head was stabilized by the use of a pig snare. The mouth was opened and gagged by a piece of wooden rod twisted across the upper and lower jaw and the tongue was gently pulled out using a piece of a cotton cloth or gauze. The under surface of the tongue was thoroughly examined visually and by palpation for evidence of cysticerci. Pigs were considered positive for cysticercosis if cyst-like nodules were either seen or felt (Gonzalez *et al.*, 1990) (Fig. 2 a and b). Positive pigs were purchased and transported to a holding ground at Tango Folk Development College, Mbulu town. From here a single animal was collected each day and transported to a nearby district veterinary laboratory where slaughtering and cyst counting was done.

During slaughter a pig was restrained by the use of ropes and while standing it was stunned by hitting the back of its head with a heavy metal instrument. While unconscious the pig's neck was quickly cut open by the use of a sharp knife, severing the jugular veins and carotid arteries. The pig was left to bleed to death. The carcass was then skinned and weighed (wet weight). The carcass was eviscerated and the diaphragm, heart, tongue, kidney, oesophagus, spleen, liver, lungs and psoas muscles were separated from the rest of the carcass. Muscle groups from half of the carcass comprising of fore-limbs, hind-limbs, head muscles, trunk muscles, were separated from the skeleton by dissection. Wet weight of the above mentioned organs/muscle groups were determined by the use of a scale. By carefully separating the sutures of the skull the brain was removed from the cranium and its wet weight recorded. External and internal masseters and the muscle *Triceps brachii* were dissected out from the other half of the carcass and weighed.

a



b

Figure 2: (a and b). Antemortem tongue examination. Cysts on the ventral surface of tongue (arrows)

3.1.3 Meat inspection procedures followed as per Tanzanian government regulations of 1993

General provisions for post-mortem inspection of pig carcasses for cysticerci of *T. solium* were followed which include long and parallel incisions into the external masseter muscles on both sides of the face in an upward direction to severe completely the parotid gland below the ear. Similar incisions were made in the internal masseters. The tongue was detached from the hyoid bone, viewed, palpated and cysts under the surface counted. A deep longitudinal incision covering about three quarters of the thickness of the tongue and covering the whole length of the tongue was made at the base of the tongue to examine for cysts. After opening the pericardium, the heart was also visually examined for the presence of cysts. The heart was cut open and a deep ¾ incision into the septum was made to expose any metacestodes (Fig.3). Three equidistant incisions were made in the *Triceps brachii* muscle proximal to the elbow joint (Tanzania Government, 1993). Cysts that were encountered on incisional and intact surfaces were classified and enumerated as either viable (translucent, fluid-filled with invaginated whitish protoscolices visible) or degenerated (black, sand-like or powdery contents).

Figure 3: A deep incision into the septum of the heart in order to expose metacestodes was made. Observe cysts on the meat inspection incision surface of the heart (arrows).

3.1.4 Slicing of tissues from carcasses and counting of cysts

The heart, masseters, tongue, lungs, kidneys and liver together with the muscle groups excised from half of each carcass were sliced in such a way that all fully developed cysts could be revealed and enumerated (i.e. each slice was less than 0.5 cm thick). The total number of cysticerci for those muscle groups where cysts were only counted in half of the carcass was calculated by multiplying the detected unilateral number by two. Fully transparent cysts with viable protoscolices were recorded as viable, and any others as degenerated as per government regulations above. For each animal the proportion of cysts located in individual muscle groups or organs was calculated as the percentage of the total number of cysts in the carcass, and the mean and 95% confidence interval (95% CI) were calculated. To calculate the relative cyst density in each muscle or organ, the wet weight of each organ or muscle site and that of the dressed carcass was determined for all the 24 animals. The proportion that each individual muscle site or organ contributed to the total weight was calculated, and divided into the percentage of cysts found in the particular site, whereby

Relative cyst density is given by the formula: (Maeda *et al.*, 1996).

$$RCD = \frac{MCD}{MPW}$$

Whereby:

RCD=Relative cyst density

MCD=Mean percent (%) of total cysts density in the site

MPW=Mean percent (%) pork weight in the site

3.1.5 Determination of surface area subjected to meat inspection

Determination of surface area subjected to meat inspection was done according to the methodology described by Maeda and others (1996). The proportion of cysticerci of *T.*

solium that was expected to be revealed by meat inspection performed according to government regulation was estimated by the following method: The areas of the surfaces exposed by visual inspection and incision were determined by outlining their shape on a sheet of manila paper. The outline was cut out and the weight determined: the area of the surface was calculated on the basis of the weight of the paper per unit area. The area revealed by complete slicing of the muscle or organ site into slices of 0.5 cm thick was determined by the same procedure. By assuming uniform distribution of cysts within the site the proportion that was expected to be revealed by meat inspection was calculated by dividing the surface area exposed after complete slicing into surface area exposed by meat inspection (Fig. 4 a and b). This percentage (x) was multiplied by the relative cyst density for the site (y) to calculate the proportion of all cysts in the carcass revealed by inspecting the particular site (xy). The percentage of cysts in the carcass which was expected to be revealed was calculated by adding the contributions of the individual muscle groups and organs (Σ xy).

a

b

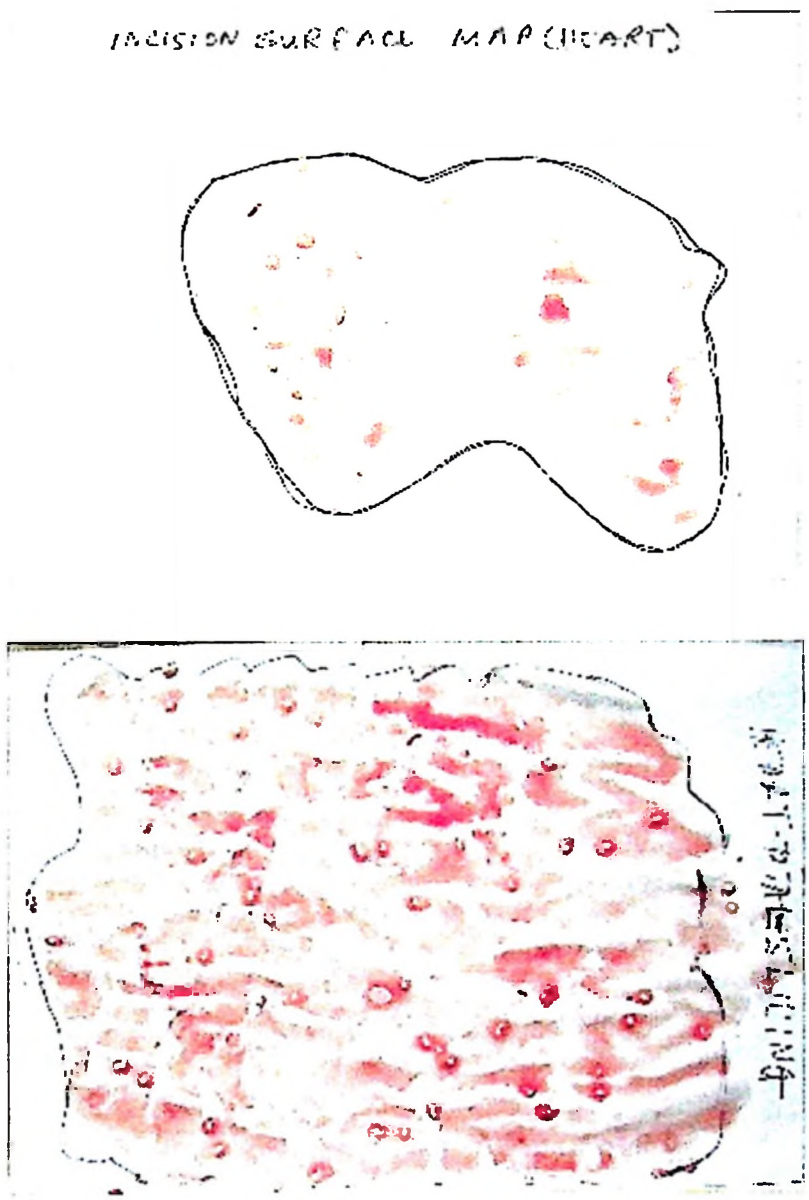


Figure 4: (a and b). The maps of meat inspection incision surface of a heart (a) and surface after total slicing (b).

3.2 Study II: Determination of prevalence and risk factors associated with the presence of cysticerci of *T. solium* in pigs raised in Chunya and Iringa Rural Districts, Tanzania

3.2.1 Preliminary study: Determination of focal areas of disease in the southern highlands of Tanzania by use of meat inspection records, antemortem lingual examination and questionnaire study

The study covered two regions of the southern highlands of Tanzania, namely Iringa and Mbeya. The survey started at the Regional Veterinary Office by examining annual meat inspection records with special interest in cases of cysticerci of *T. solium.* Regional Veterinary Officers and Regional Meat Inspectors were interviewed in relation to which districts were reporting the most cases of porcine cysticercosis. Then from the outcome of meat inspection records and interviews two districts per region were picked on the basis of having high prevalences of porcine cysticercosis. At the District Veterinary Office interviews were conducted with the District Veterinary Officer and the District Meat Inspector in relation to cases of porcine cysticercosis in the district. Annual meat inspection records that were available were collected and analysed. Also during the interview, information was gathered on areas in the district with high prevalences of porcine cysticercosis and on the pig management dominantly practised in those areas. Data on export of pigs out of the districts to major cities and towns were also collected using movement permit records available at the respective district offices. Interviews were also conducted with pig traders and selected farmers in the districts about their awareness of cysticercosis in pigs in their respective areas and if they were aware of live pigs with tongue cysts in his/her area. Suspected positive pig(s) were then subjected to ante-mortem lingual examination as described under section 3.1.2 above. Data from the preliminary study were then analysed and districts with the highest prevalence of porcine cysticercosis were chosen for exhaustive investigative survey.

3.2.2 Interviews, collection of information on cases of epilepsy, taeniosis and cysticercosis in humans in the districts

Visits were made to the District Government Medical Hospitals in the districts. Interviews were conducted with the Medical Officers of the respective hospitals (in charge of the hospitals), District Health Officers or nurse(s) who are attending patients with mental illnesses. Information was gathered concerning current epileptic cases and human taeniosis/cysticercosis in the district. Where possible information was gathered too on areas where most of these epileptic patients originated.

3.2.3 Exhaustive cross-sectional study to determine prevalence of porcine cysticercosis by ante-mortem lingual examination

3.2.3.1 Study area: Chunya District

I Topography and climate

Chunya District is located in the Northern-Western part of Mbeya Region with most parts of the district falling under the Rift Valley systems (Appendix I; Fig. 16). The climate is semi-arid to arid in nature and characterized by dry forest mainly comprised of thickets and Miombo trees. There is only one rainy season starting from December to Mid-March varying from 600 mm to 1000 mm.

II Agricultural and mining activities

Pastoral systems are found in most parts of the districts dominated by the Sukumas and Barbeigs nomadic tribes. Cattle and goats are the dominant ruminant livestock species in terms of numbers. Monogastric livestock kept in the districts are pigs and chickens. Pigs are kept all over the district but an estimated population figure was not available. The main crops are maize and rice, mostly cultivated in the low laying areas along the Lake Rukwa basin. Tobacco and cotton are grown by a substantial number of farmers as cash crops. Some persons are involved in bee keeping and charcoal burning. The area is also very popular for mining gold.

3.2.3.2 Study area: Iringa Rural District

I Topography and climate

The study was conducted in pig populations found in Iringa Rural District in Iringa Region, southern highlands of Tanzania. The district lies between latitudes 6^0-10^0 S and longitudes 33^0-37^0 E and has about 28,000 km^2 (50% of Iringa region) [Appendix 1]. The district has 3 main agro-climatic zones namely the highland zone (temperate plateau), central zone (central plain) and the lowland zone (lower plain). The highland zone lies between 1,600-2,700 m above sea level with annual rainfall about 1,000-1,600mm and annual mean temperature of 15^{0}C. The central zone lies between 1,200-1,600m above sea level and the annual rainfall is 600-1,000 mm with annual mean temperature of 15-20^{0}C, while the lowland zone lies between 900-1,200 m above sea level and the annual rainfall is below 600 mm, and the mean annual temperature of 20-25^{0}C. Vegetation cover in the higher zone is comprised of typical rain forests while derived savannah grasslands predominate in the central zone. The lowland zone is arid and semi-arid in nature and is mainly comprised of thickets and scattered bushes. The district has one rainy season that is from December to May, the other months forming the dry season. Temperature varies greatly among the three zones between 15^{0}C-25^{0}C. There is a typical cool climate especially in the highland zone from June to August.

II Farming activities

The main crop in all the zones is maize, followed by beans. However, vegetable production including tomatoes, carrots and cabbages, is very popular. Timber production plays an important role in the economy of households in the highland and central zones. Livestock kept by most inhabitants of the district include pigs which are mostly crosses of the Large White breed and the indigenous breed. Most of the pigs are confined in pens made of timber off cuts or tree poles while most of the local chickens are reared free range. Other livestock include local chickens, cattle, goats, sheep, rabbits, and guinea pigs.

3.2.3.3 Study design

This was a descriptive study, in which exposure and disease status of porcine cysticercosis were assessed simultaneously among pig populations in the two districts. The exhaustive investigative survey (main survey) was conducted using a three-stage cluster sampling method. This started by numerically listing all the villages in the district and randomly selecting those that would be involved in the study. Based on the district administrative maps of Chunya and Iringa Rural, 21 and 25 villages were chosen, respectively, for the cross-sectional study. For Iringa District the study was conducted in two phases: The first survey was conducted during the dry season, from the first of September to the second of October 1999. The second survey was done in the year 2001 from April 21st to 24th May (rainy season). In Chunya District the study commenced on

12th October 1999 and ended on 9Th November 1999. Households keeping pigs were identified and listed at village level with the help of the Village Herdsmen (Village Chairpersons). Among these households those that were accessible were randomly chosen and visited until about 30 pigs per village were examined. All the pigs in the household were examined lingually except piglets younger than two months of age and pregnant sows which were excluded from the study to avoid causing accidents or stress that might result in deaths or abortions in piglets and sows, respectively. Ante-mortem lingual examination was conducted as described above under section 3.1.2

3.2.3.4 Blood collection

Following lingual examination about 5 ml of blood was collected from either the external jugular vein or the cranial vena cava into plain blood collecting tubes and allowed to clot. Three persons restrained the pig in dorsal recumbency. The first person held the hind legs while the second held the fore legs with the third person holding the head by the level of the mandible pressing the head down. The fourth person then collected blood using a 18 or 20 gauge needle, vacutainer tube or using a 20 ml syringe. The needle, inserted in the depression between the palpable manumbrium sterni and the point of the right shoulder, is advanced in the direction of the dorsal end of the right scapular, in an attempt to puncture any of the large veins between or just in front of the first pair of ribs. The right side of the neck of the pig was preferred because on the left side, the left phrenic nerve occupies a more vulnerable position, while the unpaired thoracic duct is also more to the left (Dyce *at al.*, 1996). The blood is also obtained from the external jugular vein 1/3 (one third) the distance from the sternum to the jaw (Dyce *et al.*, 1996). To obtain serum, the clotted blood was separated by centrifugation at 3,000 rpm for 15 minutes. The supernatant (serum) was dispensed into 2 ml aliquots and stored in labelled vials, which were later frozen at -20^{0}C until tested.

3.2.3.5 Calculation of sample size and study design

The sample size (n) is given by by the formula: (Thrusfield, 1995)

n = $\frac{Z^2 \times P \times Q}{L^2}$. This formula is for simple random sampling.

Whereby = Known or estimated prevalence= 20%=0.2

Q = 1 – P = 0.8

L = Allowable error = 0.05

Z = The value of the standardized distribution for a type I error (Z = 1.96).

Then n = $\frac{1.96^2 \times 0.2 \times 0.8}{(0.05)^2}$ = 245.8624 or approximately 246 pigs.

During the study, a three-stage cluster sampling method was used. Villages with pigs were treated as primary units while the pig herds in the individual households were taken as secondary units. The tertiary unit was the individual pig in the herd as seen in Table 8. Sampling at the primary and secondary levels was conducted by the simple random method. While at the tertiary level when pigs in the household were 5 or more the simple random method was used otherwise all of them were examined since most of the households only owned one or two pigs.

Table 8: Three-stage cluster sampling; showing the primary, secondary and tertiary levels of sampling.

Level	Units	Sampling method
Primary units	Villages with pigs	Random
Secondary units	Households with pigs	Random
Tertiary units	Pigs in the herds	All/Random

In a multistage sampling e.g. in a three stage sampling in this case, an upward adjustment in the sample size was made to obtain the desired precision. In this case the number was raised three times to adjust for the three stage cluster sampling method which was used. Then the number of animals to be examined (n) became 738.

3.2.3.6 Measurement of risk factors that might be associated with the prevalence of porcine cysticercosis

A household census based on a questionnaire was conducted in selected villages (villages picked for lingual palpation of cysts in the exhaustive survey) to collect data on the number of pigs owned, general pig management with particular emphasis on the types of husbandry and feeding practices, the aim of keeping pigs, problems encountered, people's feeding habits with particular attention to ingestion of undercooked pork. Focus was made on the forms of cooking pork (frying, boiling, barbecue and raw), presence and usage of sanitary facilities especially latrines, knowledge of taeniosis and cysticercosis, specific questions regarding medical history related to the presence of helminthoses and/or symptomatology suggestive of neurological disorders (Appendix 2).

3.3 Study III: Cysticerci of *Taenia solium*: Survey of factors responsible for the absence of the disease in Mgeta Division

3.3.1 Study design

3.3.2 Investigative study on factors responsible for absence of porcine cysticercosis by the use of focus group discussions and in-depth interviews

3.3.2.1 Study area (zonation and climate), human population and farming activities

Mgeta Division is located in Morogoro Region situated about 50 kilometres southwest of Morogoro town with two distinct zones: North-Eastern and South-Western zones [Appendix 1]. The Division has an estimated population of over 100,000 people settled in 13,445 households in 22 villages. The inhabitants of Mgeta Division can be characterised as being mostly Lugurus (a Bantu tribe), Roman Catholics and pork eaters. It is estimated that every second house in Mgeta has 1 or 2 pigs that are kept in order to provide manure for fertilization of horticultural crops. In the past the farmers used chemical fertilizers which were quite effective initially; however with time they lost their effectiveness and became very expensive. The farmers were advised to switch to organic fertiliser and thus started using farmyard manure from their pigs and goats. Many farmers began raising pigs for this purpose, as they are more readily available than dairy goats (Mgumia and Ruheza, 2001).

I The North-Eastern zone

The division borders the Uluguru Forest Reserve at an altitude ranging from 1,200-2,647 metres above sea level (m.a.s.l). The North-Eastern zone is commonly referred to as Upper Mgeta, covering Bunduki, Langali, and Tchenzema wards. The climate in the zone is subtropical which allows the production of a wide range of temperate fruits and vegetables. Horticultural crops form the most important cash crops in the area.

Production in this area is mainly for market. Maize is grown for consumption although the production does not satisfy the demand for food in the area. Households purchase supplementary food from the money they earn from horticultural and fruit products. Due to high population density, the area is intensively cultivated and the use of agricultural inputs such as pesticides is a common practice (Mgumia and Ruheza, 2001).

II The South-Western zone

The South–Western zone extends towards the low lands with altitude ranging from 300-1000 m.a.s.l. The climate in this zone is semi-arid. The main crops grown in the area are maize, sorghum, beans, cassava, and pigeon peas. These crops are grown mainly for food but due to lack of reliable cash crops and other means of income the crops also serve household cash needs. Despite opportunities available in the area, the majority of households (more than 80%) are still living a sustainable life. Their annual per capita income is still very low at about 200,000 Tanzanian shillings (Mgumia and Ruheza, 2001).

III Livestock production

Livestock play an important role in the farming system in Mgeta. Besides improving the nutritional status of families, livestock is a major source of animal manure for improvement of soil fertility. Apart from pigs which are kept by a majority of farmers in Mgeta, Sokoine University of Agriculture (SUA) has actively promoted the adoption of dairy goats in the area under the project named Uluguru Mountain Agricultural Development Project (UMADEP). However, additional support is needed especially on breeding practices and management of dairy goats and pigs in terms of husbandry to improve the quality and quantity of meat and milk from pigs and dairy goats, respectively (Mgumia and Ruheza, 2001).

IV The human and pig populations

Estimated human population of Mgeta Division as of the 2003 census was 100,000 and currently the pig population is estimated at 8,858 (Anon. 1998). The division has 22 villages in total and all of them were involved in the study.

V Consent and ethical issues

The people interviewed in the study were fully informed about the background and objectives of the study, what their role would be, why and for whom the research was being conducted, how data would be collected, how the confidentiality of participants would be protected, and how the information would be used. Before discussion was initiated individual consent was requested and participants were those persons who fully volunteered to give information. Participants were given financial incentives for their time spent on the interviews/discussions.

VI Study population and its grouping

Qualitative methods of data collection involving participation of farmers and other key informants were used. Group interviews and in-depth interviews were conducted to collect data and answer research questions. Groups of between 7 to 18 persons were formed and interviewed. Pig raisers, village government leaders, butchers and village public health workers were grouped as one category at the village level and interviewed together. Other groups were medical personnel, the Veterinary and Public Health Assistant, the Ward Executive Officers and the Primary Court Magistrate.

VII Sample size and sampling

The informants included pig raisers (115), butchers (52), village public health workers (45), and village administrative officers (21), making a total of 233 participants from 22 villages among which 166 were men and 67 women. In-depth interviews were conducted with local experts including: agricultural extension officers (4), clinical officers or medical assistants (8), a public health worker (1), a primary court magistrate (1) and ward executive officers (4).

The sampled groups were selected with purpose and not at random in that the groups identified were the ones thought to be in a better position to give reliable information on the issues under investigation. With regard to sample size the aim was to have a small sample of people, nested in their context and studied in-depth (Miles and Huberman, 1994).

VIII Logistics

The respondents were informed of the meeting through their village chairpersons one week before the interviews. The interviews/discussions were conducted in village government offices or at school buildings. Interviews were conducted in only one village at a time with interviews completed in 1 - 2 villages each day. On two occasions interviews were cancelled and rescheduled because of inclimate weather as very few participants turned up for the interviews.

Group interviews for the category composed of medical and veterinary assistants, ward executive officers and the primary court magistrate were conducted in three groups with Veterinary and Public Health assistants forming one group, Medical personnel forming the second group and Ward Executive Officers and Primary Court Magistrate the third group. The three groups were interviewed on the same day at the divisional headquarters.

The pig raisers, butchers, village executive officers and village public health workers were grouped together separate from the higher level government workers because of the limited technical level of their expertise and also so as to promote more discussion free from interference of government workers for example on issues such as why pork is not inspected or fining/jailing of heads of households whose households have no latrine.

XI Questionnaire design and administration

Two types of questionnaires were designed with one questionnaire formulated for farmers, pig traders, village executive officers, and village public health workers (farmers group) [Appendix 3]. The other one was designed for interviewing medical assistants, agricultural/livestock workers, Ward Executive Officers, Primary Court Magistrate and Public Health Worker (workers group) [Appendix 4].

A. Questionnaire for "farmers" group

The questionnaire was structured to collect information on family and land holding size, education, number of pigs owned, pig husbandry and management practices, meat inspection coverage, people's pork eating habits, sanitation, awareness of cysticercosis, and any information about taeniosis (Appendix 3). The questionnaire was translated from English into Kiswahili (The national language) so that the farmers could comprehend it and then pre-tested before its administration. It was then back-translated by an independent person. The principal investigator served as the moderator of the interviews/discussions. The interviews started with a presentation of pictures of cyst-infected pork (Fig. 5, 6, and 7) followed by a number of questions. The conversations were both tape- and shorthand-recorded.

In-depth analysis involved issues concerning pig management systems including:

- Whether pigs were totally confined or kept under free-range conditions.
- If confined, were they all confined or are certain age groups or other categories of pigs (e.g. piglets) able to move about freely?
- What, if any, age group of pigs are allowed to freely forage?
- For how long are pigs allowed to free range in a day?
- Are there any village by-laws governing the issue of free ranging pigs?
- If there are community by-laws concerning pig management, how are they applied and enforced?

In-depth analysis of sanitation issues was conducted by questioning about:

- Sanitation and hygiene practices, i.e. using the latrine, washing of hands after using the latrine and before eating.
- Construction and use of latrines, especially village by-laws concerning the issue.
- Estimated construction costs of a latrine and how those costs were possibly reduced?
- What are the duties and mandate of the Village Public Health Committee?
- What is the frequency of latrine inspection in a year and what is the fate of those persons whose homesteads have no functioning latrine/toilet.
- Any records of households without a latrine and what actions were taken against those persons.

On meat inspection coverage and pork consumption analysis was on the:

- Slaughter of pigs, meat inspections and control.
- What happens to pork infected with cysts?

- The number of pigs slaughtered per month per village.
- Amount of pork consumed by an average family in a village per month.
- Preferred forms of cooking/eating pork.
- Whether it is common to consume pork in a local brew (Pombe) shop and, if yes, how much pork on average a local brew taker consumes in one month.

Other areas that were covered by the questionnaire were:

- Modes of farming.
- Land availability/scarcity in order to access the possibility of a pig having enough roaming area.
- Land use i.e. whether the farms are cultivated throughout the year or on a seasonal basis.

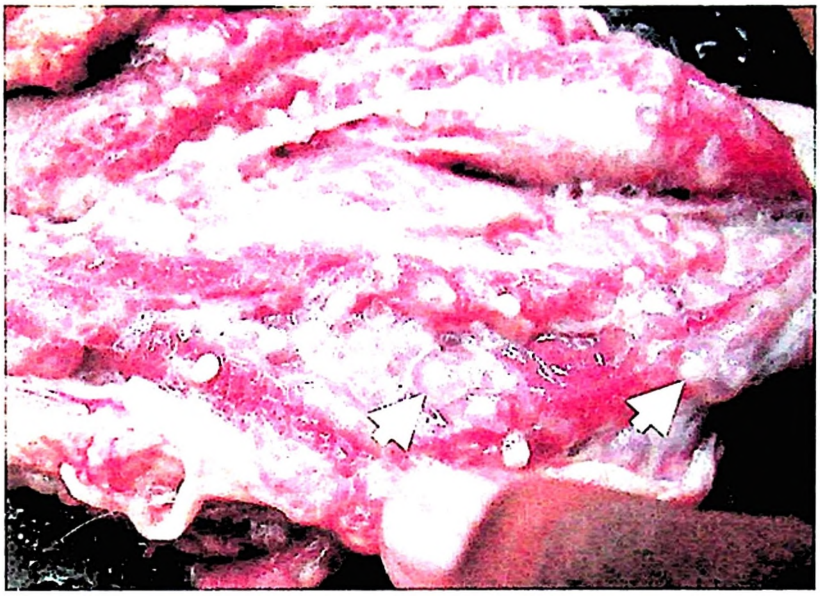


Figure 5: Cysts on the incision surface of the tongue (arrow heads).

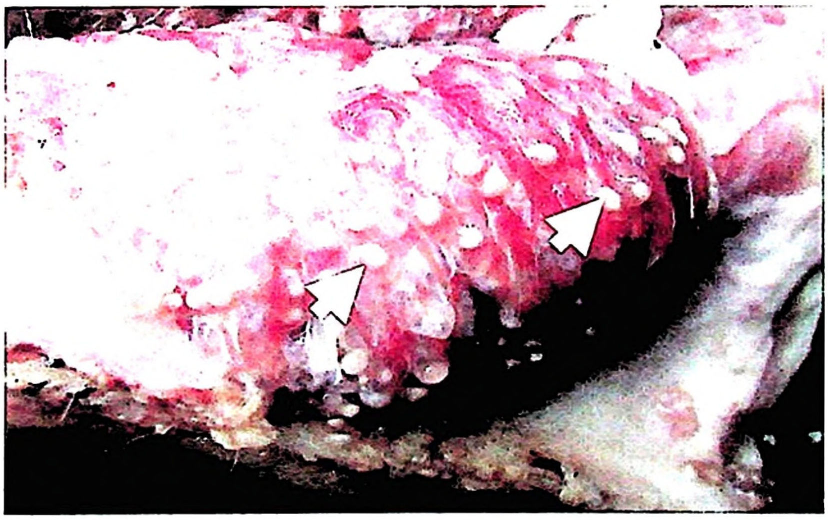


Figure 6: Cysts on the incision surface of the masseter muscles (arrow heads)

Figure 7: Cysts on the surface of heart (arrows).

B. Questionnaire for "workers" group

A structured questionnaire was designed in order to inquire about awareness of the parasite's presence in the study area and knowledge about its mode of transmission. Questions were also directed at gathering information on meat inspection coverage in the division such as the number of slaughter slabs present, whether and to what extent home slaughtering of pigs was taking place, what percentage of home slaughtered pigs were inspected, constraints preventing inspection of home slaughtered pigs and availability of transport at work (Appendix 4). In-depth analysis also involved issues concerning pig management systems, village by-laws governing issues of sanitation and pig management and the duties of the Village Health Committees. Respondents in this category were also questioned about cases of taeniosis, cysticercosis and epilepsy in humans in the district and available records concerning these cases were gathered.

Secondary data on taeniacidal drugs (praziquantel and niclosamide) used in the district currently and in the past as well as information about other helminthoses infecting humans were also gathered. The Ward Executive Officers and Primary Court Lawyer were asked about how the village by-laws concerning latrine use and pig confinement function. They were also asked about the number and fate of persons brought into their offices for not abiding by the community regulations.

X Data collection

The principal investigator was the researcher and moderator of the discussions. The discussions were started with a presentation of clear pictures of pork infected with cysts and portions of fresh pork and then followed by a number of questions posed and the informants gave responses to respective questions. Any new interesting emerging theme that was not detected by the structured questionnaire was quickly targeted and discussion focused on it. The conversations were tape-recorded and the main points recorded in writing.

3.3.2.2 Cross-sectional survey on prevalence of porcine cysticercosis by ante-mortem lingual examination

Ante-mortem lingual examination was conducted as described in section 3.1.2 above (Fig. 2).

3.3.2.2.1 Sample size

Sample size can be put in a general formula (Thrusfield, 1995):

$n = [1 - (1 - P)^{1/d} x (N - (d-1)/2]$

Whereby:

n= sample size;

P= probability of finding at least one case (confidence level, e.g., 0.95);

d= number of (detectable) cases in the population and

N= estimated population size=8,858.

d=number of diseased animals multiplied by the sensitivity of the test (tongue examination) which in Tanzania has been found to be 76% (Sato *et al.*, 2003). Thus, d= 8,858 x 0.05 x 0.76 = 336.604. Hence calculated n= 76.90666511giving a round figure of 77 animals.

3.3.2.2.2 Measurement of risk factors that might be associated with the prevalence of porcine cysticercosis

The measurement of risk factors associated with the prevalence or absence of porcine cysticercosis was accomplished by the use of a structured questionnaire as indicated in Appendix 5.

3.4 Study IV: Determination of factors responsible for presence of porcine cysticercosis in southern highlands of Tanzania [Chunya and Iringa Rural districts] and its absence in Mgeta Division, Morogoro Region by the use of ante-mortem tongue examination and Ag-ELISA

3.4.1 Treatment of serum for Ag-ELISA

The Ag-ELISA, which was initially developed for *T. saginata* cysticercosis (Brandt *et al.*, 1992), was performed as described by Dorny *et al.* (2000) with slight modifications. The sera were pre-treated using freshly prepared 5% trichloroacetic acid (TCA) (Sigma, Chemical Co.) w/v dissolved in distilled water. This was done in order to dissociate immune-complexes thereby increasing both the specificity and sensitivity of the assay. Five percent TCA was prepared by dissolving 1 gram of TCA in 20 ml of distilled water. The serum samples were pre-treated by mixing an equal volume of serum and 5% TCA. For the negative control sera, 75 µl was used and 150 µl for positive control and test sera. This mixture of serum and 5% TCA was incubated for 20 min at room temperature. After incubation, the mixture was centrifuged for 9 min at 12,000 rpm following which the supernatant (same volume as the added sera) was removed and put in microtitre tubes. Thereafter, the pH of the supernatant was raised by adding an equal volume (75 µl or 150 µl) depending on whether it was added to negative control or positive control and test sera of a sodium carbonate/bicarbonate buffer (0.610M) at pH 10.0 to the supernatant. One hundred microliter of this mixture (final serum dilution 1: 4) was used in ELISA.

3.4.2 Procedure for Ag-ELISA

Two monoclonal antibodies (MoAb) were used thus the name double sandwich ELISA as the technique involves trapping the antigen (Ag) between two monoclonal antibodies. The assay involved coating polystyrene 96 well ELISA plates (Nunc® Maxisorp).

Monoclonal antibody B158C11A10 was used as first MoAb and a biotinylated MoAb B60H8A4 was used as the detector antibody (second MoAb). The plate was coated with 100 µl of MoAb B158C11A10 diluted at 5 µg/ml in carbonate buffer (0.06 M, pH 9.6) and incubation was carried out at 37°C on a shaker for 30 min. After coating, the plates were washed once with PBS–Tween-20 and dried by beating the plate vigorously on blotting paper. Blocking to avoid non-specific reactive sites was done by adding 150 µl per well of PBS-Tween-20 + 1% newborn calf serum (NBCS) and then the plates were incubated on a shaker for 15min at 37°C. Thereafter plates were emptied and dried. Without washing the plate, 100 µl of pretreated sera at a dilution 1/4 was added and incubated on a shaker at 37°C for 15 min. After washing the plate five times it was dried. 100 µl of biotinylated MoAb B60H8A4 diluted at 1.25 µg/ml in PBS–T20/1%NBCS was added and the plate incubated on a shaker for 15 min at 37°C. After this the plate was washed five times with PBS–Tween-20 and then dried. A hundred µl of streptavidin-horseradish peroxidase (Jackson Immunoresearch Lab. Inc.) diluted at 1/10,000 in PBS–T20/1%NBCS was added to act as conjugate after which the plate was incubated on a shaker at 37°C for 15 min. Two tablets of the chromogen/substrate, orthophenylene diamine (OPD) (DAKO, #S2045) were added to 12 ml of distilled water, to which was added 5 μl of H_2O_2. A hundred μl of this solution was added to the wells and incubation was done at room temperature for 15 min in the dark without shaking. To stop the reaction, 50μl of 4N H_2SO_4 was added to each well. The plates were read using an ELISA reader (Labsystem Multiskan RC) at 492 nm.

3.5 Statistical analyses

3.5.1 Study I: Statistical analysis

Data were analysed for the effect of host sex (male versus female) on the cyst numbers in different organs/muscle groups in the carcasses using nonparametric statistical procedures of SPSS® (Howitt and Cramer, 2000). A Mann -Whitney test was carried out to test the hypothesis that the two populations are the same. The P-value for testing the hypothesis of identical populations with the Mann - Whitney test is 0.0089 level (Shott, 1991) so the hypothesis was rejected at the 0.05 or 0.01 level of significance.

3.5.2 Study II: Statistical analysis for lingual examination test

A number of risk factors using antemortem tongue examination were analysed by Statistical Analysis Systems [SAS®] and Statistical Package for Social Sciences [SPSS®] programs and Chi-square and P-values were calculated (Howitt and Cramer, 2000; Letz, 1996). The tests were performed at household level considering a house as positive if any of the pigs from the household were lingually detected as positive. It was observed that the pig could have access to free-range in two ways. One way was in the absence of a pig pen thereby allowing all age groups of pigs to roam freely around. The other-way of gaining access to free-range in the cases where the pig pen was constructed in such a way, that the smaller piglets were able to escape. A new variable was constructed, where the pigs were considered to have access to free-range if they had access by any of the above ways. The effect of pig management practices (free-range), sanitary facilities (lack of latrine), hygiene (pork consumption, home slaughter and pork is not inspected, forms of cooking pork e.g. barbecuing), and knowledge of *T. solium* infection in pigs and taeniosis in humans was done by means of logistic regression using SAS® program (Letz, 1996).

3.5.3 Statistical analysis for study III

3.5.3.1 Focus group discussion

Interviews and discussions were reviewed through audiotapes and field notes. By using a pencil, units were marked off that cohered because they dealt with the same topic and then divided into topics and sub-topics at different levels of analysis. Those identifiable topics or themes, which recurred with some regularity, were given names and instances of them were marked with a short label (i.e. a code). With scissors and file cards the topics were differentiated, clustered and re-labelled. Data were then displayed in a matrix. The patterns and themes were noted and then the logical chain of evidence that led to the absence of disease was built (Miles and Huberman, 1994).

3.5.3.2 Questionnaire analysis

The effect of pig management practices (husbandry), sanitary facilities and hygiene (pork consumption, home slaughter, meat inspection, presence and use of latrine) and knowledge of taeniosis/cysticercosis in humans and cysticercosis in pigs was done by Epi Info 2000 program (Dean *et al.*, 2000). Odds ratios with corresponding 95% confidence intervals and P-values were calculated to identify factors associated with tongue positivity. Logistic regression analysis using SAS® and SPSS® statistical programmes were used to assess the association between different variables and lingual studies.

3.5.4 Study IV: Statistical analysis for Ag-ELISA and tongue examination tests

The optical density (OD) of each serum sample was compared with a series of reference negative serum samples ($n = 8$) at a probability level of $P = 0.05$ to determine the cut-off using a modified-Student t-test (Sokal and Rohlf, 1981). The SPSS® (Version 10) and Epi-info 2002 software were used for statistical analysis and included χ^2 and Fisher's exact tests (two tailed) with 95% confidence intervals (95% CI) and the corresponding values of P were used to determine statistical probability to assess the association between porcine seropositivity and the different risk factors.

3.5.5 Study IV: Kappa statistics

Kappa statistics indicates percent agreement or disagreement between the two tests and in this case between tongue examination and Ag-ELISA test. Kappa statistics is given by the formula [Gordis, 1996]:

$$\text{Kappa} = \frac{[\text{\% Observed Agreement}]-[\text{ \% Agreement Expected by Chance Alone}]}{100\%-[\text{\% Agreement Expected by Chance}]}$$

CHAPTER FOUR

4.0 RESULTS

4.1 Study I: Distribution of cysticerci of *T. solium* in naturally infected local finished pigs, Mbulu District, Tanzania

The distribution of *T. solium* cysts in the individual pigs is shown in Table 9. Cysts were frequently localised in the heart, tongue, internal masseter, external masseter, *Triceps brachii*, diaphragm, brain, head muscles, forelimbs, hindlimbs, oesophagus, trunk muscles, abdominal muscles and psoas muscles. Cysts were not observed in the kidneys, spleens, livers or lungs of any of the 24 animals examined. The proportion of cysts was highly variable between organs and muscle groups. The highest proportions were observed in the hind and forelimbs. The lowest proportions were observed in the oesophagus and brain. The mean total number of cysts per carcass was found to be 11,698 ranging from 76 to 80,340 cysts.

Table 9: Distribution of cysticerci of *T. solium* between muscle groups and organs in carcasses of 24 naturally infected local finished pigs from Mbulu District, northern Tanzania.

Pig No.	He	To	In	Ex	Tri	Dia	Bra	Hea	Ab	Fl	Hl	O	Tr	K	S	L	Lu	Psoas	Total
1	45	78	194	400	308	34	6	706	16	1170	1208	0	636	0	0	0	0	300	5101
2	16	39	12	16	54	16	1	188	32	250	316	1	138	0	0	0	0	84	1163
3	9	24	16	4	94	18	3	66	26	170	150	1	54	0	0	0	0	28	663
4	720	244	164	244	342	333	29	1016	512	2394	2274	15	1690	0	0	0	0	682	10659
5	56	82	198	442	362	1	14	1148	28	1140	1620	1	254	0	0	0	0	318	5664
6	131	1557	918	1314	2080	142	163	5424	548	8902	8024	17	5078	0	0	0	0	1556	35854
7	48	40	14	40	56	34	3	178	18	276	396	0	92	0	0	0	0	62	1257
8	239	636	288	468	1224	249	26	2046	262	4862	2848	32	622	0	0	0	0	448	14250
9	590	608	266	344	772	301	11	1288	418	3384	3344	9	124	0	0	0	0	610	12069
10	1	0	0	4	0	0	13	12	0	8	28	0	0	0	0	0	0	10	76
11	179	274	232	250	348	44	37	720	94	886	484	1	44	0	0	0	0	158	3751
12	25	476	112	150	1356	95	138	1006	172	2854	3702	3	174	0	0	0	0	270	10533
13	763	2023	800	1510	7054	1156	51	5432	2568	20780	25592	41	90	0	0	0	0	12480	80340
14	226	381	252	366	794	293	13	960	312	2266	1836	12	368	0	0	0	0	348	8427
15	15	27	56	16	56	28	11	130	14	222	184	0	10	0	0	0	0	64	833
16	361	647	436	390	1048	425	11	2020	348	4582	1928	6	180	0	0	0	0	932	13314
17	125	650	416	796	974	545	18	2636	840	7502	5838	4	302	0	0	0	0	1412	22058
18	82	410	220	312	672	4	98	1170	30	2020	3698	6	482	0	0	0	0	768	9972
19	88	217	166	252	640	111	33	1086	330	1986	2720	2	406	0	0	0	0	428	8465
20	146	605	332	536	870	460	147	1126	240	2600	6574	7	440	0	0	0	0	778	14861
21	180	184	118	124	174	106	8	202	66	1270	1162	12	216	0	0	0	0	222	4044
22	166	155	86	262	1076	128	47	856	316	2764	3370	24	618	0	0	0	0	728	10596
23	18	248	54	90	230	138	*	508	2	416	962	0	40	0	0	0	0	170	2876
24	57	46	88	152	236	106	*	634	98	960	1236	2	26	0	0	0	0	284	3925
Total	**4286**	**9651**	**5438**	**8482**	**20820**	**4767**	**881**	**30558**	**7290**	**73664**	**79494**	**196**	**12084**	**0**	**0**	**0**	**0**	**23140**	**280751**
% total	**1.53**	**3.44**	**1.94**	**3.02**	**7.42**	**1.70**	**0.31**	**10.88**	**2.60**	**26.24**	**28.32**	**0.07**	**4.30**	**0**	**0**	**0**	**0**	**8.24**	**100**

Key: He, heart; To, tongue; In, internal masseter; Ex, external masseter; Tri, *Triceps brachii*; Dia, diaphragm; Bra, brain; Hea, head muscles; K, kidneys; Fl, forelimbs; Hl, Hindlimbs; O, oesophagus; Tr, trunk muscles; Ab, abdominal muscles; S, spleen; L, liver; Lu, lungs; and *, missing data.

Source: Boa *et al.*, 2002

Table 10 shows mean cysts proportions, relative cyst density, proportions of carcasses parasitized at the organ/muscle group site and proportions of carcasses with viable cysticerci at the site. The highest proportion of cysts was found in the hindlimbs followed by the forelimbs and head muscles. The lowest proportions were observed in the oesophagus, brain, internal masseter muscles, diaphragm and abdominal muscles (Table 10, Fig. 8).

Almost all of the organs/muscle groups were parasitized with the same frequency (96 - 100 %) in the pigs with the exception of the oesophagus which was parasitized in only 75 % of the carcasses. A mean of 17.2 % of the total carcass cysts were located in the organs/muscle groups which are routinely examined during meat inspection in Tanzania, i.e. heart, tongue, internal masseter, external masseter and *Triceps brachii* muscles. Of these, *Triceps brachii* muscles had the highest mean proportion of cysts (7.4 %). Of the meat inspection organs relative cyst density was found highest in the internal masseter with the value of 8.1 and lowest in the heart with density of 1.9. However, psoas muscles, which is not in the current Tanzanian meat inspection regulation of 1993, was found to have a higher value than any of the meat inspection organs with a density of 10.5 (Table 10 and Fig. 8).

Analysis of cyst distribution in male and female animals indicated that host sex did not have any significant influence on cyst numbers in the carcasses examined (P=0.204, two-tailed).

Table 10: Distribution of cysticerci of *T. solium* between muscle groups and organs in carcasses of local slaughter pigs from Mbulu, Tanzania.

Organ/muscle	Distribution of cysts[1]		Mean weight of organ[2]		Relative cyst density	P[1]	P[2]
	%	95% CI	%	95% CI			
Heart	1.5	1.3 – 2.7	0.81	0.71- 0.90	1.9	100	33
Tongue	3.4	2.8 – 4.3	1.10	0.88 -1.22	3.1	96	58
Internal masseter	1.9	1.8 – 3.0	0.23	0.19 - 0.27	8.3	96	83
External masseter	3.0	2.7 – 4.2	0.42	0.34 - 0.50	7.1	100	79
Triceps brachii	7.4	5.8 - 8.2	1.50	1.31-1.65	4.9	96	88
Diaphragm	1.7	1.4 - 2.5	0.72	0.65 - 0.79	2.4	96	63
Brain	0.3	0.0 - 2.5	0.34	0.28 - 0.39	0.9	100	100
Head muscles	10.9	11.3 - 14.4	3.02	2.7 - 3.35	3.6	100	71
Fore limb	26.2	22.2 - 26.8	6.60	6.19 - 7.00	4.0	96	67
Hind Limb	28.3	24.8 - 30.7	8.88	8.14 - 9.21	3.2	96	46
Oesophagus	0.1	0.0 - 0.1	0.24	0.18 - 0.29	0.4	75	75
Trunk muscles	4.3	3.0 - 6.7	4.09	2.53 - 5.65	1.1	96	63
Abdominal muscles	2.6	1.6 - 2.7	2.07	1.77 - 2.36	1.3	96	54
Psoas muscle	8.2	5.1 - 7.4	0.77	0.67 - 0.87	10.7	100	75

[1]Mean of individual percentages of total cysts per carcass.

[2]Expressed as a percentage of the total weight of organs/muscles.

P^1 = Proportion of carcasses parasitized at the site.

P^2 = Proportion of carcasses with only viable cysticerci at the site.

Source: Boa *et al.*, 2002

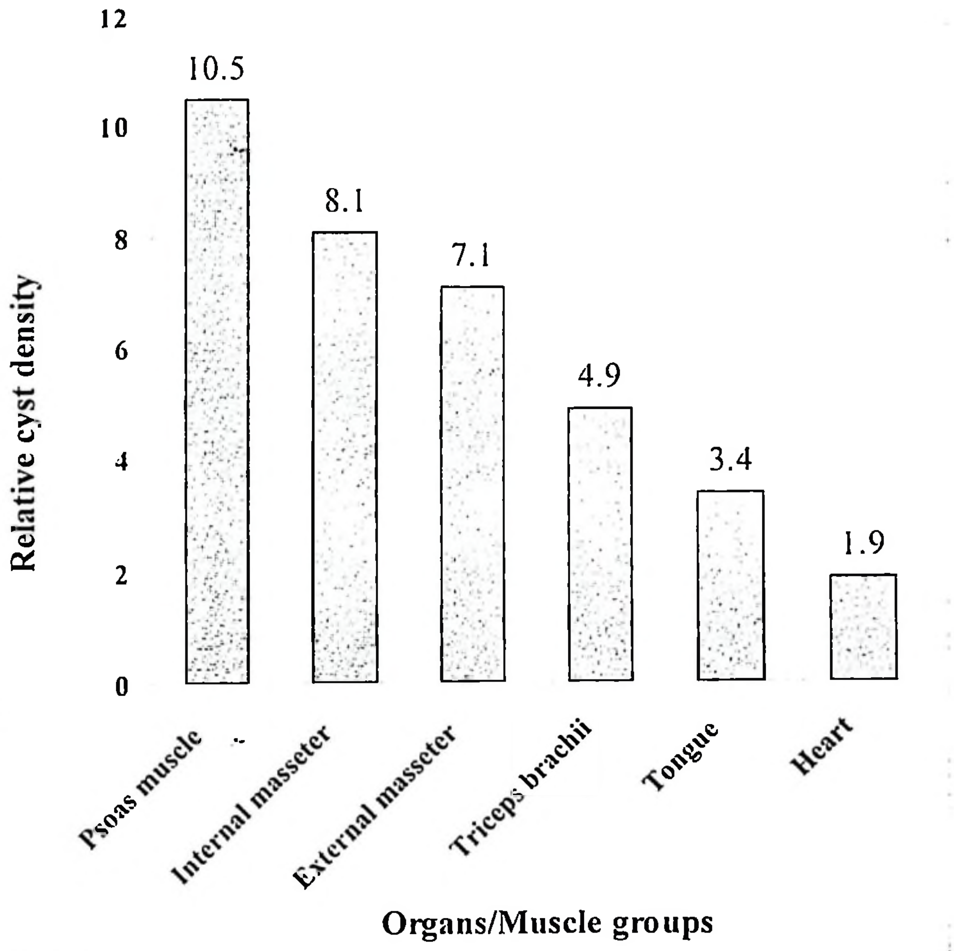


Figure 8: Relative cyst density of cysticerci of *T. solium* of meat inspection organs and psoas muscle in carcasses of local slaughter pigs from Tanzania.

Source: Boa *et al.*, 2002.

Table 11: Mean areas of meat inspection organs revealed by meat inspection and total slicing, proportion of area located in the site and proportion of *T. solium* cysticerci expected to be revealed at inspection sites.

Organ or muscle group inspected	Mean area revealed by meat inspection (cm^2)	Mean area revealed by total slicing (cm^2)	Inspection proportion of area located in the site x (%)	Relative cyst density (y)	Proportion of cysts expected (xy) (%)
Heart	136	425	32	1.9	0.6
Tongue	187	492	38	3.4	1.3
Internal masseter	86	158	54	8.1	4.4
External masseter	116	245	47	7.1	3.3
Triceps brachii	172	868	20	4.9	1.0
Total	**697**	**2,188**		**25.4**	**10.6**

Source: Boa *et al.*, 2002.

The areas accessible for visual examination following the government-prescribed meat inspection procedures of the organs and muscle groups are shown in Table 11. Mapping of the inspected surfaces showed that a mean area per animal of 697 cm^2 was inspected by visual examination of the surfaces following incisions according to the meat inspection regulations. The inspected area of each individual site was divided by the area of the incision necessary to reveal all cysts. The inspected areas constituted between 20 - 54 % of that necessary to find all cysts in the particular site. These figures were compared with the proportions of cysts found in that site, whereby the contribution of each site to cyst detection could be calculated (Table 11). When summing the results from the different sites it can be seen that, theoretically, 10.6% of the total cysts could be detected by incising the organs recommended in the meat inspection regulations.

4.2 Study II: Determination of prevalence and risk factors associated with porcine cysticercosis in southern highlands of Tanzania

4.2.1 Preliminary study: Determination of focal areas of disease by the use of meat inspection records

4.2.1.1 Preliminary study covering Chunya and Rungwe Districts, Mbeya Region

A slaughter slab survey conducted in Chunya District in the year 1998 indicated an overall porcine cysticercosis prevalence of 20.8% with the range of 0-35.7% [Table 12(A)]. While in 1999 with observations recorded for only seven months the mean prevalence and range were found to be 28.7% (16.7-36.8%) [Table 12 (B)].

Table 12: Cases of porcine cysticercosis from slaughter slabs in Chunya District, Mbeya Region, Tanzania, from 1998 (Table 12(a)-12 months) to 1999 (Table 12(b)-7 months).

(A) 1998.

Month	Carcasses examined	Positive cases	% Prevalence
January	14	5	35.7
February	13	3	23.1
March	11	0	0.0
April	16	4	25.0
May	13	4	30.8
June	12	1	8.3
July	18	6	33.3
August	18	1	5.5
September	13	2	15.4
October	16	1	6.3
November	15	5	33.3
December	24	6	25.0
Total	**183**	**38**	**20.8**

(B) 1999.

Month	Carcasses examined	Positive cases	% Prevalence
January	11	4	36.4
February	6	1	16.7
March	14	3	21.4
April	11	3	27.3
May	14	3	21.4
June	19	7	36.8
July	19	6	31.6
Total	**94**	**27**	**28.7**

Meat inspection records at Kiwira slaughter slab shows that of the 2,511 pig carcasses examined, 48 had cysticercosis making the mean overall prevalence of 1.9% with the range of 0 - 4.3 (Table 13). Chunya and Rungwe Districts were the two districts in Mbeya Region covered in the preliminary survey. From the meat inspection records described above Chunya was found to have a significantly higher mean prevalence proportion of 24.8% than Rungwe District with a prevalence proportion of 1.9% thus, Chunya District was chosen for an exhaustive survey of *T. solium* cysticercosis/taeniosis.

Table 13: Cases of porcine cysticercosis determined by post-mortem pork inspection at Kiwira, Rungwe District, Mbeya Region, Tanzania.

Year	Number of carcasses inspected	Positive cases	% prevalence
1992	343	15	4.4
1993	489	17	3.5
1994	445	8	1.8
1995	358	4	1.1
1996**	308	2	0.7
1997*	241	1	0.4
1998	249	0	0.0
1999***	78	1	1.3
Total	**2,511**	**48**	**1.9**

* Data for one month was missing.

**Data for two months were missing.

***Data was available for only the first 7 months of the year.

4.2.1.2 Preliminary study covering Iringa Rural and Ludewa Districts, Iringa Region

Available information from slaughter slab inspection conducted in Iringa Rural District for the years 1996, 1997 and 1998 indicated that the disease is prevalent in the district however, the recording of data during these years was rather erratic. For example in 1996 the only records available were for the month of October. Also, the numbers of pigs examined in some of the years (*e.g.* 1997) when cases of porcine cysticercosis were recorded are not known (Table 14).

Table 14: Prevalence of porcine cysticercosis from slaughter slabs in Iringa Rural District, Tanzania, for the years 1996, 1997 and 1998.

Year	Carcasses examined	Positive cases	% prevalence
1996*	63	2	3.2
1997**	-	8	-
1998***	103	19	18.5

* Data were available for the month of October only.

** Data on positive cases were available but those on number of carcasses examined were not available. Data that were available are for the months of April and June.

*** Data is for the whole year.

Post mortem meat inspection conducted in Ludewa District in the years 1993 to 1998 showed that a total 1,530 pigs were examined during the 6 year period and only 60 were found positive making the overall prevalence of 3.9% with the range of 2.3 to 6.6% (Table 15). Based on the meat inspection records described above in Tables 14 and 15 Iringa Rural District was observed to have significantly higher porcine cysticercosis cases proportion than Ludewa District and was thus chosen for an exhaustive survey of the disease.

Table 15: Prevalence of porcine cysticercosis determined by post-mortem meat inspection, Ludewa District, Iringa region, Tanzania.

Year	Carcasses examined	Positive cases	Prevalence (%)
1993	272	11	4.0
1994	387	9	2.3
1995	356	8	2.3
1996	148	8	5.4
1997	182	12	6.6
1998	185	12	6.5
Total	**1,530**	**60**	**3.9**

4.2.2 Preliminary study: Determination of focal areas of disease by the use of interviews, hospital records and tongue examination of pigs claimed to be positive for cysticercosis

4.2.2.1 Interviews and ante-mortem lingual examination of suspect pigs

Interviews of pig traders/farmers in the four selected districts (Chunya, Rungwe, Iringa Rural and Ludewa) about porcine cysticercosis indicated that they knew the problem was there and it is widely distributed in pig raising communities. Cysticercosis has become a major obstacle for farmers to market their pigs as pig traders have become aware of the problem and they make pre-purchase lingual examination in order to determine the infection status of the pigs. Traders do not buy positive pigs and the fate of these pigs is left with the owners. These positive pigs are usually slaughtered at home and consumed or sold locally. At the time of the investigation inquiry of the pig traders/farmers about lingually positive pigs revealed that several pigs currently in the villages had been found to be tongue positive for cysticercosis and in many cases we were able to confirm their infection status by our own lingual examination. The interviewed farmers were unaware of the mode of transmission of *T. solium* cysticercosis/taeniosis (*i.e.* how a pig gets cysts and humans get tapeworms and the connection between the two).

4.2.2.2 Hospital Records

4.2.2.2.1 Chunya District

Recorded cases of epilepsy for the years 1995 to 2000 is presented in Table 16. The records indicate that in both under fives and over, there was a dramatic increase in the cases of epilepsy. For over 5 years age category the cases rose from 9 in 1995 to 450 in 2000. While in under fives the cases rose from 0 in 1995 to 36 in 2000.

Table 16: Cases of epilepsy recorded at the government hospital, Chunya District, Mbeya Region, Tanzania.

Year	Age Category	
	Under 5	**Over 5**
1995	0	9
1996	0	2
1997	31	207
1998	Missing	Missing
1999	0	289
2000	36	450

4.2.2.2.2 Rungwe District

Table 17 depicts cases of human taeniosis confirmed by microscopic examination of stools in the government hospital of Rungwe District at 3 different time points: 1979, 1994 and 1997-1998. In this period a total of 7.524 samples were examined and only 10 were found to be positive for *Taenia* eggs giving a very low overall prevalence of 0.1% (0.0-0.3). Notably no cases were detected in 1997 and 1998.

Table 17: Cases of human taeniosis confirmed by coprological examination at Tukuyu government hospital, Rungwe District, Tanzania.

Year	Total samples examined	Positive cases	Prevalence (%)
1979	3,413	9	0.3
1994	675	1	0.2
1997	564	0	0.0
1998	2872	0	0.0
Total	7,524	10	0.13

Table 18 shows cases of epilepsy recorded at Rungwe government hospital for the years 1997 and 1998. In 1997, 46 patients attended the clinic while in 1998 the cases increased by 20 patients making the recorded cases of 66. However, this increase could not be traced back to determine whether any of the patients seen in 1998 were also included in the 1997 records.

Table 18: Cases of epilepsy in patients attended at Rungwe District, Tanzania governmental hospital for the years 1997 and 1998.

Year	Cases
1997	46
1998	66
Total	**112**

4.2.2.2.3 Iringa District

Recorded cases of psychiatry and epilepsy in Iringa Rural District for the years 1993 through 1996 are displayed in Table 19 below. Among 3,121 psychiatric cases 1,058 were due to epilepsy making the overall prevalence 33.9% with the range of 28.6% to 40.1%. Over the 4 years observation period the prevalence of epilepsy has been gradually increasing from 28.6% in 1993 to 40.1% in 1996.

Table 19: Cases of psychiatry and epilepsy attended at government hospital, Iringa District, Tanzania.

Year	Psychiatric cases	Epileptic cases	% Prevalence
1993	926	265	28.6
1994	930	343	36.9
1995	666	210	31.5
1996	599	240	40.1
Total	**3,121**	**1,058**	**33.9**

4.2.2.2.4 Ludewa District

Table 20 depicts recorded cases of epilepsy at the government hospital in Ludewa District from 1991 to 1999. Over the six and a half years observational period there has been a significant increase in the number of cases whereby in the early 1990s the cases were as low as 4 in 1993 and dramatically rose to 89 cases in 1998. However, there was a drop in the number of cases between 1991 and 1992 whereby there were 17 cases in 1991 while in 1992 the number of cases were only 8.

Table 20: Cases of epilepsy in patients received at the government hospital in Ludewa District, Tanzania.

Year	Cases
1991	17
1992	8
1993	4
1994	7
1997	81
1998	89
1999*	58
Total	**264**

Key: *Data that were available are those of the first six months of the year.

Note: Data for the years 1995 and 1996 were not available.

Table 21 shows the prevalence of human taeniosis in Ludewa District diagnosed using microscopic examination of stool samples. The overall mean prevalence of 1.7% (1.1% – 2.3%) was observed by examining 2055 samples among which 35 were found positive. There is no clear trend in the rate of prevalence over the five year observation period.

Table 21: Cases of human taeniosis confirmed by coprological examination in the laboratory at Ludewa, Tanzania government hospital from 1995-1999.

Year	Number examined	Positive cases	Prevalence
1995	506	8	1.6
1996	483	11	2.3
1997	401	6	1.5
1998	396	7	1.8
1999*	269	3	1.1
Total	**2,055**	**35**	**1.7**

Key: *Data that were available are those of the first six months of the year.

4.2.3 Study II: Exhaustive cross-sectional survey to determine prevalence of porcine cysticercosis by ante-mortem lingual examination

4.2.3.1 Chunya District

A total of 722 pigs raised in 231 households were lingually examined in the 21 randomly selected villages in Chunya District. Fifty-five were found infected with cysticerci of *T. solium*, giving an overall prevalence of 7.6% (Table 22). The prevalence varied between villages from 0% to 23.8% and of the 21 villages examined 13 (61.9%) had at least one pig infected. The results of the survey shows that over half of the villages involved in the study were infected. Thus, porcine cysticercosis is a widely distributed condition in the district.

Table 23 groups 722 pigs that were examined lingually into age categories of breeders, fatteners and weaners. It also depicts prevalence rates by age categories, risk ratios and its confidence intervals and respective p-values. Three hundred eighteen (44.0%) were categorized as breeders with the age over 12 months. While 280 (38.8%) pigs between 6 months and 11 months were categorized as fatteners. And 124 (17.2%) pigs were those between two and five months of age, which were categorized as weaners. Breeders were found to have higher prevalence proportions than fatteners. Also breeders and fatteners were found to have higher prevalence proportions than younger pigs (weaners). However, these differences were not statistically significant as odds ratios and 95% confidence intervals indicate in Table 23.

Table 22: Prevalence of porcine cysticercosis by village as observed by lingual examination, Chunya District, Tanzania.

Village	Pigs examined	Pigs Positive	Prevalence [%]
Chalangwa	32	0	0
Galula	38	4	10.5
Ifumbo	50	5	10.0
Igundu	21	5	23.8
Ileya	41	0	0
Kalangali	23	5	21.7
Kaloleni	18	0	0
Kanga	34	4	11.8
Lupatingatinga	38	0	0
Magamba	43	6	14.0
Manda	41	0	0
Matwiga	14	0	0
Mbuyuni	32	2	6.3
Mkwajuni	51	10	19.6
Mlimanjiwa	32	2	6.3
Muheza	44	2	4.6
Namambo	31	3	9.7
Sangambi	31	2	6.5
Tete	46	0	0
Totowe	31	3	9.7
Mamba	31	2	6.5
Totals	**722**	**55**	**7.6**

Table 23: Prevalence of porcine cysticercosis by tongue examination as a function of pig age, Chunya District, Tanzania.

Category	Pigs observed	Pigs infected	Prevalence [%	Odds Ratio [OR]	OR 95%CI
Breeders	318	27	8.5	1.31	0.69-2.49
Fatteners	280	20	7.1		
Breeders	318	27	8.5	1.35	0.57-3.34
Weaners	124	8	6.5		
Fatteners	280	20	7.1	1.12	0.45-2.85
Weaners	124	8	6.5		

Among 231 persons interviewed 114 (49.4%) were male and 117 (50.6%) were female with an overall median age of 38 years ranging from 14 to 80 (Table 24). More than half (62.3%) of the interviewees were graduates of elementary school while only 2.2% had gained secondary education and none went beyond secondary education. More than one third (35.5%) of interviewed persons were illiterates. Respondents who were pork eaters were 197 (85.3%) and among them 66 (33.5%) preferred barbecued pork. None of the interviewees preferred raw pork. One hundred twenty-nine (55.8%) respondents said they were conducting home slaughters of pigs and among these persons 116 (89.9%) said the pork was not inspected. Households that were lacking a latrine were 14 (6.1%) only. Respondents who managed their pigs under the freerange system were 104 (45.0%) and those who corralled their animals were 93 (40.3%). Among 93 pig pens that were inspected 82 (88.2%) were found inadequate to totally confine piglets that are 2 months old or younger [Fig. 12]. Thus, 88.2% of the households were managing their pigs under freerange system (Fig. 9. Table 24). Persons who heard or knew of tapeworm carriers in the villages where they lived were 79 (34.2%) and those who don't know how a person can get taeniosis were 75 (94.9%). Persons who said they will do nothing in case they have taeniosis were 41 (17.7%). Respondents who don't know how a pig becomes infected were 213 (92.2%). While those who don't know what to do with an infected pig were 115 (49.8%). Most (94.8%) of the interviewed persons knew at least one person with epilepsy in the village where they lived.

Table 24: Questionnaire study results on knowledge of *T. solium* taeniosis/cysticercosis and possible transmission factors, Chunya District, Tanzania.

Categories and education level of respondents and types of responses	No. (%)
Categories of respondents:	
Males	114 (49.4)
Females	117 (50.6)
Education level:	
Illiterate	82 (35.5)
Primary education	144 (62.3)
Secondary education	5 (2.2)
Beyond secondary education	0 (0)
Possible transmission factors:	
Respondents consuming pork	197 (85.3)
Respondents who prefer barbecuing as form of cooking pork	66 (33.3)
Respondents who prefer deep frying as form of cooking pork	82 (41.4)
Respondents who prefer boiling as form of cooking pork	50 (25.3)
Respondents who preferred raw pork	0 (0)
Households which conducted home slaughters	129 (55.8)
Conducted home slaughters and pork was not inspected	116 (89.9)
Households without latrine	14 (6.1)
Respondents who manage pigs under free range system	104 (45.0)
Respondents who kept their pigs in pens	93 (40.3)
Pig pens that will allow a weaner pig to escape	82 (88.2)
Knowledge on taeniosis/cysticercosis:	
Respondents who heard of tapeworms infection in humans	79 (34.2)
Respondents who don't know how people get taeniosis	75 (94.9)
Respondents who will do nothing in case they have taeniosis	41 (17.7)
Respondents who don't know how a pig gets cysts	213 (92.2)
Respondents who don't know what to do with a pig with cysticercosis	115 (49.8)
Respondents who know someone in the village with epilepsy	219 (94.8)
Respondents who have seen cysts in pork	160 (69.3)

Table 25 presents percentage of pigs positive by lingual examination as a function of the presence or absence of a latrine, free range system of management, home slaughters and pork not inspected or no home slaughters, and form of cooking - barbecue against frying and boiling. Of the 722 pigs examined 670 (92.8%) were reared in households with a latrine while 52 (7.2%) were raised in households without a latrine. Prevalence proportion of pigs reared in households without a latrine and those with a latrine were 26.9% and 6.1%, respectively. Pigs that were kept in households without a latrine had a significantly higher prevalence proportion than those kept in households with a latrine (OR =5.65; 2.68<OR<11.83). Four hundred sixty-two (77.6%) pigs were kept under the free range system while 260 (22.4%) were under total confinement and the prevalence proportion in free range pigs was significantly higher (10.0%) compared to those kept under total confinement (3.5%) (OR= 3.08; 1.43<OR<6.9). Pigs managed in households that were conducting home slaughters where pork was not inspected were found to have significantly higher prevalence proportions (12.0%) than those reared in households where home slaughters were not conducted (2.2%) (OR= 6.1; 2.61<OR<14.97). Pigs that were raised in households where the preferred form of cooking is barbecue had higher prevalence proportions than those coming from homes where boiling and frying were the preferred forms of cooking pork. However, the difference was not statistically significant (OR=1.63; 0.86<OR<3.08). Thus, in Chunya District risk factors associated with the presence and maintenance of the disease were free-range management of pigs, absence of a latrine and conducting home slaughters of pigs with no inspection of the pork.

Table 25: Prevalence of porcine cysticercosis by tongue examination and associated risk factors, Chunya District, Tanzania.

Factor	Pigs observed	Pigs infected	Prevalence	Odds Ratio	OR 95%CI
Latrine : Absent	52	14	26.9	5.65	2.68-11.83
Latrine: Present	670	41	6.1		
Free range	462	46	10.0	3.08	1.43-6.88
Confined	260	9	3.5		
Home slaughter	401	48	12.0	6.10	2.61-14.97
No home Slaughter	321	7	2.2		
Barbecuing	201	21	10.5	1.63	0.86-3.08
Frying & boiling	404	27	6.7		

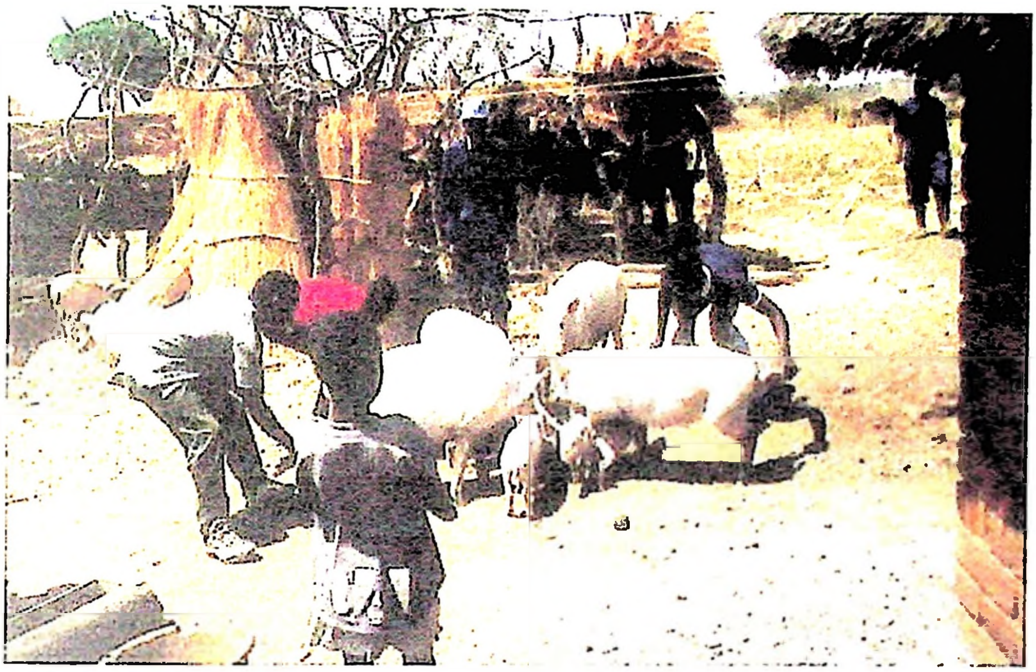


Figure 9: Unrestrained sows and piglets freely roaming around the household compound in Chunya District where 88.2% [n=231] of the respondents admitted that they allowed their pigs to freely forage.

4.2.3.2 Iringa Rural District

From the 808 pigs sampled in Iringa Rural District. 68 were found positive by tongue examination making the overall prevalence 8.4% (Table 26). Based on these examination results, evidence of porcine cysticercosis was found in 17 (68%) of the villages and in 52 (15.3%) of the 341 households sampled. The prevalence varied among villages from 0 to 29.0% and of the 25 villages examined 17 (68%) had at least one pig infected. The findings of the survey shows that 2/3 of the sampled villages were infected implying wide distribution of infection in the district pig population. However, at household level the disease distribution seems to be focal in that few (15.3%) households had large numbers of infected pigs while most (84.7%) households had no pigs infected.

One hundred ninety-three males and 148 females (age range 14 to 80 years: median age 35 years) responded to the questionnaire (Table 27). More than three quarters (76.8%) of the interviewees had a primary school education while only 4.7% had secondary education and none went beyond secondary education. Just below a quarter (18.7%) of interviewed persons were illiterates. Three hundred twenty-nine respondents (96.5%) were consuming pork and 171 (52.0%) preferred barbecue as a form of cooking pork (Table 27). None of the 341 persons questioned reported that they preferred raw pork. Respondents who said they were conducting home slaughters with no meat inspection were 116 (74.8%). While those who kept their pigs in pig pens that allowed piglets of two months old or less to escape were 195 (62.7%) (Fig.12. Table 27). A very minor percentage (0.9%) of respondents kept their pigs under free-range system (Table 27). Persons who heard or knew of tapeworm carriers in the village where they lived were 186 (54.5%) and those who do not know how a person becomes infected with taeniosis were 155 (83.3%).

Persons who said they will not take any action in case they have taeniosis were 104 (30.5%) and those who do not know how a pig becomes infected with cysts were 302 (88.6%). While those who do not know what to do with an infected pig were 29 (15.7%). Most (94.1%) of the interviewed persons knew at least one person with epilepsy in the village where they lived (Table 27).

Table 26: Prevalence of porcine cysticercosis by village as observed by lingual examination in Iringa Rural district, Tanzania.

Village	Pigs examined	Pigs Positive	Prevalence [%]
Kipaduka	43	0	0.0
Imalutwa	35	1	2.9
Itungi	31	1	3.2
Ilulaltunda	46	1	2.2
Lulanzi	29	1	3.5
Mibikimitali	30	8	26.7
Nyabula	37	0	0.0
Wangama	19	0	0.0
Mlanda	32	3	9.4
Tagamenda	32	0	0.0
Wenda	29	3	10.3
Ng'ingula	31	6	19.4
Idegenda	31	9	29.0
Ilutila	45	8	17.8
Udumka	30	6	20.0
Mfukulembe	32	3	9.4
Itengulinyi	33	3	9.1
Sadani	16	1	6.3
Lusinga	34	5	14.7
Ndiwili	32	7	21.9
Irole	35	0	0.0
Matembo	32	0	0.0
Nduli	36	2	5.6
Mazombe	20	0	0.0
Mbigili	38	0	0.0
Total	**808**	**68**	**8.4**

Table 27: Questionnaire study results on knowledge of *T. solium* taeniosis/cysticercosis and probable risk factors, Iringa Rural District, Tanzania.

Categories, education level of respondents and types of responses	No. [%]
Categories of respondents:	
Males	193 (56.6)
Females	148 (43.4)
Education level:	
Illiterate	63 (18.5)
Primary education	262 (76.8)
Secondary education	16 (4.7)
Beyond secondary education	0 (0)
Possible transmission factors:	
Respondents consuming pork	329 (96.5)
Respondents who prefer barbecuing as form of cooking pork	171 (52.0)
Respondent who preferred deep frying as form of cooking pork	100 (30.4)
Respondent who preferred boiling as form of cooking pork	58 (17.6)
Respondent who preferred raw pork	0 (0)
Households which conducted home slaughters	155 (45.6)
Conducted home slaughters and pork was not inspected	116 (74.8)
Households without latrine	19 (5.6)
Respondents who managed pigs under free range system	3 (0.9)
Respondents who kept their pigs in pens	311 (91.2)
Pig pens that will allow a weaner pig to escape	195 (62.7)
Knowledge on taeniosis/cysticercosis:	
Respondents who heard of tapeworms infection in humans	186 (54.5)
Respondents who don't know how a person gets taeniosis	155 (83.3)
Respondents who will do nothing in case they have taeniosis	104 (30.5)
Respondents who don't know how a pig gets cysts	302 (88.6)
Respondents who don't know what to do with a pig with cysticercosis	29 (15.7)
Respondents who know someone in the village with epilepsy	319 (94.1)
Respondents who have seen cysts in pork	123 (36.1)

The number of pigs examined by ante-mortem lingual examination in different age groups, number of cases positive per age group, prevalence rates, odds ratios and its confidence interval are displayed in Table 28. A total of 808 pigs raised in 341 households were lingually examined in the 25 randomly selected villages in Iringa District. Two hundred seventeen (26.9%) were breeders, 337 (41.7%) were fatteners and 254 (31.4%) were weaners. Prevalence proportions of porcine cysticercosis were found to be increasing with the age of the pig. Breeders were observed to have a higher prevalence proportion than either the fattener or weaner age groups. There was no significant difference between prevalence proportion of breeders compared to fatteners (OR= 0.99; 0.55<OR<1.78) however, breeders were found to have a significantly higher prevalence proportion than weaners (OR=3.23; 1.38<OR<7.71). Similarly fatteners were found to have significantly higher prevalence proportion than weaners (OR=3.26; 1.47<OR<7.42).

Table 28: Prevalence of porcine cysticercosis by tongue examination as a function of pig age, Iringa Rural District, Tanzania.

Age category	Pigs observed	Pigs infected	Prevalence [%]	Odds ratio [OR]	OR 95%CI
Breeder	217	23	10.6	0.99	0.55 – 1.78
Fattener	337	36	10.7		
Breeder	217	23	10.6	3.23	1.38 – 7.71
Weaner	254	9	3.5		
Fattener	337	36	10.7	3.26	1.47 – 7.42
Weaner	254	9	3.5		

Possible risk factors for porcine cysticercosis determined by ante-mortem tongue examination are shown in Table 29. Pigs that were raised at households with latrines were observed to have slightly higher prevalence proportions (8.5%) than those raised in households without a latrine (7.0%). The Odds Ratio between households without latrines and those with latrines was found to be 0.8. However. this difference is not statistically significant (OR=0.81; 0.19<OR<2.82). Pigs that were reared under the free-range management system were observed to have higher prevalence proportions (12.9%) than those reared under total confinement (4.3%). Maintaining pigs under a free-range system was found to be a risk factor (OR = 3.32; 1.85 <OR< 6.43). In households where the preferred form of cooking pork was barbecuing, pigs raised in those households had significantly higher prevalence proportions (10.7%) than those raised in households where the preferred form of cooking was either boiling or frying (1.0%). Barbecuing was also found to be a risk factor (OR= 11.56; 3.92 <OR<38.4). Pigs raised in households where home slaughters were conducted but the pork not inspected were observed to have higher prevalence proportions (14.2%) than those in which pork was inspected (4.0%). Home slaughter with no pork inspection was identified as a risk factor (OR=4.03; 1.33<OR<13.61). Pigs that were reared by respondents who were ignorant of the mode of transmission of porcine cysticercosis were found to have higher prevalence rate (8.6%) than those raised by respondents who were knowledgeable (1.4%). However, this difference was not statistically significant (OR=6.66; 0.95<OR<132.98). Thus, risk factors identified to be associated with porcine cysticercosis in Iringa Rural District were free-range pig management, barbecuing of pork as the preferred form of cooking and home-slaughtering of pigs with no inspection of the pork.

Table 29: Prevalence of porcine cysticercosis by tongue examination and associated risk factors, Iringa Rural District, Tanzania.

Factor	Pigs observed	Pigs infected	Prevalence [%]	Odds ratio [OR]	OR 95% CI
No latrine	43	3	7.0	0.81	0.91-2.82
Latrine is present	765	65	8.5		
Free range	387	50	12.9	3.32	1.85-6.43
Confined	421	18	4.3		
Form of cooking: barbecuing	384	41	10.7	11.56	3.92-38.40
Form of cooking: frying and boiling	391	4	1.0		
Home-slaughters	288	41	14.2	4.03	1.33-13.61
No home-slaughters	101	4	4.0		
Ignorant of mode of transmission	385	33	8.6	6.66	0.95-132.98
Knowledgeable of mode of transmission	72	1	1.4		

Figure 10: Pigs freely foraging in a farm after harvest season (dry season) in Mibikimitali Village, Kiponzelo Division, Iringa Rural District where pig raisers admitted that 62.7% [n=341] of the pigs are free ranged.

Table 30 depicts the association between cases of porcine cysticercosis in the household and two management factors: Absence of latrines and allowing pigs to freely forage. There was a very strong association between the management factors "No latrine" and "Free-range" as reflected in the extremely few houses with good pig pens but no latrines (OR=24.4: 12.5<OR<48.4). Farmers appear to give priority to the construction of latrines before making good pig pens. Due to the association it was decided to analyze these two management factors in a single table. The analysis indicates strong interaction between the absence of a latrine and free-range pig management. Thus, "free-range" pig management leads to increased risk in the *T. solium* infection farms where latrines were absent. Whereas free-ranging of pigs did not lead to any increased risk of pigs acquiring cysticercosis if the household had a latrine (OR≈1.0: 0.33<OR<3.82).

Table 30: The association between cases of porcine cysticercosis in the households and absence of a latrine and maintaining pigs under free-range conditions.

Interaction factors		Cases in household	No cases	Households infected [%]	OR
No latrine	Free-range	43	19	69	24.4
No latrine	Constantly confined	0	2	0	
Latrine	Free-range	39	421	8.5	≈1.0
Latrine	Constantly confined	4	44	8.3	≈1.0

Note: *In the analysis data for Chunya and Iringa Rural Districts were combined.*

Table 31 presents the interactions of the risk factors, home-slaughtering of pigs and pork inspection. Home slaughtering of pigs did not add extra risk in the households where pork inspection was conducted (OR=0.94; 0.26<OR<3.0) compared to the groups that did not practice home slaughtering of pigs (OR=1.0; 0.3<OR<3.8). However, the households where home-slaughtering of pigs took place without pork inspection had a higher risk of porcine cysticercosis (OR=3.9; 2.3<OR<6.8).

Table 31: The relation between home-slaughter of pigs, pork inspection and occurrence of porcine cysticercosis cases (cases versus no-case) at the household level.

Interaction factors		Cases	No cases	OR
Home-slaughter	Pork not inspected	59	172	3.9
Home-slaughter	Pork inspected	4	49	0.94
No home-slaughter	Pork not inspected	23	264	≈1

Note: *In the analysis data for Chunya and Iringa Rural Districts were combined.*

4.3 Study III: Investigative study on factors responsible for the absence of porcine cysticercosis in Mgeta Division, Morogoro Rural District, Tanzania

4.3.1 Tongue examination, serological testing of pigs and pork inspection findings

A total of 609 pigs [118 (19.4%) breeders. 241 (39.6%) fatteners and 250 (41.0%) weaners] were examined lingually for *T. solium* cysts. All of the pigs were found negative by tongue examination. Serological testing of these pigs using an antigen-ELISA confirmed that 98.7% had no circulating antigens against *T. solium* or *T. hydatigena* cysticercosis. Also. 124 pigs were examined post-mortem at homesteads and all were found negative for *T. solium* cysticercosis. However, one pig was found infected with the larval form of *T. hydatigena* that was observed as a solitary cyst in the liver.

4.3.2 Questionnaire study results on knowledge and possible prevention factors on *T. solium* taeniosis/cysticercosis, Mgeta Division, Tanzania

Table 32 depicts categories of respondents, their educational levels, possible preventative factors and their knowledge on *T. solium* taeniosis/cysticercosis. Of the 216 interviewees 124 (57.4%) were male and 92 (42.6%) were females. The median age for females was 35 (range: 14 to 72 years) while that for males was 39.5 years (range: 15 to 74 years). On education status 21 (9.7%) respondents did not attend any kind of formal education while 194 (89.8%) were primary school graduates. Only 4 (1.9%) of the interviewees completed secondary education and none of the respondents went beyond secondary education.

Most (98.6%) of the interviewed persons eat pork and those who prefer their pork to be fried were 138 (63.9%) while those who preferred boiling as a form of preparing pork were 69 (31.9%). The minority (2.8%) preferred barbecue as a form of cooking pork and none preferred raw pork (Table 32). Eighty-three (38.4%) respondents said they have conducted home slaughter of pigs and among those 77 (92.8%) said the pork was not inspected. Of the 216 households visited 210 (97.2%) had latrines that were being used and only 4.2% of them had latrines that were full or had no latrine at all. With regard to pig management (housing) 210 (97.2%) pig pens were scored good, meaning the pens can totally confine all the age categories of pigs [Fig. 11]. However, those that can allow a piglet to escape were scored bad [Fig. 12]. A small percentage (2.8%) of respondents kept their pigs indoors and none kept their pig tethered or under free-range conditions.

Respondents who had heard about or seen tapeworms in humans in the study area were only 3 (1.4%) while the majority (98.6%) have not seen the tapeworms or heard of the disease. A total of 216 (100%) respondents reported that they did not know how people become infected with tapeworms. None of the respondents reported seeing pork infested with *T. solium* cysts in Mgeta Division (Table 32).

Table 32: Questionnaire study results on knowledge and possible prevention factors on *T. solium* taeniosis/cysticercosis in Mgeta Division, Tanzania.

Categories and education level of respondents and types of responses	No. (%)
Categories of respondents:	
Males	124 (57.4)
Females	92 (42.6)
Education level:	
Illiterate	21 (9.7)
Primary education	194 (89.8)
Secondary education	4 (1.9)
Beyond secondary education	0 (0)
Possible transmission factors:	
Respondents consuming pork	213 (98.6)
Respondents preferring frying as a form of cooking pork	138 (63.9)
Respondents preferring boiling as a form of cooking pork	69 (31.9)
Respondents who prefer barbecuing as a form of cooking pork	6 (2.8)
Respondents who preferred raw pork	0 (0)
Respondents who conduct home slaughters of pigs	83 (38.4)
Respondents who didn't conduct home slaughters of pigs	133 (61.6)
Conduct home slaughter and pork not inspected	77 (35.6)
Conduct home slaughter and pork inspected	3 (1.4)
Households without latrine or latrines were full	9 (4.2)
Households with latrine	210 (97.2)
Pigs kept indoors	6 (2.8)
Pigs totally confined in pigpens	210 (97.2)
Pigs kept under free range system	0 (0)
Knowledge on taeniosis/cysticercosis:	
Respondents who heard of tapeworms infection in humans	3 (1.4)
Respondents who have not seen/heard of tapeworms in humans	213 (98.6)
Respondents who do not know how people get taeniosis	216 (100)
Respondents who will do nothing in case they have taeniosis	50 (23.2)
Respondents who will go to the hospital/dispensary when infected with tapeworm	165 (76.4)
Respondents who has not seen cysts in pork	216 (100)
Respondents who know someone in the village with epilepsy	180 (83.3)

3.3.3 Focus group discussions

4.3.3.1 Farmers group

4.3.3.1.1 Knowledge and awareness about porcine cysticercosis

When participants in all the focus groups were shown several pictures of pork infected with *T. solium* cysts and asked if they have ever seen such lesions (Fig. 5. 6. and 7) they responded that they had never come across pork with such lesions in Mgeta. However, one male respondent from Kododo village said that he had seen beef with such lesions in Mahenge District, Morogoro Region in 1986 when he was there doing his secondary education. These responses made questions on knowledge of the parasite and its mode of transmission unnecessary.

4.3.3.1.1.1 Mgeta division administrative organization and Village Public Health Committees

Each village has a village government which is officially recognised by the central government. The village government structure is composed of a Village Chairperson, Secretary and four committees: 1) Village Public Health Committee. 2) Finance and Planning Committee. 3) Education and Culture Committee and 4) Agriculture and Land Development Committee. Each committee is made up of 6 members elected by secret balloting every 5 years during local government elections.

The Village Public Health Committee (VPHC), like all the other committees, is responsible to the village government and works within the local government system. Every month the committee contacts health officials (i.e. medical assistants) at the dispensary situated in the Ward (The Ward services between 5 to 6 villages) to discuss current important issues pertaining to human health. VPHC also handle first aid kits containing essential drugs for their villages. The committee works closely with the Finance and Planning Committee to surrender monies collected from services discharged like weighing children and pregnant women or fines collected from persons found to have no latrine at their household. The members meet on a monthly basis to discuss what activities need to be conducted during the month and estimate the medical supplies that will be needed for such.

All 22 discussion groups (representing 22 villages) informed that their villages have a VPHC and the duties of those committees are:

- Supervising construction and use of proper latrines,
- Supervising construction and use of waste (kitchen and other home wastes) pits,
- Educating the population on proper cleaning of utensils,
- Educating the communities on the importance of keeping water intake clean,
- Educating the families on the importance of boiling drinking water to control epidemics like cholera,
- Sensitising the masses on how to control HIV and AIDS,
- Educating and sensitising the population on the importance of pregnant women and children under the age of five years attending monthly clinics,
- Mobilising communities for attending mass vaccination campaigns for children,
- Sensitising the communities on the benefits of family planning and the available methods for such,

- Sensitizing villagers on different ways of controlling malaria, e.g. the use of impregnated mosquito nets and elimination of potential mosquito breeding sites around homesteads.

When asked why members of the VPHC are so motivated to fulfil their responsibilities the respondents noted that committee members are sensitised and stimulated by their good local leadership to work for the communities so that health problems such as cholera epidemics do not reoccur. Furthermore, the VPHC members are provided a commission of approximately 50% of the money they collect from weighing children and pregnant women as well as the fines assessed people for not having a latrine at their homestead.

4.3.3.1.1.2 Guidelines for latrine inspection and available inspection records

The groups provided the following list of guidelines with regard to latrine inspection used for assessing households in their communities:

- A latrine is present and used.
- The latrine is not full to the brim (more than 4ft deep equivalent to 1.2 meters).
- It has proper walls and is roofed.
- The pit has a cover.
- There is water and soap in the latrine and it has a door that can be opened and closed.

4.3.3.1.1.3 Latrine coverage and inspection findings

According to the combined latrine inspection records of all 22 VPHCs, out of a total of 13,445 households 72 (0.5%) homes were found to lack a latrine and 256 (1.9%) had latrines that were full. Overall, 97.6% of the homesteads had working latrines implying very good sanitation coverage.

4.3.3.1.1.4 Measures taken for a household without a latrine

All 22 groups (100%) reported similar actions taken against the head of a household whose homestead has no latrine as follows:

- He/she is advised by the VPHC to construct a new latrine and given a certain period of time (a maximum of 10 days) in which to do so.
- After 10 days have elapsed and no latrine has been built he/she will be reported to the village government (Village Chairman) for disciplinary action. Normally they will be fined and advised to construct a new latrine.
- If he/she still does not comply he/she will be taken to the Ward Executive Officer who can reprimand and detain him/her for 12 hours and order the fine to be paid.
- If still not complying he/she will be taken to the primary court to either pay the fine or be jailed for 3 months.

4.3.3.1.1.5 Fines in monetary values or man-hours of labour and records of fined persons

At village level the mean fine for not having a latrine was 1,545.5 ± 972.9 Tanzanian shillings (Tshs) which is equivalent to 21.3 ± 10.0 man hours of labour (mhl) while at ward level the mean fine was 5,000.0 ± 0.0 Tshs or 69.3 ± 10.5 mhl. At primary court level the fine was double the amount of what one has to pay at the ward level and thus 10.000.0 ± 0.0 Tshs equivalent to 138.7 ± 21 (mhl)

[Note: One mhl is equivalent to 72.5 Tshs although there were some minor variations from ward to ward].

From the records at village level a total number of 41 (0.3%) heads of households from only 4 villages in the division were fined. In Kododo Village 5 persons were taken further to the ward level after being noncompliant at village level and each of them was fined a total of 5.000 Tshs. The 5 fined persons from Kododo claimed that their latrines were not full while the committee informed that they were full using the set division standards. No one in any of the villages was taken to the level of Primary Court on this particular issue.

4.3.3.1.1.6 Attitudes concerning sanitation

When asked why they have taken the issue of sanitation seriously the general response was that in the years 1978 to mid 1980s Mgeta Division experienced frequent cholera outbreaks resulting in several deaths [Appendix 6]. To control cholera local government health workers in liaison with village government leaders closed the local brew shops and weekly markets (usually conducted every Monday and Thursday) where farm products were traded. These closures were necessary in order to control the spread of the outbreak by preventing people from drinking and eating unsafe water and food, respectively. The closure of the markets and local brew shops brought economic hardship on most of the local inhabitants. The economic hardship provided an entry point for the government health workers to implement a prevention and control strategy for combating cholera acceptable to the division population which included sensitising the communities on the need for construction and use of proper latrines, washing hands with soap after using the latrine, boiling drinking water and thoroughly cooking food. In that way they managed to control the disease. However, in 1988 they had an outbreak of bacillary dysentery (shigellosis). It started in Nyandira, a village at a high altitude were most streams producing water for the Division villages originate. The families of shigellosis-infected persons in this village were washing clothes contaminated with faeces of infected persons directly into the streams while downstream people were using the same water for home consumption. This led to an increased number of cases of shigellosis across several villages in the Division. Eight deaths were reportedly registered in Nyandira Village alone where the outbreak started. The respondents said that this outbreak re-emphasised the need for improved sanitation in the Division. Records on cases of shigellosis or cholera in the Division were not available to determine how successful the strategy has been. However, when the Regional Public Health Department was consulted on the reported cases of both diseases, it was observed that the District had experienced frequent outbreaks of cholera as from 1982 through 1986 and thereafter nine years elapsed untill another outbreak occurred in 1996 [See appendix 6]. This trend is in agreement with what has been reported in focus groups discussions. It was interesting to note that cases of bacillary dysentery has been recorded in the district in 1988 as claimed by respondents in the group discussions, however the records indicated that there were no deaths in contrast to what has been reported by focus groups in that there were 8 deaths in Nyandira Village alone.

4.3.3.1.1.7 Latrine construction and estimated costs

The respondents were asked about the most commonly used materials in their villages for construction of latrines and to estimate the total cost for constructing a modest pit latrine. Respondents informed that most people in their villages made latrines using inexpensive locally available materials. For the outer structure respondents from 10 villages (45.5%) reported using mostly burnt bricks, 4 villages (18.1%) used mostly timber off cuts and 8 villages (36.4%) use mostly tree poles. All 22 groups responded that in their villages grass was the most commonly used material for thatching the latrine roofs. The mean total cost of building a latrine for all 22 villages was 19,250.0 ± 3,398.0 Tshs equivalent to 265.52 mhl.

The respondents were then asked if the estimated total cost of constructing a latrine was considered expensive for an average family in their villages. They said that was true however, the families could still manage latrine construction costs by doing some of the construction activities themselves such as digging the pit and making bricks thus lowering the costs. They also minimise costs by using available personal properties at the farm, for example trees or grass or even use some of the materials from the nearby forest reserve. For example instead of using nails to fix tree poles on the roof they could use twine made from the bark of trees in the nearby forest reserve after obtaining permission from the local forester and village government. The respondents in each group were asked to list activities or items for latrine construction which could be done or provided by the household and which items had to be purchased with cash. The items/activities were then valued using local prices. On average, across all the villages, 84.0% of the costs of constructing a latrine were covered by respondents doing things themselves or by using inexpensive farm/forest products. While only 16.0% of the latrine cost was paid in cash. They informed that the same system applies for lowering the cost of making a pigpen.

4.3.3.1.1.8 Pig management practices

Of the 22 villages respondents of 14 (63.6%) reported that all pigs in their villages were kept under total confinement in pens. They informed that if a pig were to escape it would be for only a very short time as the owner would be alerted so that the pig was immediately put back in its pen. Respondents from the remaining eight (36.4%) villages informed that pigs are kept under total confinement except piglets younger than 2 months of age (suckling-piglets). After weaning these piglets are also totally confined like the older pigs by placing timber off cuts or tree poles into spaces used by piglets to escape from the pens.

4.3.3.1.1.9 Reasons for totally confining pigs, responses from focus groups discussions

The following were the reasons mentioned across all the groups for totally confining pigs:

- To avoid destruction of other peoples' property.
- To avoid worm infection.
- Confined pigs grow faster.
- When pigs are confined it is easy to collect manure.
- Forced by village by-laws.

- Land shortage (scarcity) prohibits pigs from roaming about and most of the farms are cultivated throughout the year therefore there is no free area where a pig can roam even during the dry season.

When asked to rank the most important reasons for confining pigs avoiding destruction of personal property was ranked as the number one reason by all 22 discussion groups. The second ranked reason was limited roaming space with 14 (63.6%) village discussion groups ranking it. This point was further elaborated by information provided by the respondents on their family size and amount of land owned which revealed that the average family size was 6 (range: 5-7) persons owning 0.61 ± 0.29 acres. The third ranked reason was the ease of collecting manure when pigs are confined.

When asked why pigs were not allowed to roam freely during the dry season when probably there were no crops being raised on the farms the response across all the 22 groups was that most of the farms will still have a variety of crops under cultivation due to the presence of an irrigation system. Further inquiry from other sources revealed that traditional irrigation has been practiced in the area for more that fifty years with about 50% of the land available for growing crops currently irrigated during the dry season. It has been estimated that up to 70% of the land available for growing crops in Mgeta Division could be covered by the irrigation system. Currently the Uluguru Mountain Agricultural Development Project (UMADEP) coordinated by Sokoine University of Agriculture is attempting to improve the field water distribution system in Mgeta in order to increase the farmland that can be covered by the irrigation system (Marisa, D. personal communication, 2003).

Table 33 shows various reasons that made pig farmers confine their pigs. Of the 216 questioned persons interviewed at household level 200 (92.6%) of them stated that they do not allow their pigs to forage freely in order to avoid destruction of property like crops in the fields. Thirteen farmers (6.0%) said the main reason for confining pigs was that manure accumulates in the pen making collection easier.

Table 33: Structured questionnaire study results on the most important factors that were responsible for total confinement of pigs, individual pig farmer's responses, Mgeta Division, Tanzania.

Factor	Frequency of positive responses	% Positive response
To avoid destruction of personal property	200	92.6
To avoid worm infection	0	0.0
Confined pigs grow faster	0	0.0
Forced by village bylaws	3	1.4
Easy to collect manure	13	6.0
No land for roaming	0	0.0
Total	**216**	**100.0**

4.3.3.1.1.10 What happens to a person if his/her pig(s) destroys another person's property

The groups gave the following lists of actions taken by individuals or village governments against the owner of a roaming pig:

- Charged according to village by-laws.
- Destroyed property is evaluated and the pig owner has to pay accordingly.
- The roaming pig is confiscated and sold to pay for destroyed property +/- a fine.
- The pig owner and the person whose property is destroyed negotiate and settle the matter on their own.

4.3.3.1.1.11 Penalties for a roaming pig

Seventeen village discussion groups (77.3%) reached a consensus that the action most practised in their villages in regard to destruction by roaming pigs was that destroyed property is evaluated and the pig owner pays accordingly. The evaluation of the destroyed property and settlement of the case is normally negotiated by the two parties in dispute, the village agricultural extension worker and 2 or 3 village elders. The involvement of agricultural extension workers is because they are usually very knowledgeable of the costs associated with crops destroyed by roaming pigs and thus able to provide a reasonable estimation of their value for reaching a proper settlement. Three (13.6%) discussion groups reported that in their villages the most practised compensation system is for the pig owner and the person whose property is destroyed to negotiate and settle the matter on their own. The other two (9.1%) discussion groups informed that in their villages the owners of roaming pigs were charged according to village by-laws governing confinement of pigs whereby a set fine of 5,000.00 Tshs (69.0 mhl) is assessed in both villages.

4.3.3.1.1.12 Frequency of pork consumption and forms of cooking

Pork butchers in the group were asked to estimate the average number of pigs slaughtered and sold locally per month in their village. On average about 22 ± 23 (range 4 to 80 per village) pigs are slaughtered and consumed locally in the division each month. However, it was noted that this number might be an underestimation during the harvest period when people have more money and more pigs are slaughtered and consumed.

Every individual in each discussion group was asked if they consume pork. Pork-eaters were asked to give a rough estimate of the amount of pork that is purchased and consumed by his or her family in a month. Of the total number of 233 respondents who were interviewed in all the 22 villages, two hundred and twenty- seven (97.4%) reported eating pork. The monthly amount of pork consumed by a family ranged from 2.0 to 15.0 kg with a mean of 5.25 kg across villages. However, many respondents noted that the amount is probably an underestimation because many people eat pork at the market or at the local brew pubs without bringing it home. The preferred forms of cooking pork were: 1) boiling with 96 (43.4%) of respondents mentioning it, 2) frying with 78 (35.3%) respondents preferring it, and 3) barbecuing was the least preferred form of cooking pork with 47 (21.3%) respondents mentioning it. No respondents preferred raw pork. When asked about the consumption of beef, a common response in all discussion groups was that they rarely eat beef because it is usually not available and they may go years without eating any. Some respondents noted that they occasionally eat beef when they visit Morogoro town.

4.3.3.1.1.13 Home slaughtering of pigs and pork inspection

Nineteen discussion groups (86.4%) informed that they do not have official slabs available for slaughtering pigs in their village. Three groups (13.6%) informed that they have a few slaughter slabs in their villages strategically located at business centres owned by individual butchers. Lolo township (the main business centre in the division) in Langali village has 3, while Pinde and Kibaoni villages have 1 and 2 slabs, respectively. All the 22 village discussion groups reported that home slaughtering of pigs is a common practice in their villages especially after the harvest period when most people have cash. Most groups also informed that pigs and pork are not inspected in their villages. When asked why pork is not inspected the discussion groups gave various reasons ranked in the following order:

- Due to shortage of meat inspectors.
- Mgeta Division is vast and has difficult terrain, thus official meat inspectors cannot go to distant areas and inspect pigs. Even for farmers to go and tell the inspector that he/she has pork that needs to be inspected is a problem.
- Lack of transport for Meat Inspectors.
- Farmers are not aware that pork is supposed to be inspected.

4.3.3.2 Workers group

4.3.3.2.1 Veterinary and Public Health Assistants

4.3.3.2.1.1 Presence/absence of porcine cysticercosis in Mgeta

Livestock Extension Officers and the Public Health Assistant informed that they have not come across pork infected with *T. solium* cysts in their areas of coverage during the time they have worked in Mgeta. The 5 respondents have worked in Mgeta Division for 3 to 12 years with an average of 7.4 years. All correctly described the appearance *of T. solium* cysts, nevertheless they were shown pictures of pork infected with cysts (Figs. 5, 6, and 7) and still maintained that they have not seen such infected pork in their areas. When queried about the possible reasons for the absence of porcine cysticercosis cases in Mgeta Division they responded that the situation is due to the confinement of pigs and people using latrines. All reported that the reason pigs are confined is that Mgeta is highly populated and most farms raise crops throughout the year thus pigs have no roaming space.

4.3.3.2.1.2 Meat inspection coverage and slaughter facilities

The group reported that most of the pigs slaughtered in the division take place at people's homes and pig carcasses are seldom inspected. Meat inspectors are usually given a small amount of pork to compensate for their service though there is no specific rule about this. When queried about the constraints of inspection of pig carcasses and pork the following reasons-were given:

- Farmers must come long distances to inform the Meat Inspectors.

- The terrain of Mgeta makes travel very difficult.

- Transport is often unavailable preventing Meat Inspectors from going to homesteads.

- The division extension services is short of staff with five officers covering the 22 villages with only 2 of the 5 interviewees having reliable transport (motor bikes).

- Only a few official standard slaughter slabs exist in the division with 3 located at Lolo, the main business centre, 2 in Pinde village and 1 each in Bunduki and Kibaoni.

4.4.3.3 Medical Assistants/Clinical Officers

4.4.3.3.1 Awareness of human cysticercosis/taeniosis

The medical assistants reported that they had not encountered any cases of taeniosis in Mgeta. However, all but the one coming from Mgeta health centre reported that their health centres are not equipped with microscopes nor reagents necessary for diagnosing intestinal parasitic infections. Nevertheless all reported that they did not suspect any taeniosis cases in the division based on patients' medical histories.

One respondent in the group informed that he had worked previously at Ngerengere health centre in Morogoro Rural District, and had experience there diagnosing taeniosis cases based on patient history confirmed by laboratory diagnosis. He reported that he had now been working in Mgeta for over 15 years and was confident that no cases of taeniosis were reported or diagnosed during that time at his station

The respondent from the Mgeta rural health centre was asked to provide hospital records on cases of intestinal helminthoses. The medical assistants as a group informed that for intestinal parasitic infections they prescribe mebendazole, dispensing about 6,000 tablets of the drug every 3 months. Praziquantel and niclosamide are normally not ordered. The respondents noted as a group that cases of people with subcutaneous nodules were not very common and only a few epileptics were known in the area and these people are normally treated with anticonvulsants.

4.4.3.3.2 Sanitation issues

The respondents informed that latrines at the household level are supposed to be inspected on a quarterly basis by the health assistants in cooperation with the VPHC. However, due to chronic lack of transport for the health assistants, latrine inspections are usually conducted solely by the VPHC, though at times of epidemic outbreaks the VPHC and health assistants will most certainly go to villages together to conduct mass campaigns for disease control.

The respondents also noted that most households in the district have latrines and if a household does not have a functioning latrine then most likely it is because the one they have is full and they have not been able to construct a new one and are most probably using their neighbour's latrine. In such instances the head of the household will be advised to construct a new latrine during the inspection. They also informed that the high district-wide compliance with regard to latrine construction and usage is mostly a result of previous prevention and control programmes for cholera and shigellosis, which had been serious problems in the division during the 1970s and 1980s. Unfortunately the exact dates of the cholera and shigellosis outbreaks could not be ascertained from hospital records, however in recent years the two epidemics have been under control with no cases reported at the Mgeta rural health centre for more than five years.

A total of 394 intestinal helminthoses cases were diagnosed microscopically at the Mgeta Rural Health Centre from the second half of 1999 to the end of 2002. Of these cases 315(71%), 119(26.8%), 5(1.1%) and 5(1.1%) were due to ascariosis, ancylostomosis, trichurosis, and strongyloidosis, respectively. No cases of taeniosis were observed during the same periods. Records of the Mgeta Rural Health Centre also indicate that 34, 41 30, 29 and 11 (first 2 months of the year) cases of epilepsy were treated in the years 1998, 1999, 2000, 2001 and 2002, respectively. Of these 4 of the cases in 1998 and 1 of the cases in 2000 were in children under 5 years of age.

4.4.3.4 Ward Executive Officers and Primary Court Magistrate

4.4.3.4.1 Compliance with by-laws concerning latrine construction and use

The Ward Executive Officers and the Primary Court Magistrate informed that the Village Public Health workers are responsible for latrine inspections; however they become involved in the issue when people are remanded for not having a properly functioning latrine. The Ward Executive Officers stated that on a few occasions they have had cases referred to them and fined people for not having a usable latrine based on recommendations outlined in village by-laws. The Primary Court Magistrate reported that during his 11 years service in Mgeta Division he has never had a case referred for not having a latrine. All concluded the discussion by stating that most people in Mgeta know the importance of having and using a latrine.

Fiure11: Pigs totally confined in a pen made from tree poles. This is the management system mostly [97.2%, n=216] practiced in Mgeta Division, Morogoro Rural District, where porcine cysticercosis is absent.

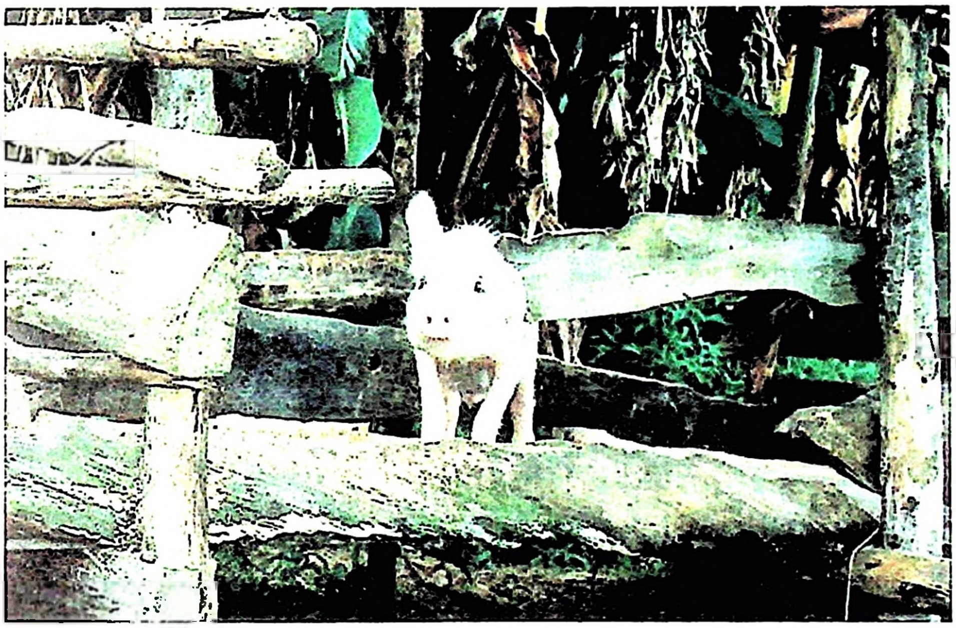


Figure 12: Piglet trying to escape from a poorly made pen using timber off cuts. During surveillance in all the 3 study areas pens of this standard were scored poor. And pigs kept in this manner were considered as being managed under freerange system.

4.4 Study IV: Identification of factors responsible for presence in Chunya and Iringa Rural Districts and for absence of porcine cysticercosis in Mgeta Division using Ag-ELISA and tongue examination tests

4.4.1 Prevalence of *T. solium* cysticercosis using antemortem tongue examination and Ag-ELISA tests in Mgeta Division, Chunya and Iringa Rural Districts

Prevalence of cysticerci of *T. solium* in pigs after analysis by antigen ELISA ranged from 1.3% in Mgeta Division to 28.0 % in Chunya District as seen in Table 34 and Figure 13. Chunya District (28.0%) had the highest cysticercosis prevalence after Ag-ELISA analysis while Mgeta Division with only 1.3 % positive pigs had the lowest prevalence of the 3 areas surveyed. Statistical analysis clearly showed that Chunya District (28.0%) had a significantly higher prevalence (χ^2 = 119.88, $p < 0.001$) than Mgeta Division (1.3%). Similarly Chunya District (28.0%) had higher prevalence than Iringa Rural District (10.6%) (χ^2 =20.98, $p<0.001$). Also, Iringa Rural District had a significantly higher prevalence than Mgeta Division (χ^2 =30.8, $p<0.001$). When the prevalences of Chunya and Iringa Districts were combined (19.8%) for a general prevalence of the southern highlands then compared to that of Mgeta Division the difference was also statistically significant (χ^2 =83.08%, $p<0.001$) [Fig. 13 and Table 34].

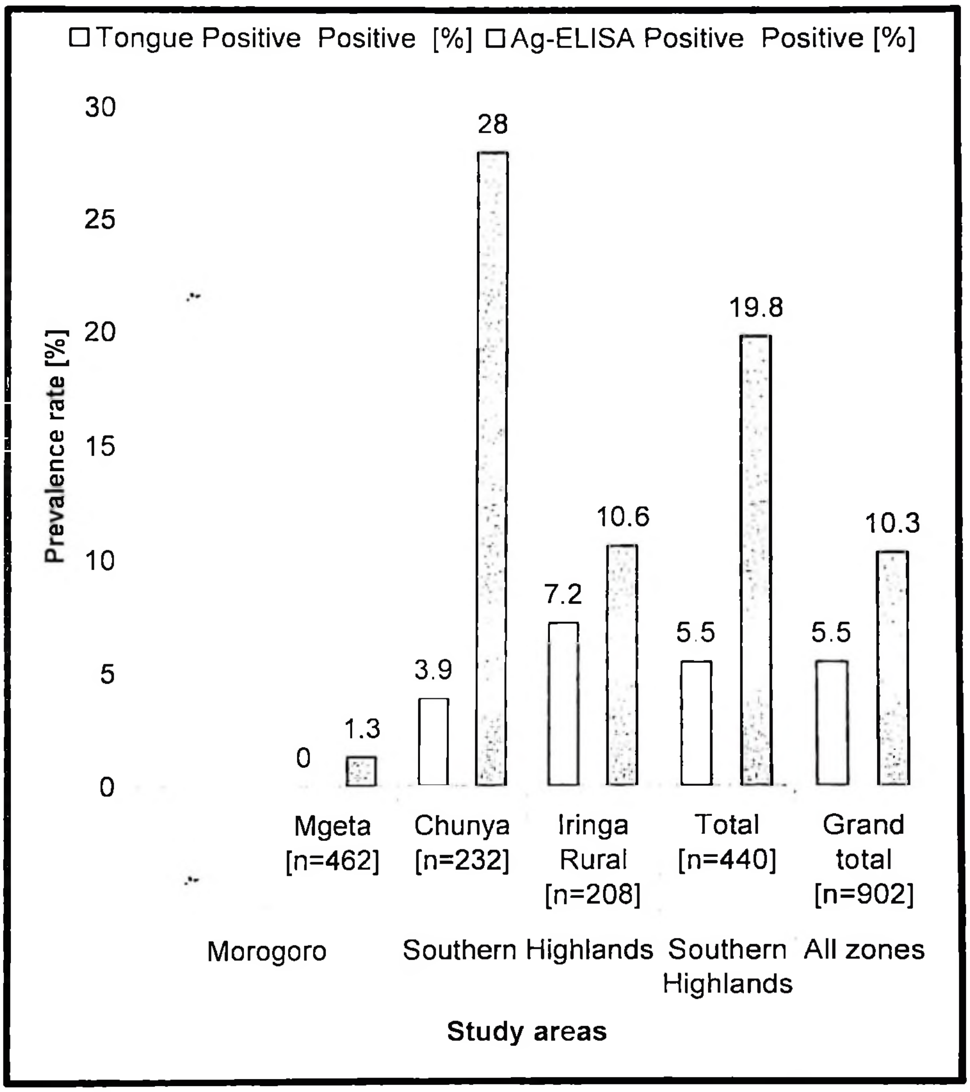


Figure 13: The prevalence (%) of *T. solium* porcine cysticercosis after tongue examination and Ag-ELISA assay in 3 study areas.

Using the lingual examination method in this study no pig was found positive (0%) in Mgeta division, while Iringa Rural District had the highest prevalence 15 pigs (7.2%) and Chunya District was second with 9 pigs out of 232 examined being positive making the overall prevalence of 3.9% (Fig. 13 and Table 34). Iringa Rural and Chunya Disticts had significantly higher prevalences than Mgeta Division with Chi-square values of 34.03. $p<0.001$ and 17.5. $p<0.001$ respectively. The difference between Iringa Rural and Chunya Districts was not statistically significant (χ^2 =2.36. p=0.12). When Mgeta was compared to the southern-highlands (combined Chunya and Iringa Rural districts) the statistical analysis indicated a very high significant difference in prevalences (χ^2 =25.86. $p<0.001$) [Fig.13 and Table34].

Table 34: The prevalence of *T. solium* cysticercosis in pigs after tongue examination and Ag-ELISA in the study areas.

Region/Zone	District/ Area	Tongue Palpation		Ag-ELISA	
		No. of Positives	**Positive [%]**	**No. of Positives**	**Positive [%]**
Morogoro	Mgeta [n=462]	0	0	6	1.3
Southern Highlands	Chunya [n=232]	9	3.9	65	28.0
	Iringa Rural [n=208]	15	7.2	22	10.6
Southern Highlands	**Total [n=440]**	**24**	**5.5**	**87**	**19.8**
All zones	**Grand total [n=902]**	**24**	**5.5**	**93**	**10.3**

4.4.2 Prevalence of *Taenia solium* cysticercosis in pigs according to sex by the use of ante-mortem and Ag-ELISA tests

The tongue examination test showed no statistical significance between the two sexes (male versus female) either within or between the Districts of Chunya or Iringa Rural [within Chunya (χ^2 = 0.58, p =0.45)] [within Iringa Rural (χ^2 = 0.76, p = 0.38) and between districts (χ^2 = 0.00, p=0.96)] (Table 35 and Fig. 14). Ag-ELISA test showed similar results in that there was no statistical significance found between the two sexes within Mgeta Division, Chunya and Iringa Rural Districts and between Chunya and Iringa Rural Districts [within Mgeta (χ^2 =0.20, p =0.66)]; [within Chunya (χ^2 =0.02, p =0.89)] and [within Iringa Rural (χ^2 =0.9, p=0.49)] [Fig. 14 and Table 35].

Table 35: Prevalence of *T. solium* porcine cysticercosis according to sex in the study areas.

Area	Sex	Tongue		Ag-ELISA	
		No. of positives	Positive [%]	No. of positives	Positive [%]
Mgeta Division	Male [n=191]	0	0	3	1.6
	Female [n=271]	0	0	3	1.1
Chunya District	Male [n=53]	3	5.7	15	28.3
	Female [n=179]	6	3.4	49	27.4
Iringa Rural District	Male [n=78]	4	5.2	9	11.7
	Female [n=130]	11	8.5	13	10.0

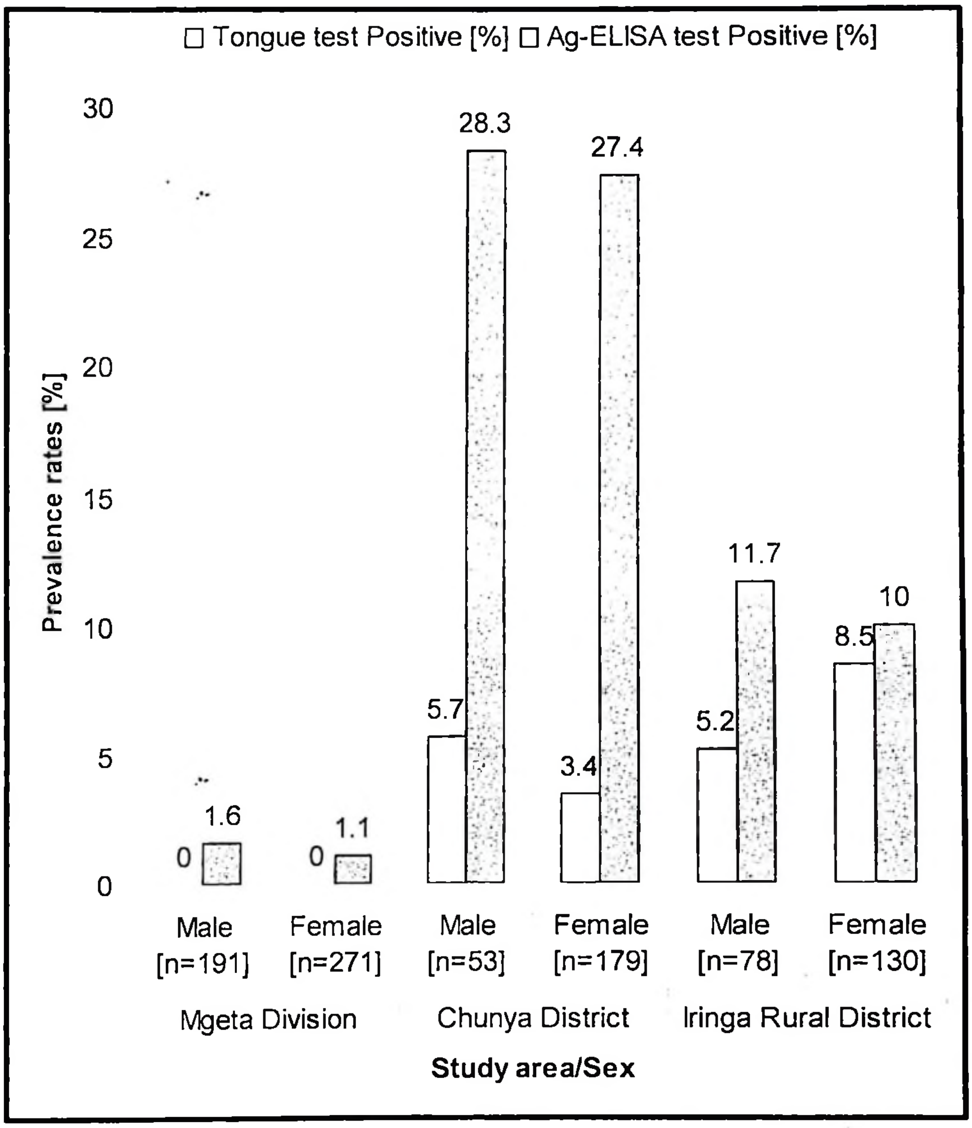


Figure 14: Prevalence of *T. solium* porcine cysticercosis according to sex in Mgeta Division and Chunya and Iringa Rural Districts.

4.4.3 *T. solium* cysticercosis prevalence in pigs according to age

Of the 462 pigs examined by age group in Mgeta Division, the prevalence after tongue examination was 0.0% in all the age groups. The prevalence rates for the Ag-ELISA test were 1.4%, 2.3% and 0.5% for breeders, fatteners and weaners, respectively. Statistical analysis has shown that fatteners [2.3%] had higher prevalence than breeders [1.4%] but the difference was not statistically significant [χ^2 = 0.21, p = 0.643]. Similarly fatteners had higher prevalence rates than weaners but the difference was not statistically significant [χ^2 = 2.39, p = 0.122]. Breeders had higher prevalence rates that weaners, however, the difference was not statistically significant [χ^2 = 0.60, p = 0.437].

In Chunya District the prevalence rates using tongue examination test for breeders, fatteners and weaners were 5.0%, 3.5% and 0%, respectively (Table 36). The difference in prevalence between breeders and weaners was found to be statistically significant [χ^2 = 10.84, p<0.001]. There was no significant difference on prevalence between breeders and fatteners and between fatteners and weaners [breeders versus fatteners: (χ^2 = 0.29, p =0.59) and fatteners versus weaners [χ^2 = 7.33, p =0.067)] (Fig. 15 and Table 36). The prevalence rates using Ag-ELISA test for breeders, fatteners and weaners were 27.7%, 27.6% and 30.8%, respectively. Statistical analysis has shown that there is no significant differences between the three age groups: breeders ver sus fatteners, [χ^2 = 0.00, p=0.982]; breeders ver sus weaners, [χ^2 = 0.10, p=0.756]; fatteners ver sus weaners, [χ^2 = 0.10, p=0.753].

In Iringa Rural District the observed prevalences by age groups are 6.1%, 13.8% and 0% for breeders, fatteners and weaners, respectively (Fig.15 and Table 36). The difference in prevalence between breeders and weaners and between fatteners and weaners were found to be statistically significant breeders versus weaners [χ^2 = 3.85, p <0.05] and fatteners versus weaners [χ^2 = 9.30, p <0.05] (Fig. 15 and Table 36). Fatteners were observed to have higher prevalence than breeders however, the difference was not statistically significant [χ^2 = 2.38, p = 0.123]. In Iringa Rural District Ag-ELISA analysis has shown that prevalences in fatteners, breeders and weaners were 16.3%, 9.1% and 4.8%, respectively. The difference between fatteners and weaners was found to be statistically significant [χ^2 = 4.63, p < 0.05]. Breeders had higher prevalence than weaners however, the difference was not statistically significant [χ^2 =0.88, p=0.35]. Similarly the difference in prevalence between breeders and fatteners was not statistically significant [χ^2 = 1.7, p = 0.192].

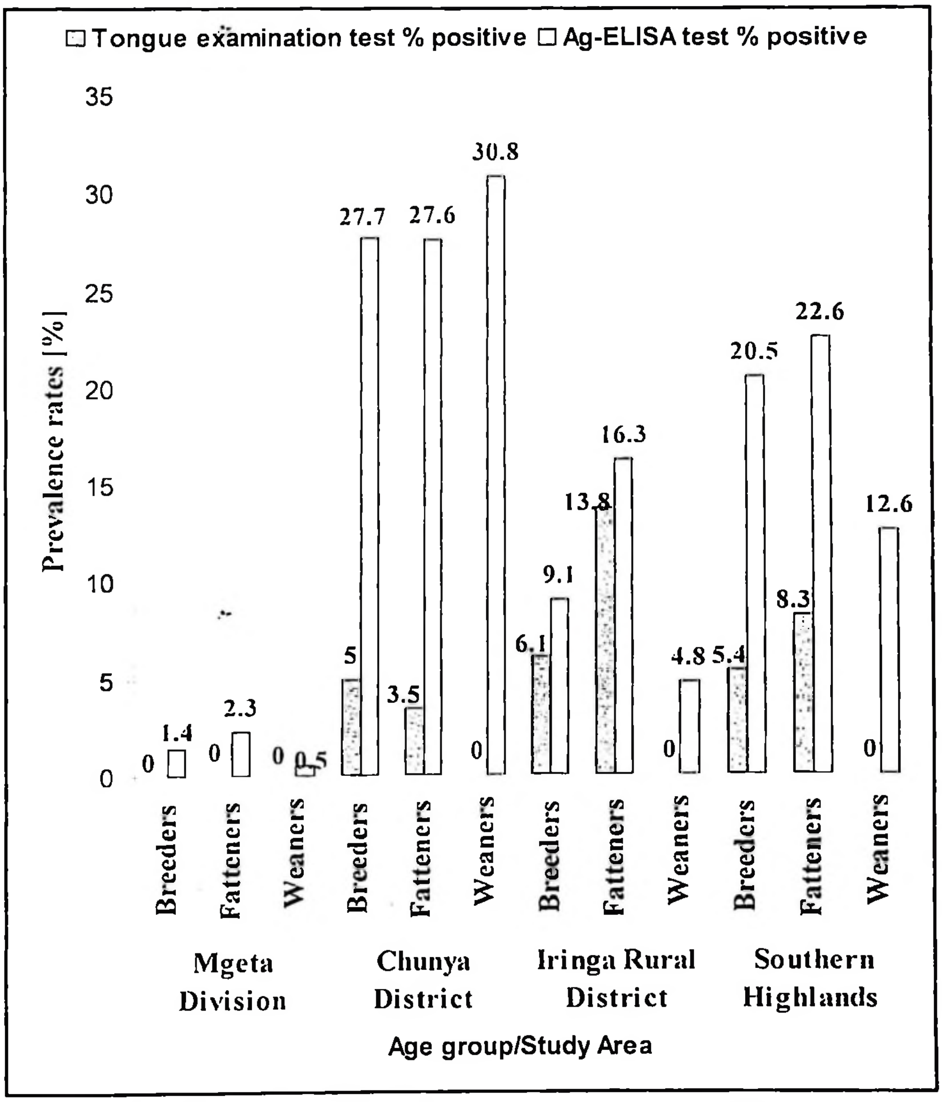


Figure 15: Prevalence of porcine cysticercosis according to age using antemortem tongue examination and Ag-ELISA tests in the 3 study areas.

Table 36: Prevalence of *T. solium* porcine cysticercosis according to age using ante-mortem tongue examination and Ag-ELISA tests in the study areas.

Zone /Division	Age category	Tongue palpation		Ag-ELISA status	
		No. Positive	% positive	No. positive	% positive
Mgeta Division	Breeders [n=74]	0	0	1	1.4
	Fatteners [n=178]	0	0	4	2.3
	Weaners [n=210]	0	0	1	0.5
Chunya District	Breeders [n=119]	6	5.0	33	27.7
	Fatteners [n=87]	3	3.5	24	27.6
	Weaners [n=26]	0	0.0	8	30.8
Iringa Rural District	Breeders [n=66]	4	6.1	6	9.1
	Fatteners [n=80]	11	13.8	13	16.3
	Weaners [n=62]	0	0.0	3	4.8
Southern Highlands	Breeders [n=185]	10	5.4	38	20.5
	Fatteners [n=168]	14	8.3	38	22.6
	Weaners [n=87]	0	0	11	12.6

4.4.4 *T. solium* cysticercosis prevalence in pigs according to age by zone

Of the 462 pigs examined by age group in Mgeta Division, the prevalence after tongue examination was 0.0% in all the age groups. The prevalence rates by Ag-ELISA test were 1.4%, 2.3% and 0.5% for breeders, fatteners and weaners, respectively.

In the southern highlands the prevalence rates by tongue examination were found to be 5.4%, 8.3% and 0% in breeders, fatteners and weaners, respectively (Fig.15, Table 36). It was observed that fatteners had a higher prevalence than breeders however, the difference was not statistically significant [χ^2 = 1.2, p = 0.28]. Breeders were found to have significantly higher prevalence than weaners [χ^2 = 4.9, $p < 0.05$]. Similarly fatteners were observed to have significantly higher prevalence proportions than weaners [χ^2 = 7.6, $p < 0.01$] (Fig. 15, Table36).

Using Ag-ELISA the observed prevalence rates were 20.5%, 22.6% and 12.6% for breeders, fatteners and weaners. It was observed that fatteners had higher prevalence than breeders with prevalences of 22.6% and 20.5%, respectively, however, the difference was not statistically significant [χ^2 = 0.22, p= 0.64]. Fatteners were observed to have a higher prevalence proportion than weaners however, the difference was not statistically significant [χ^2 = 2.5, p = 0.11]. Southern highlands breeders were observed to have a significantly higher prevalence than weaners from Mgeta Division [χ^2 = 44.8, $p < 0.001$]. Breeders from the southern highlands were observed to have a significantly higher prevalence than fatteners from Mgeta Division [χ^2 = 29.2, $p < 0.001$]. Breeders from the southern highlands were observed to have a significantly higher prevalence than breeders from Mgeta division [χ^2 = 15.2, $p < 0.001$]. Fatteners from the southern highlands were observed to have a significantly higher prevalence than weaners from

Mgeta Division [χ^2 = 49.8, p < 0.001]. Southern highlands' fatteners were observed to have a significantly higher prevalence proportion than Mgeta fatteners [χ^2 = 33.1, p < 0.001]. Similarly southern highlands' fatteners were observed to have a significantly higher prevalence proportion than Mgeta breeders [χ^2 = 15.2, p < 0.001]. Southern highlands weaners were observed to have a significantly higher prevalence than Mgeta weaners [χ^2 = 23.6, p<0.001]. Southern highlands weaners were found to have a significantly higher prevalence than Mgeta division fatteners [χ^2 = 11.6, p < 0.001]. Southern highlands weaners were observed to have a significantly higher prevalence than breeders raised in Mgeta division [χ^2 = 7.4, p < 0.01] (Fig. 15, Table 36).

4.4.5 Comparison of risk factors for porcine cysticercosis identified using Ag-ELISA and antemortem tongue examination

Possible risk factors for porcine cysticercosis were determined by ante-mortem tongue examination and Ag-ELISA and the results are displayed in Table 37 and Figure 16. In Chunya District pigs that were raised in households that were practicing free-range management were observed to have significantly higher prevalence proportions by ante-mortem tongue examination than those raised in households that always confined their pigs (6.0% versus 2.3%) however, the difference was not statistically significant [Chi-square = 2.11, p = 0.15]. Similarly using the antigen-ELISA technique it was observed that pigs that were allowed to freely forage had significantly higher prevalence than those totally confined with prevalences of 44% versus 15.9%, respectively [Chi-square = 22.3, p < 0.001]. Pigs that were raised in households without a latrine using ante-mortem tongue examination were observed to have higher prevalence (5.4%) than those raised in households with functioning latrines (2.5%) however, the difference was not statistically significant [Chi-square = 1.32, p = 0.24].

Using Ag-ELISA it was observed that pigs that were raised in households without a latrine had a significantly higher prevalence than those raised in households with latrines (36% versus 20.7%) [Chi-square = 6.8, $p < 0.05$].

In Iringa Rural District using ante-mortem tongue examination it was observed that pigs raised in households which allowed their pigs to freely forage prevalences were found higher than in those households which totally confined their pigs with prevalences of 11.2% and 3%, respectively. The differences were statistically significant [Chi-square = 5.3, $p < 0.05$]. Using Ag-ELISA it was observed that pigs that were freely foraging had a higher prevalence than those under total confinement with prevalences of 13% and 7.9%, respectively, however, the differences were not statistically significant [Chi-square = 1.46, $p = 0.22$]. Using tongue examination it was observed that pigs raised in households without a latrine had a higher prevalence than those raised in households with a latrine with prevalence of 24.0% and 3.0%, respectively, and the differences were statistically significant [Chi-square = 22.4, $p < 0.001$]. Using Ag-ELISA it was observed that pigs raised in households without a latrine had a significantly higher prevalence than those raised in households with a latrine with observed prevalences of 19.5% and 8.4%, respectively [Chi-square = 6.8, $p < 0.01$].

In the southern highlands (combined Chunya and Iringa Rural Districts) using tongue examination it was observed that pigs raised under the free-range system had a significantly higher prevalence than those raised under total confinement with prevalences of 8.2% and 3.0%, respectively [Chi-square = 5.6, $p < 0.05$]. Using Ag-ELISA it was observed that pigs that were raised under the free-range system had a significantly higher prevalence than those reared under total confinement with prevalences of 25.5% and 14.7%, respectively [Chi-square = 8.1, $p < 0.01$]. Using ante-mortem tongue examination it was observed that pigs raised in households without a latrine had a significantly higher prevalence proportion than those raised in households with a latrine with prevalences of 8.8% and 4.1%, respectively [Chi-square = 3.9, $p < 0.05$]. Using Ag-ELISA it was observed that pigs raised in households without latrines had a significantly higher prevalence than those raised in households with latrines with observed prevalences of 28.8% and 16.1%, respectively [Chi-square = 9.1, $p < 0.01$].

Using Ag-ELISA it was observed that Mgeta pigs that came from households where total confinement was the form of management practiced had a lower prevalence than those in the southern highlands under the same management system with prevalence proportions of 1.3% and 14.7%, respectively [Chi-square = 50.7, $p < 0.001$]. Using the same Ag-ELISA it was observed that pigs raised in households practicing the free-range system in the southern highlands had a higher prevalence than those under total confinement in Mgeta Division with prevalence proportions of 25.5% and 1.3%, respectively [Chi-square = 104.3, $p < 0.001$]. Using Ag-ELISA it was observed that pigs raised in households using latrines in the southern highlands had significantly higher prevalence proportions than those raised in Mgeta Division with functioning latrines with prevalence of 16.1% and 1.3%, respectively [Chi-square = 60.6, $p < 0.001$]. Other possible risk factors like home slaughtering without pork inspection and form of pork cooking such as barbecuing were analysed however, no statistical significance was observed at the district and zonal levels.

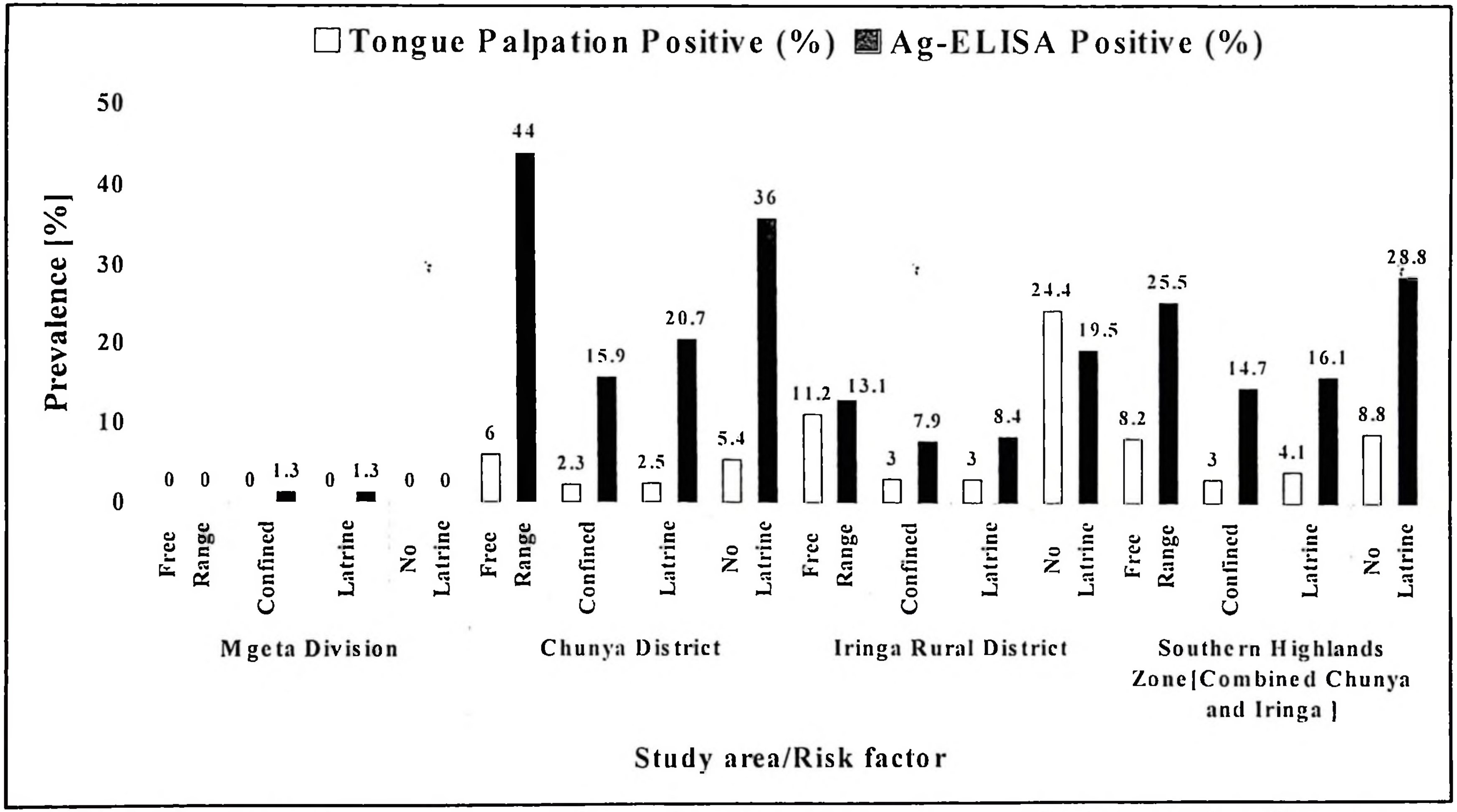


Figure 16: Risk factors (free range pig keeping and absence of a latrine) of porcine cysticercosis in pigs coming from different geographical locations of Tanzania.

Table 37: Comparison of risk factors for porcine cysticercosis identified using Ag-ELISA and ante-mortem tongue examinations.

Study area	Risk Factor	Tongue		Ag-ELISA	
		No. positives	Positive [%]	No. positives	Positive [%]
Mgeta Division	Free Range	0	0	0	0
	Confined	0	0	6	1.3
	Latrine	0	0	6	1.3
	No Latrine	0	0	0	0
Chunya District	Free Range	6	6.0	44	44.0
	Confined	3	2.3	21	15.9
	Latrine	3	2.5	25	20.7
	No Latrine	6	5.4	40	36.0
Iringa Rural District	Free Range	12	11.2	14	13.1
	Confined	3	3.0	8	7.9
	Latrine	5	3.0	14	8.4
	No Latrine	10	24.4	8	19.5
Southern Highlands Zone[Combined Chunya and Iringa Rural District]	Free Range	17	8.2	53	25.5
	Confined	7	3.0	34	14.7
	Latrine	13	4.1	51	16.1
	No Latrine	11	8.8	36	28.8

4.4.6 Comparison of the two diagnostic tests i.e. lingual palpation and Ag-ELISA used in the survey

The rate of agreement and disagreement between tongue and Ag-ELISA was 90.6% and 9.4%, respectively, and these rates were found to be statistically significant (Kappa = 0.24, $p < 0.001$) (Table 38). The value of Kappa above 0.75 implies good agreement and that below 0.40 implies poor agreement between the two tests, which is the case in this study (Gordis, 1996). The findings on cysticercosis prevalence in this study show that 801 pigs were negative in all the two tests whereas 16 were positive in all the two tests as shown in Tables 38. The study shows that 8 of the 16 lingual positive animals were negative on Ag-ELISA. Seventy-seven pigs were found positive on Ag-ELISA but negative by tongue examination. The sensitivity and specificity of tongue examination test were found to be 17.2% and 99.0%, respectively. The predictive value of a negative by tongue test was observed to be 99.0% and that of positive was found to be 17.2%.

Table 38: Measures of agreement (Kappa) between the two different tests; tongue examination and Ag-ELISA using a 2 by 2 table for detection of porcine cysticercosis.

		Ag-ELISA		
		+	-	**Total**
Tongue	+	16	8	24
	-	77	801	878
Total		**93**	**809**	**902**
Kappa	0.24 ..	P<0.001		

Sensitivity of tongue examination test = $\frac{16}{16+77} x100$ = 17.2%

Specificity of tongue examination test = $\frac{801}{8+801} x100$ =99.0%

Predictive value of a negative of tongue examination test = $\frac{801}{809} x100$ =99.0%

Predictive value of positive of tongue examination test = $\frac{16}{93} x100$ =17.2%

CHAPTER FIVE

5.0 DISCUSSION

5.1 Distribution, density and intensity of cysticerci of *Taenia solium* in naturally infected pigs from Mbulu District, Tanzania

Previous studies have shown that the northern highlands of Tanzania are endemic for porcine cysticercosis (Boa *et al.*, 1995; Nsengwa, 1995; Nsengwa and Mbise, 1995; Boa *et al.*, 2002; Ngowi *et al.*, 2004 and Phiri *et al.*, 2003). Findings from study II (Chunya and Iringa Rural Districts) show that the southern highlands of Tanzania are also endemic for porcine cysticercosis. Post-mortem meat inspection and control of infected pork is one way of breaking the transmission cycle of *Taenia solium* infection. In order to formulate appropriate guidelines for routine post-mortem detection of porcine cysticercosis in various regions of the world, it is important to determine the predilection sites of cysticerci of *T. solium* in finished pigs. By definition these are organs or muscle groups that harbour a high proportion of cysts, have the highest cyst density and are parasitized in the vast majority of animals examined. Examining such targeted organs and muscle groups facilitates the identification of infected pig carcasses and, when combined with appropriate judgment, safe and wholesome pork for human consumption can be provided. In this study the psoas muscle was found to be an important site for localization of cysticerci in pigs since it ranked high as a site of predilection, having the highest relative cyst density and a high proportion of total cysts as well as being parasitized in all the carcasses examined. However, the 24 pigs examined were probably relatively heavily infected ones, since they were selected on the basis of the presence of cysticerci in the tongue. It is well known that the sensitivity of the tongue inspection is low and may fail to identify many infected pigs especially those with low intensities of infection (Gonzalez *et al.*, 1990; Phiri *et al.*, 2002). Thus, the 24 pigs examined were perhaps not totally representative for a pig population, in which heavily as well as moderately and lightly infected pigs may be present. Therefore, while the psoas muscles may be the carcass site most likely to harbour cysts, they should not be the sole site examined since site predilection may be dependent on infection intensity. The psoas were followed by muscles of *Triceps brachii*, tongue, internal masseter, external masseter, diaphragm and heart as important sites for localisation of cysticerci in pigs. Based on our findings, all of these muscle groups/organs are proposed as predilection sites of *T. solium* in Tanzanian pigs and thus their examination should be mandatory for efficient and effective routine inspection of pig carcasses.

The results from this study are in accordance with previous reports by Viljoen (1937) who found the predilection sites of *T. solium* cysts in South African pigs to be the forequarters above the elbows (pork shoulder), psoas muscles, tongue and heart. Similar findings to ours were made by Mendez and others (1986) who found the masseters and triceps muscles to be predilection sites.

Examining targeted predilection sites where large concentrations of metacestodes are expected to be found if present during routine meat inspection helps to reduce the aesthetically unacceptable heavily infected carcasses from appearing in the market places. However, to control the parasite effectively unofficial slaughtering of pigs should be stopped. This necessitates provision of slaughterhouse facilities for handling pig carcasses and/or the provision and training of meat inspectors in the rural areas, towns and cities. To overcome clandestine marketing of pork, governments must enact and enforce legislation concerning meat inspection and control as well as provide financial market incentives to reimburse the farmers and or slaughterhouses for infected pigs that are taken out of circulation or made safe for consumption by processing the meat only after boiling. Also, strict bylaws which require that pigs be confined have to be enacted and enforced to effectively confine pigs and deny them access to human faeces. However, this has to be preceded by mass education and sensitisation on public health importance of the disease.

The Tanzanian Meat Inspection Regulations of 1993 does not include comprehensive instructions concerning detection of porcine cysticercosis, in contrast to bovine cysticercosis which is thoroughly covered. This is most likely due to the lack of awareness of porcine cysticercosis being present in the country when the act was formulated. Considering the results of several recent studies indicating *T. solium* infections to be highly prevalent in many areas of Tanzania it is therefore recommend that guidelines and law(s), which cover detection and control of porcine cysticercosis, be drafted and enacted immediately to protect pork consumers.

The distribution of cysts of *T. saginata*, the beef tapeworm, in different organs/muscle groups of naturally infected cattle may depend on the geographical location, breed or age of the animals as well as the activity of the muscle group (Kearney, 1970; Pawlowski and Schultz, 1972). One would presume that similar factors influence the distribution of *T. solium* cysts. In this study cysticerci were recovered from the heart, tongue, internal masseter, external masseter, T*riceps brachii*, diaphragm, brain, head muscles, psoas and muscles of the forelimbs, hindlimbs, head, oesophagus, trunk and abdomen. Cysts were not recovered from the kidneys, livers, spleen and lungs (Boa *et al.*, 2002). Similar findings were reported from Nigeria by Onah and Chiejina (1995). However, Ma *et al.* (1992) recovered cysticerci of *T. solium* from the lungs, kidneys and livers of pigs from Hunan Province, People's Republic of China. These contrasting results may be due to strain differences or intensity of infection of *T. solium* and/or pig breeds from Africa and

Asia, which could affect the host-parasite relationship. Also, the Chinese pigs may have actually been infected with another species of *Taenia*, *T. saginata asiatica*, which occurs in Asia and has a predilection, in the larval form, for localising in pig's liver (Fan *et al.*, 1990). However, the study in China was an experimental infection that used the above-specified strain of *T. solium*. Secondly the experimental animals used in the study were free from *Taenia* infection, since they were purchased from an animal farm with very good sanitary conditions and no history of porcine cysticercosis cases.

Mapping of the inspected surfaces demonstrated that a mean area of 697 cm^2 was inspected by visual and incisional examination of the surfaces according to the local meat inspection regulations, indicating that only about 10.6% of the cysts are detected under optimal conditions using these detection methods. In Tanzanian towns and cities, where large numbers of pig carcasses are handled, pigs are generally slaughtered in the early hours of the morning when light for inspection of dressed carcasses is often inadequate. With practices such as these compounded by the, and the due to poor facilities such as lack of qualified pork inspectors in some local slaughter slabs in Tanzania, the practical detection rate of carcasses infected with cysticerci of *T. solium* is undoubtedly lower than the potential determined by mapping of inspected surfaces.

5.2 Surveillance of *Taenia solium* cysticercosis/taeniosis in the southern highlands of Tanzania

This is the first community-based survey of *T. solium* taeniosis/cysticercosis in the southern highlands of Tanzania. In this study, crude prevalence estimates based on tongue examination indicated prevalence rates of 7.6% and 8.4% for Chunya and Iringa Rural Districts, respectively. These prevalences are quite high indicating significant transmission of the disease. However, the overall prevalences for Chunya and Iringa Rural Districts were lower than the findings by Ngowi *et al.* (2004a) from Mbulu District, northern Tanzania, in which the overall prevalence by lingual examination was found to be 17.4%. The pigs in Mbulu had a higher prevalence than those from the southern highlands districts probably due to the fact that a significant number of pigs in Mbulu were free ranging (96%) compared to Chunya and Iringa Rural Districts where 88.20% and 62.7% of the pigs, respectively, were recorded as being kept under free-range condition. Secondly, in Mbulu the numbers of households that were lacking latrines (22.7%) were found to be significantly higher than the numbers in Chunya (10.4%) and Iringa (5.6%) Districts, respectively. Higher prevalences were also observed in neighbouring Kenya by Githigia and others (2002) who recorded prevalence rates of 10% and 14% by tongue examination in Nyanza and Busia Districts of Western Kenya, respectively. However, findings in this study are similar to those by Phiri and others (2002) in Zambia where the prevalence by tongue examination in the districts of Sinda (Eastern Province) and Kalomo (Southern Province) were 5.3% and 8.2%, respectively. Also, Pouedet and others (2002) had similar findings from Cameroon, whereby prevalences of porcine cysticercosis in the western communities of Bafou and Bamendou were observed to be 5.5% and 6.8%, respectively.

As already mentioned, visual inspection of the ventral surface of the tongues of pigs in Chunya and Iringa Rural Districts revealed cysticerci in 7.6% and 8.4%, respectively. This figure is a minimal estimate of infection prevalence because not all infections (*e.g.* light intensity infections) can be detected by this method. A study in Peru by Gonzalez and others (1990) indicated that 70% of infected pigs could be detected by lingual examination however, an earlier study from South Africa reported by Viljoen (1937) indicated that only 25% of infected pigs had cysticerci visible by tongue inspection confirmed by post-mortem inspection. Recently, Phiri and others (2002) in Zambia lingually examined 1,316 pigs ante-mortem, and found 143 pigs (10.9%) positive. From these suspected animals, 116 pigs (79.4%) were confirmed after slaughter. Only 17 animals found positive at lingual examination could not be confirmed infected at post-mortem. A total of 271 (20.6%) out of the 1,316 pigs were found positive at post-mortem examination. This suggests that 155 pigs (57%) with cysticercosis were not detected by lingual examination. Thus, the sensitivity of tongue examination in the Zambian study was 43%. However, these studies used post-mortem meat inspection for confirmatory diagnosis. Unfortunately the accuracy of meat inspection remains controversial and is thought to be less sensitive particularly in early and light infections (Kyvsgaard *et al.*, 1990; Sciutto *et al.*, 1998). Recently the study conducted by Dorny and others (2004) using local pigs from Zambia confirmed this hypothesis by estimating the sensitivity and specificity of tongue examination to be 21% and 100% respectively. And that of meat inspection was estimated to be 22.1% and 100% respectively. Therefore, prevalence obtained using the lingual examination method should be regarded as an underestimation of the true prevalence and thus the prevalence of porcine cysticercosis in Chunya and Iringa Rural Districts may actually be considerably higher. Further studies are needed to assess the accuracy of meat inspection and lingual examination in detecting porcine cysticercosis in local Tanzanian pigs.

Epidemiological surveillance in Chunya and Iringa Rural Districts identified the absence of a latrine, freerange management of pigs, home slaughtering of pigs, lack of pork inspection and barbecuing of pork as risk factors. Porcine cysticercosis is known to be associated with the accessibility of pigs to human faeces (Pawlowski, 2002). Free foraging of pigs allows them to wander around homesteads and farms where they are more likely to come into contact with human faecal material containing *T. solium* eggs unlike confined pigs fed in pens or indoors where chances of coming in contact with faecal material are very minimal. However, there is a possibility of these confined pigs being infected by attendat who was doesn't observe hygienic standards and contaminate concentrate/feed with *T. solium* eggs. In Chunya it was observed that a significant increase in prevalence in pigs raised in households that were not using latrines (26.9%) as compared to those raised in households that were using latrines (6.1%) (Odds ratio (OR), 5.7; 95% confidence interval (95% CI), 2.88-11.83) (Table 24). This indicates that pigs in the former group had greater access to human faeces than the latter. People from households without latrines will generally defecate in the bush and roaming pigs are likely to feed on the faecal material that at times may contain *T. solium* eggs. Similar findings were those by Ngowi *et al.* (2004a) in a community-based survey study in Mbulu District, northern Tanzania where the lack of a latrine was identified as a risk factor for porcine cysticercosis. This is supported by Carrique-Mass and others (2001) in Honduras who used the indirect ELISA technique of Larralde and others (1986) where they observed that pigs raised in households without sanitary facilities had significantly higher prevalence rates of cysticercosis than those kept by households with latrines. In addition, observations similar to the ones in this study were those noted by Sanchez (1999) who found that lack of latrines in the rural households of Honduras (Agua Caliente) was a risk factor for porcine cysticercosis. However, findings in the present study are different from those by Sarti and others (1992) in Mexico and those by Pouedet and others (2002) from Cameroon. In those two studies, pigs were reported to have easier access to faeces when a latrine was present in the homestead. In western Cameroon the pigpen is made in such a way that a person will defecate from the top of the pigpen and faeces will drop down right into the pen where the pig is located, so that the pig has direct access to the solid waste faecal matter. In Mexico the faeces from the latrine/toilet are deliberately directed to the pigpen to act as a supplementary feed for the pig (Sarti *et al.*, 1992). However, in this study when a latrine is present in the homestead it protects pigs from being infected in that it is built in such a way that pigs will be prevented from entering it, thus denying them from having access to human faeces. However, there is a possibility that confined pigs may also be infected with *T. solium* eggs especially if the person attending the pigs is infected with the tapeworm and doesn't observe good hygienic practices. These findings underline important regional differences in the use of latrines such that one should be careful in generalizing risk factors for porcine cysticercosis from one culture to another and one geographical region to another.

The surveillance in Iringa Rural District failed to incriminate the lack of latrines as a risk factor. It is admitted that the situation on the use of latrines was not quite clear during this epidemiological surveillance, since most of the respondents informed that all members of their family were using the observed latrines. However, while examining pigs and walking from one household to another, human faeces were frequently observed in the fields/bushes strongly suggesting that perhaps not all persons in the household were using the latrine. Thus, the responses from pig farmers in Iringa concerning latrine use was contradicted by field observations. Hence, the reported high latrine coverage blindly accepted by the researcher as the actual situation without going into further investigation might have resulted in false findings. Phiri and others (2002) made similar observations in Zambia in a study conducted in 2 Districts, Kalomo (Southern Province) and Sinda (Eastern Province), whereby they were unable to conclude that the lack of latrines was a risk factor for porcine cysticercosis in either district. In that study they actually failed to identify a single risk factor for porcine cysticercosis. Possible reasons for failing to identify risk factors in the Zambian study were that the study population was fairly homogeneous in terms of most of the possible risk factors (free-roaming of pigs, lack of latrines in the households, lack of meat inspection, ignorance of pig raisers on the transmission of the disease and eating of raw or undercooked pork) such that all pigs appeared to be equally and permanently at risk of coming into contact with the parasite. They also attributed the small sample size in their study as one of the factors responsible in weakening the statistical significance of any relationships whereby they examined 98 pigs from 21 households in Kalomo District and 151 pigs from 66 households in Sindi District. However, in the study presented the issue of small sample size does not apply since the number of pigs examined were 808 from 341 households over and above the required sample size of 738.

In Chunya District there was a significant difference in cysticercosis prevalence between pigs that were confined in pens (3.5%) and those which were allowed to free range (10.0%) (OR, 3.1; 95% CI, 1.43-6.88) [Table 25]. In Iringa District too there was a significant difference in cysticercosis prevalence between pigs that were free-ranging (12.9%) and those which were confined in pens (4.3%) (OR, 3.32; 95% CI, 1.85-6.43) [Table 29]. When the data for the two districts were compiled it was determined that free ranging of pigs only contributed to an increased risk in the households where latrines were absent (OR, 25.0; 95% CI, 12.44-48.41) [Table 30]. On the contrary, in households where latrines were present, free ranging of pigs did not lead to any increased risk (OR, 1.0; 95% CI, 0.33-3.53) [Table 30]. These results should be viewed in light of the high proportion of households having latrines in the surveyed area. The pigs will therefore only have limited access to human faeces even if they roam around in the area. The finding is also an indirect indication that the latrines are actually being used. The significance of free-range pig grazing may well be very different in communities where latrines are more rare or not being used as in the case of the Zambian study discussed above.

In both Chunya and Iringa Rural Districts home slaughtering of pigs without inspection was significantly associated with increased prevalence of cysticercosis (OR, 3.9; 95% CI, 2.28-6.84) [Table 31]. The nature of the relationships between porcine cysticercosis and home-slaughter may be duplicitous: One possible explanation is that these households consume more pork, thereby they have a higher risk of human taeniosis, which in turn leads to a higher risk of cysticercosis among the pigs. Another possible explanation is that the households, who suspect that their pigs have cysticercosis may tend to slaughter their pigs at home and eat the pork at home or share with neighbours or later sell the meat through informal channels rather than risk their condemnation at the slaughter facility (Ngowi *et al.*, 2004b; Phiri *et al.*, 2003). The present study cannot determine which of the two explanations is the most likely or whether both are to some degree valid. Pigs slaughtered at home and not officially inspected pose a serious public health risk. Public education on the danger of consuming infected pork is a necessity in these areas. On a few occasions in Iringa and Mbulu it was observed that respondents admitting to have knowingly consumed infected pork and this can mainly be attributed to abject poverty or ignorance. Also in Mbulu on one occasion it was observed that a farmer with infected pigs refusing to accept a lower price for a pig that was infected, indicating that it can fetch a higher price at the clandestine market, contrary to assumption that it has no/very little value since if it were to go through the formal meat inspection channels it would be condemned. Previous findings by Ngowi and others (2004b) support these observations whereby pigs discovered by tongue examination to be infected at the village level in Mbulu District are rarely transported out of the area. From the interviews conducted in the villages some farmers claimed that some of the detected infected pigs were sold at a lower price to butchers who normally slaughter the pigs at home. In many rural communities of the developing world pigs and pork are often not inspected due to the shortage of meat inspectors, lack of transport for the meat inspectors, risk of confiscation of infected pork and lack of slaughter slabs/abattoirs (Gonzalez *et al.*, 1990; Phiri *et al.*, 2003). Under these situations infected pork can have a significant value to the owner and will always have a market and later find its way to the dining table (The Cysticercosis Working Group in Peru, 1993; Phiri *et al.*, 2002). Similar interesting observations were made in the Peruvian Sierra, endemic for porcine cysticercosis by The Cysticercosis Working Group in Peru (1993) in that pigs are sold only in the informal sector. Porcine cysticercosis in this area was found to be so common that one out of every five or six pigs is likely to be infected. Such pigs would normally be confiscated and destroyed if they were channelled through the formal marketing sector. Therefore, the threat of confiscation without compensation forced farmers to use the informal/clandestine market. From the questionnaire study it was observed that most respondents admitted conducting home slaughter and pork was not inspected [Chunya District, 89.9%, n=231 and Iringa Rural District, 74.8%, n=341]. The reason most frequently reported for pork not being inspected was shortage of meat inspectors. In order to solve this problem there is a need for the local and central governments in these areas to recruit meat inspectors at least one per village (instead of the current situation of one inspector catering for 5 villages or more) and provide them with proper training and transport. Then meat inspection in all slaughter places in these rural areas should be instituted as soon as possible and bylaws regarding pork inspection enforced by the local police.

To overcome the problem of clandestine marketing of pork infected with cysticerci of *T. solium* governments have to provide financial market incentives to reimburse the farmers and/or slaughterhouses for infected pigs that are taken out of circulation or made safe for consumption by processing the meat by boiling. Even then, some of the lightly infected pigs may enter the food chain because the technique of meat inspection using visual inspection of key carcass sites is not 100% effective since its sensitivity is only 22.1%

(Dorny *et al.*, 2004). This has been demonstrated in cattle in that those animals which are lightly infected with *T. saginata*, a close relative of *T. solium*, only 15% are detected by classical meat inspection (Kyvsgaard *et al.*, 1990). Geerts (1990) found that, although the official figures returned by the meat inspection services show that the number of Belgian cattle infected with cysticercosis decreased during recent years from 0.3% to 0.03%, systematic search and careful detection proved that 9.5% of cattle were infected with cysticerci of *T. saginata*. This discrepancy with the official figures was due to the inappropriate detection techniques used routinely in the meat inspection at slaughtering, and demonstrated that, even in Europe, official data may differ considerably from reality. However, porcine cysticercosis is usually characterized by heavy infection (Boa *et al.*, 2002) compared to bovine cysticercosis because pigs have much higher exposure to infection through direct consumption of human faeces, thus many of the porcine cysticercosis cases can be detected by routine meat inspection and taken out of the food chain. But light infections may still occur thus the risk of infected pork reaching the consumer still exists.

In Chunya and Iringa Rural Districts respondents who said their preferred form of cooking pork was barbecue were 33.3% and 52.0%, respectively, and this is the form that might be responsible for transmission and maintenance of the disease. This form of preparing pork is believed wouldn't kill *T. solium* cysticerci, and thus may be responsible for transmission and maintenance of the disease in these two districts. To control taeniosis pork should be thoroughly cooked, since cysticerci are killed only at temperatures of 45-50^{0} C for 10 minutes or more, but can survive in big chunks of meat if the centre is inadequately cooked (Robinson, 1978; Garcia *et al.*, 1997; Dada *et al.*, 1993). Observations made in the Kwande community, northern Nigeria, by Dada and others (1993) showed that the mode of roasting meat [pork, beef or dog meat] is by arranging large chunks of meat on iron rods or sticks and placing them near smoking fire when cooking their local brew. Evidence abounds that meat exposed in this fashion seldom attains a high enough temperature to kill the cysticerci. Further observations in this study showed that persons who ate these half roasted meat had significantly higher prevalence [17.2%] of taeniosis than those who ate well roasted/cooked meat [7.9%] (Dada *et al.*, 1993). Therefore the local habit of consuming barbecued pork in the southern highlands is probably one of the factors responsible for the high prevalence of *T. solium*. Thus, the rural communities of southern highlands should be informed about proper pork preparation and the eating of undercooked pork should be discouraged or even prohibited in community gatherings like local brew shops where mostly undercooked pork is believed to be consumed.

In this study, it was evident that most farmers from the southern highlands opted for rearing their pigs on a free-range system because of the problems associated with the lack of resources such as feed and labour involved in feeding the confined pigs and also ignorance about the economic and health impacts of cysticercosis in pigs and humans. This is in agreement with observation by Gilman and others (1999) who reported that in Peru a pig can be fed at little cost by allowing it to roam free in villages or on farm land and in this way obtain a variety of food to supplement its diet. However, this kind of husbandry is the main risk factor associated with porcine cysticerosis, as free ranging pigs have much greater access to human faeces in communities with few or no working latrines (Ngowi *et al.*, 2004, Phiri *et al.*, 2003, Pouedet *et al.*, 2002; Rodriquez-Canul *et al.*, 1999 and Sarti *et al.*, 1992). To promote confinement of pigs in order to facilitate prevention of cysticercosis the issue of available and affordable pig feeds must also be considered in order to ensure a sustainable confined pig production system through understanding what is appropriate and acceptable to smallholder pig keepers. Therefore, agricultural extension programmes addressing smallholder pig production systems is a necessity to facilitate needed smallholder pig management changes.

The results of the present study in Iringa Rural District indicates a higher prevalence of cysticercosis among adult pigs. One obvious reason for this is that older animals have had greater exposure to infection than younger ones simply because they have stayed in the contaminated environment longer (Sarti *et al.*, 1992; Pouedet *et al.*, 2002).

5.3 Investigative study on factors responsible for the absence of porcine cysticercosis in Mgeta Division, Morogoro Rural District, Tanzania

Lingual and post-mortem examination of Mgeta pigs indicated that they were free from porcine cysticercosis with none of 609 pigs examined lingually and none of the carcasses of 124 pigs from 20 different villages examined post-mortem being found positive. Analysis of focus group discussions and in-depth interviews of 251 informants further supported the absence of *T. solium* cysticercosis/taeniosis in Mgeta Division, confirming previous claims by butchers, meat inspectors and pig traders that Mgeta pigs are clean of porcine cysticercosis.

Serological examination of Mgeta pigs indicated that 1.3% of 462 pigs raised in Mgeta Division had circulating antigens to *Taenia* species. The Ag-ELISA test used to detect porcine cysticercosis has a reported specificity of 94.7% and is known to cross-react with larval infection with *T. hydatigena* (Dorny *et al.*, 2001; Dorny *et al.*, 2004). It is possible that these positive animals were infected with the larval stage of *T. hydatigena* and not *T. solium* as roaming dogs, the definitive host of *T. hydatigena*, are frequently observed in Mgeta and could thus be contaminating the environment with eggs of the other *Taenia* species. Mgeta Division has the topography of "rolling" countryside such that when it rains the *Taenia* eggs can be easily disseminated onto farm pastures and horticultural crops by water run-offs. When farmers were asked with what do they mostly feed their pigs, 51.4% of respondents from Mgeta Division said vegetation from green pastures of farms including horticultural crops by-products/waste. These pastures may be contaminated with *T. hydatigena* eggs, thus if pigs are fed vegetation from these contaminated pastures they may be exposed to the parasite eggs. Otherwise if the infection in 1.3% of the pigs is due to cysticeri of *T. solium* then meat inspection of 124 animals from 20 villages, tongue examination of 609 pigs and group discussions with butchers and pig farmers from all 22 villages should have indicated the presence of the parasite in Mgeta division. During pork inspection in Mgeta Division an observation was made of the larva of *T. hydatigena* as a solitary cyst in the liver in one pig. Therefore, the parasite is rare in the study area. Similar findings to this one were those by Ngowi and others (2004b) in Mbulu District whereby after post mortem examination of 70 pigs only 1.4% of pigs were found infected with cysticerci of *T. hydatigena*. The point that *T. hydatigena* cysticercosis is uncommon in pigs in Africa is supported by finding by Dorny and others (2004) in neighbouring Zambia whereby among 65 rural pigs examined by complete slicing of carcasses and only 2 pigs were found infected by the parasite making a prevalence rate of only 3.1%.

While it could be argued that perhaps *T. solium* has never been introduced into the Division, this possibility is considered to be unlikely due to the movement of people and pigs in the country. Rather the information gathered during the group discussions and interviews suggests that several factors may be involved in keeping Mgeta Division *T. solium*-free including strictly enforced community regulations concerning sanitation and pig management practices as well as pork consumption habits of the local population.

The availability and use of latrines in Mgeta Division was found to be very high (97.6%) indicating minimal risk of environmental contamination with human faeces. Education and sensitisation of the Division population about the need for constructing and using latrines is apparently a result of a division-wide prevention and control programme for cholera and shigellosis. The presence and community acceptance of a Village Public Health Committee for implementing by-laws concerning sanitation through quarterly latrine inspections and fining of persons not abiding by the regulations appears to have been highly successful. Thus, the resulting improved sanitation situation in the Division has not only eliminated the problem of cholera and shigellosis but also established the conditions for preventing the transmission of *T. solium*.

Latrine coverage in the districts of Mbulu, Chunya and Iringa have been reported to be 80.8%, 93.9% and 94.4%, respectively (Ngowi *et al.*, 2004a; Phiri *et al.*, 2003), also fairly high, however all 3 districts are endemic for *T. solium*. Evidence suggests that although most households have latrines in these districts transmission of *T. solium* is still occurring because many people do not use the latrines and instead defecate in the bush. For example in Chunya it has been reported that the mother and older children use the latrine while the father (head of household) uses the bushes nearby. During a survey of porcine cysticercosis in Iringa interviewed respondents informed that all family members use the latrine however researchers frequently came across human faeces on and nearby the farms contradicting the information on latrine usage. In Mbulu local reports suggest that latrines are used more for privacy rather than any concern for disease control, with many families constructing latrines for the sole purpose of just being able to show it to the government inspectors so they will not be fined. For various reasons even if a latrine is present some family members may still defecate elsewhere and human faeces have been observed frequently in the fields and bushes. However, in Mgeta latrine inspection programmes work because of the establishment and acceptance of a highly motivated Village Public Health Committee which is lacking in the other three districts. The lack of an effective Village Public Health Committee in these 3 districts did not provide any incentives for increasing latrine usage, thus providing an enabling environment for the transmission of cysticercosis.

The information from these different districts indicates that the presence of latrines and their usage by different tribes and ethnic groups in Africa is not exactly straightforward such that the presence of a latrine at a homestead does not necessarily mean that it is used all the time and by all the persons in the homestead. Nevertheless, in contrast to these other areas, researchers very rarely observed human faeces in the fields or farms of Mgeta providing further evidence of the high compliance of latrine usage in that Division.

A major reason for the absence of porcine cysticercosis in Mgeta Division is believed to be due to strict confinement of pigs in pens. Unlike most other pig raising areas of Tanzania, Mgeta Division is a densely populated area with year round cultivation of crops thus there is no free space for foraging pigs. The communities in the division have realised that the cost of allowing pigs to run freely resulting in destroyed crops is higher than that of confining and feeding them. This economic incentive instigated the legislation and strict implementation of community by-laws resulting in serious punishment (i.e. monetary fines/reimbursement for damages) of people whose pigs have destroyed the personal property of others. These findings are similar to those of communities reporting little or no porcine cysticercosis in other *T. solium* highly endemic countries such as Mexico and Peru. Flores and others (2001) reported that local regulations to keep pigs restrained were implemented and found responsible for the absence of cysticercosis in Coapeche, Mexico.

Garcia and others (2002) made similar observations in pigs raised in the Monterendondo community situated in the coastal zone of Peru. In this community surveys of pigs and humans in 1990 indicated sero-prevalences of 13% and 16%, respectively. Previous studies in the same community had shown porcine sero-prevalence to be at least twice that of human prevalence suggesting a substantial reduction of porcine infections in Monterendondo (Gilman *et al.*, 1999). The most likely reason behind the substantially lowered porcine cysticercosis prevalence was that the community began to grow rice 3 years before the latest survey which led the villagers to tether pigs in order to protect the rice crop. The introduction of rice meant that for the first time the benefit accrued by tethering pigs outweighed the cost of feeding them. Therefore, at the time of the most recent survey, all pigs were less than 3 years of age and were tethered; accordingly the sero-positivity rate of pigs was considerably lower. In contrast the serological status of humans remained high in the community since their infections represented the cumulative effects of exposure over a much longer period.

Pig management practices in Mgeta Division contrasted significantly from those of the *T. solium* endemic districts of Mbulu, Iringa Rural and Chunya. Respondents who allowed their pigs to freely forage in Mbulu, Iringa and Chunya Districts were 98%, 62.7% and 45%, respectively and free-range pig management was indicated as a risk factor in all three districts. While in Mgeta 97.2% and 2.8% of respondents kept their pigs confined in total enclosures and indoors, respectively. Hence no respondents kept pigs on free range. Thus, total confinement of pigs in pig pens/indoors might have played a very significant role in preventing the occurrence of *T. solium* taeniosis/cysticercosis in Mgeta Division.

In addition to pig confinement and the high level of sanitation in Mgeta the avoidance of ingesting pork containing viable *T. solium* cysts by thorough cooking was also believed to be partly responsible for the absence of cysticercosis/taeniosis. From the focus group discussions most respondents in Mgeta preferred deep-frying (35.3%) and boiling (43.4%) summing up to 78.7%, as their standard way of cooking pork. A questionnaire survey of pig farmers in Mgeta Division also gave similar results with respondents who preferred deep-frying, boiling, and barbecuing being 63.9%, 31.9% and 2.8%, respectively. In contrast, respondents who preferred barbecuing as a form of cooking pork in southern highlands of Tanzania were significantly many (22.0%) compared to those who preferred the same form of cooking in Mgeta Division (2.8%) [χ=3.9, $p<0.05$]. Therefore the habit of consuming barbecued pork in the southern highlands is probably one of the factors responsible for maintenance of taeniosis in that zone in contrast to Mgeta Division where the proportions of respondents preferring barbecued pork is quite insignificant compared to those preferring boiling and frying and the disease is found absent. The deep frying and boiling of pork practiced by Mgeta farmers are considered adequate to kill *T. solium* cysts, as they die at temperatures of 45-50°C after 10 minutes or longer, thus preventing people from becoming infected with the tapeworm (Robinson, 1978; Garcia and Bruckner, 1997). This is important considering that inspection and control of pork in Mgeta is a serious need due to coverage constraints by meat inspectors.

The information gathered in this study suggests that community practices and regulations in Mgeta Division have effectively prevented the establishment and transmission of *T. solium* cysticercosis/taeniosis even though it was not their original intention since most community members are not aware of the parasite's presence in Tanzania much less its mode of transmission. Regardless, the results indicate the case and appropriateness of integrating cysticercosis prevention strategies with those for other health and agricultural concerns and should serve as a good model for communities in the country where *T. solium* infections are a problem like in Chunya, Iringa Rural and Mbulu Districts. Consideration should be given to making local stakeholders in affected communities aware of the impact of and possibilities for preventing cysticercosis using methods proven elsewhere in the country as well as the many additional benefits that could result by doing so such as prevention of other diseases, improved marketing possibilities for pigs, provision of organic fertiliser, etc. In particular the by-laws concerning the construction and usage of latrines and confinement of pigs in effect in Mgeta as well as the role and effectiveness of the Division's Village Public Health Committees serve as good examples of acceptable and sustainable community-based interventions, which could make a difference in many other communities.

5.4 Study IV: Identification of factors responsible for presence of porcine cysticercosis in Chunya and Iringa Rural Districts and for absence of porcine cysticercosis in Mgeta division using Ag-ELISA and tongue examination tests

The Ag-ELISA detects antigens secreted or excreted by viable *T. solium* larvae. The adult tapeworm does not produce these antigens, and therefore, the test is very specific in detecting pig *T. solium* cysticercosis with sensitivity and specificity values of 86.7% and 94.7%, respectively (Dorny *et al.*, 2004) compared to the sensitivity and specificity of lingual examination which has been found to be 70.8% and 100%, respectively (Gonzalez *et al.*, 1990).

Comparison of the two diagnostic techniques indicated that the Ag-ELISA detected more cases of cysticercosis than were detected by tongue examination. In Chunya District, for example prevalence by tongue examination was found to be 3.9% compared to 28.0% by Ag-ELISA showing that Ag-ELISA was 7.2 times more sensitive than lingual examination. Similarly in Iringa Rural District Ag-ELISA detected more cases of cysticercosis in comparison to tongue examination. When data for Chunya and Iringa Rural District were combine [southern highlands] Ag-ELISA detected more cases than tongue examination test, and was found 3.6 times more sensitive than tongue examination test. Results from the current study indicate that the Ag-ELISA is, in practice, at least more than three times as sensitive as tongue examination. Similar findings to these are those by Phiri *et al.* (2002) in Zambia where Ag-ELISA was found to be more sensitive than tongue examination by a factor of two.

The Ag-ELISA has proved useful as a seroepidemiological tool, and will also facilitate field-based epidemiological studies on live herds since it allows ante mortem diagnosis. Finally, this Ag-ELISA offers the opportunity for farmers/pig traders to make decisions over the management of their known infected pigs. The infected pigs can be treated successfully with oxfendazole at a single dose of 30mg/kg bwt and pork was found safe and clean aesthetically after 3 months [12 weeks] post administration of the drug (Gonzalez *et al.*, 1998). Currently pig traders in Mbulu District are reported to be purchasing tongue positive pigs at a significantly lower price then treating them with a local herb that is claimed to clear cysts after 2 months since its administration [Mr. John S. personal communication, 2004]. Then these pigs are taken to towns/cities for marketing. But not all cysts can be detected by ante mortem tongue examination (Dorny *et al.*, 2004) as has been demonstrated recently by Sato and others (2003) who found out that 34% of tongue inspection negative pigs from endemic district of Mbulu, Tanzania were seropositive by ELISA using glycoproteins. Therefore, Ag-ELISA can be used in this case to diagnose all the cases of cysticercosis 3 months before the pigs are ready for marketing and positive cases treated using the local herb or oxfendazole. In this way transmission of *T. solium* taeniosis/cysticercosis can be minimised and might be eliminated if mass chemotherapy of pigs and humans is conducted. Secondly the losses that could arise from confiscation and condemnation of infected pork at slaughter slabs or abattoirs in cities or towns can be avoided if the program of testing and treating will be applied. The only problem with Ag-ELISA used in this study is it's cross-reaction with *T. hydatigena* cysticercosis (Dorny *et al.*, 2001; Dorny *et al.*, 2004). However, the large cysticerci of *T. hydatigena* are very common in small ruminants but rather uncommon in pigs in Africa. They are, however, much more wide spread in pigs in Vietnam, thereby seriously impairing the usefulness of Ag-ELISA in that country (Dorny *et al.*, 2001). The point that *T. hydatigena* cysticercosis is uncommon in pigs in Africa is supported by finding by Dorny and others (2004) whereby among 65 rural pigs examined by complete slicing of carcasses only 2 pigs were found infected by the parasite making a prevalence of only 3.1%. Also the findings in Mgeta Division of prevalence rate of 1.3 % by Ag-ELISA, most probably caused by cysticerci of *T. hydatigena* in this very study supports the findings in Zambian study. Similarly Ngowi *et al.* (2004b) observed the prevalence of 1.4% after post mortem examination of 70 finished pigs from Mbulu District. Thus, the parasite is uncommon in pigs raised in Africa as per above cited findings.

The Kappa value in this study was found to be 0.24, which implies poor agreement between the tongue and Ag-ELISA tests. Possible reasons for the disagreement might be due to the fact that observed or palpable 'cysts' could have been scars/dead cysts or that the number of live cysts was too small to be detected by Ag-ELISA. However, on the issue of low number of cysts, Nguekam and others (2003) in their recent experimental study in pigs could detect one live cyst by the same Ag-ELISA. Similar findings to this one were those by Phiri and others (2002) in Zambia where they could not confirm observed several tongue positives cases by Ag-ELISA.

Using the Ag-ELISA results from the southern highlands free-range management of pigs and absence of a latrine in the household were identified as risk factors. However, the method of cooking pork, home slaughtering of pigs and lack of pork inspection did not show any statistical association with porcine cysticercosis when the two districts of the southern highlands were compared using Ag-ELISA results. This may be due to the small sample size used for the analysis [Chunya, n=232 and Iringa, n=208] compared to contrasting previous findings by lingual examination where analysis utilised a large sample size of 722 and 808 pigs in Chunya and Iringa Rural Districts, respectively.

Findings of the study indicate that porcine cysticercosis is a common and serious problem in small scale pig production systems in the rural areas of Chunya and Iringa Rural Districts. Results from these two surveys have revealed important risk factors contributing to the spread and distribution of porcine cysticercosis in the two districts which were lack of latrines and free-range pig rearing. The high prevalence of porcine cysticercosis indicated by both lingual and Ag-ELISA examination indicates heavy environmental contamination of *T. solium* eggs from human tapeworm carriers. Thus, an important step to prevent cysticercosis in the southern highlands is to improve the sanitary conditions and pig management practices in the pig raising areas. However, the respondents to questionnaires were found to be mostly ignorant about how the pigs acquire the infection [Chunya District, 92.2%, n = 231 and Iringa Rural District, 88.6%, n = 341]. They generally believed that it is acquired by feeding pigs with brewer's mash or pumpkins. Thus, health education and agricultural extension are necessary to provide an entry point for confinement of pigs and construction of latrines. The rural communities need to be informed of the dangers of eating raw or undercooked pork and the importance of using the latrine not only for controlling *T. solium* taeniosis/cysticercosis but also other infectious diseases. In order to eliminate or reduce infection risks in these "hot spot" areas, it is necessary to conduct education campaigns and sensitisation of the communities on the mode of transmission and impact of the parasite as well as the need for and benefits of total confinement of all pigs, increase in latrine coverage and usage, rigorous meat inspection by recruiting more meat inspectors and providing them with proper training and transport, improvement of slaughter facilities such as having slaughter slabs provided with water, and lastly, thorough cooking of pork.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

In Study I the psoas muscle was found to be an important site for localisation of cysticerci in pigs since it ranked high as a site of predilection, having the highest relative cyst density and a high proportion of total cysts as well as being parasitised in all of the carcasses examined. Muscles of *Triceps brachii*, the tongue, internal masseter, external masseter, the diaphragm and the heart followed the psoas as important sites for localisation of cystcerci in pigs. Based on these findings, all of these muscle groups/organs are proposed as predilection sites of *T. solium* in Tanzanian pigs and thus their examination should be mandatory for efficient and effective routine inspection of pig carcasses in Tanzania.

The Tanzanian Meat Inspection Regulations of 1993 does not include comprehensive instructions concerning detection and judgement of porcine cysticercosis, in contrast to bovine cysticercosis which is thoroughly covered.

Based on these findings it is therefore recommended that the government of Tanzania consider drafting guidelines and enacting legislation concerning the inspection of pig carcasses and control of pork with regard to *T. solium* infection as soon as possible to protect pork consumers.

Results from Study II have revealed important factors responsible for transmission and maintenance of porcine cysticercosis in Chunya and Iringa Rural Districts of Mbeya and Iringa Regions, respectively. Poor management (free range) of pigs, absence of latrines, consumption of undercooked pork, lack of pork inspection and control, and ignorance about the mode of transmission of *T. solium* taeniosis/cysticercosis are the most important of the factors. Thus, a successful prevention and control program in Chunya and Iringa will need to focus on these factors, in addition to diagnosis and treatment of human and porcine cases coupled with public education. To significantly reduce the prevalence of cysticercosis in these two districts some lessons from Mgeta Division, where pig keeping is popular but the disease is found to be absent, can be learnt. In particular the by-laws concerning the construction and usage of latrines and confinement of pigs in effect in Mgeta as well as the role and effectiveness of the Division's Village Public Health Committees serve as good examples of acceptable and sustainable community-based interventions for prevention of cysticercosis. These initiatives could make a difference in the local communities of Chunya and Iringa Rural Districts where the transmission of cysticercosis is considerable.

Therefore it is recommended that total confinement of pigs and improment on sanitation in these districts as in Mgeta be considered as part of an eventual prevention and control strategy dependent on the local situations. However, risk communication (sensitisation) and education must be a prerequisite before advising the farmers to confine their pigs.

Therefore the major conclusions are:

- Inclusion of porcine cysticercosis in the national meat inspection regulations with inspection of predilection sites and proper disposal of infected carcasses.
- Cysticercosis is prevalent in the southern highlands of Tanzania.
- Recruitment of meat inspectors where there is shortage is required in order to control *T. solium* taeniosis/cysticercosis in Tanzania.

- One way of improving the inspection of pork would be through the introduction of village by-laws directing the Division meat inspectors to train key people (e.g. community-based health/animal health workers, veterinary auxiliaries) in each of the villages on easy ways to detect *T. solium* cysts in pig carcasses. This would facilitate local inspection resulting in lowered risk of consuming cyst-infested pork. As is current practice with meat inspectors, the local cysticercosis "inspectors" could be compensated for their service through the provision of a small amount of pork as stipulated in any community by-laws governing the practice.
- To prevent uncontrolled slaughtering of pigs in the rural areas, towns and cities there should be provision of slaughter slabs/slaughterhouses and meat inspection and control.
- Community-based regulations on sanitation and pig keeping and their enforcement could be an effective way of preventing and controlling cysticercosis (and other diseases) as has been seen in Mgeta Division.
- Pig husbandry practices that will prevent pigs from having access to human faeces have to be adopted. Community livestock extensionists will need to be trained in proper smallholder pig management including housing, feeding, etc. so that the proper information can be passed on to the smallholder pig owners.
- Community health education on cysticercosis transmission and ways to avoid its transmission must be conducted and health education should be imparted effectively to farmers, butchers, pork sellers, consumers of pork and politicians. Various communication medias like television, radios, newspapers, leaflets, posters and brochures must be

broadcast/circulated/posted/distributed regularly in order to create mass awareness.

- Regular and active surveillance, to know the prevalence, incidence and burden of taeniosis and cysticercosis in both definitive and intermediate hosts should be carried out in order to monitor the status of cysticercosis in Tanzania. This information provides the essential evidence base for establishment of policies, formulation of strategies and implementation of actions aimed at combating cysticercosis.
- Ag-ELISA can be used for surveillance, although it has been reported that the sensitivity of the technique is low in pigs with low levels of cyst burdens (Sciutto *et al.*, 1998), although others have been able to detect pigs harbouring one single cyst using the test (Nguekam *et al.*, 2003). A serious concern with using the test in pigs is cross-reaction with *T.hydatigena*. But the good thing is that the prevalence of *T. hydatigena* in pigs in Africa is very low.
- Lingual examination may only be appropriate for rapid assessment surveys to determine the endemic status of communities due to its low sensitivity (<70%) (Gonzalez *et al.*, 1990).

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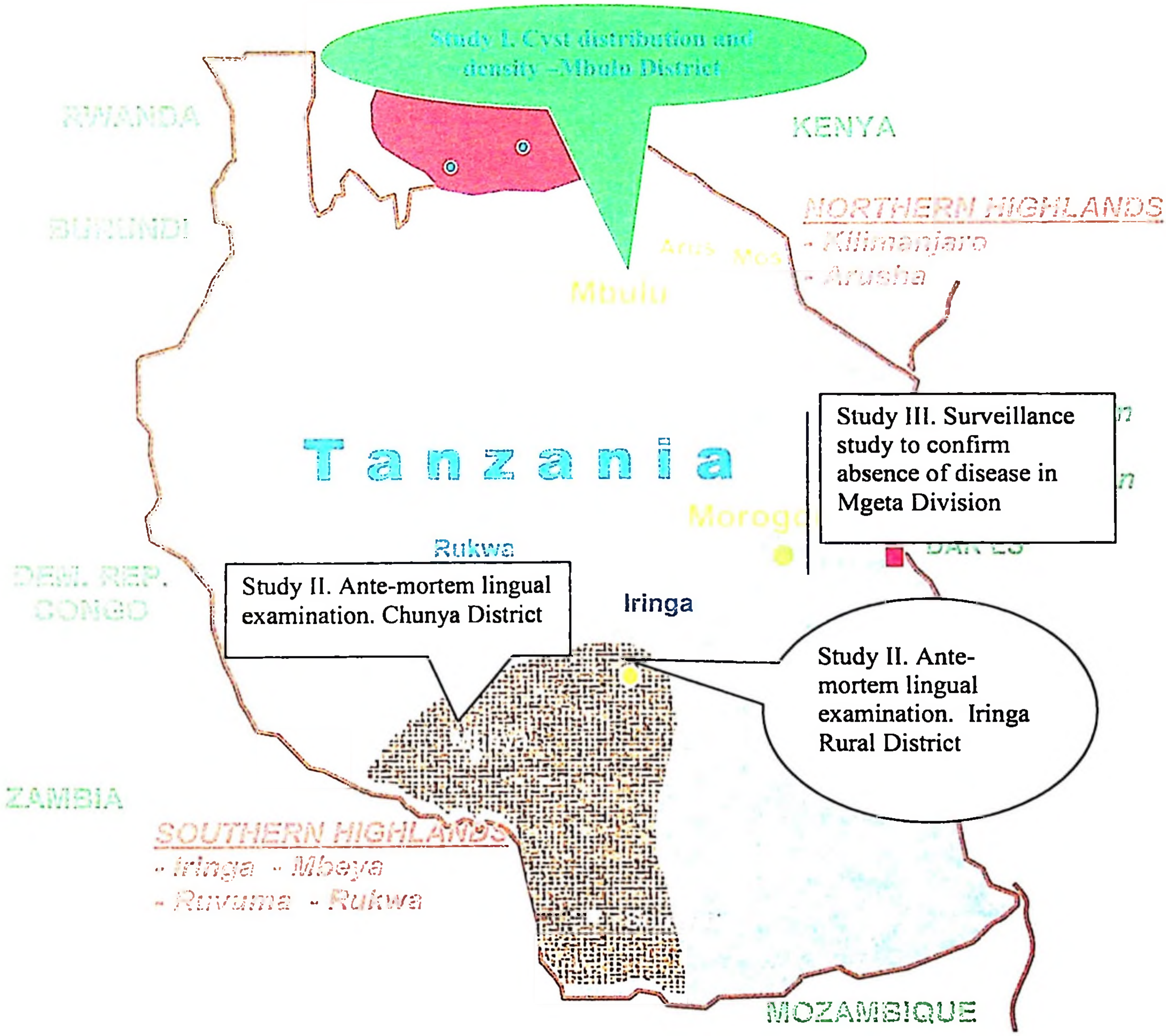
APPENDICES

Appendix 1: Map of Tanzania showing the 3 study areas.



Appendix 2: The questionnaire for Chunya and Iringa *T.solium* taeniosis/cysticercosis survey at household level

Number of pigs positive by tongue examination...........out of.........pigs examined in the household

Date ....

1.Village................... Division..................... District...........................

HOUSEHOLD DESCRIPTION

2.Main income..

3.Ethnic background......................................

RESPONDENT:

4.Name ....

5.Age ....

6. Sex ....

7.Position in the household................................

8.Education level ....

9.Occupation...

10.Experience in pig management (years)................

PIG MANAGEMENT

11. How many pigs do you have in each of the following categories?

(a) Breeders........................

(b) Piglets ....

(c) Fattener........................

(d) Total................................

12. Have you ever-bought piglets outside your own farm? (YES__, NO __)

13. If "Yes". (a) Where? ....

(b) How often? ....

14. What is the aim of keeping pigs?...................................

For sale at (a) Local market _

(b) Market in another village_

(c) Pig traders _

Where do the pig traders sell the pigs?...

(d) For home consumption_

(e) Any other (Mention)...

15. Which system do you use to feed your pigs?

(a) Indoor_

(b) Free-range_

(c) Tethering_

(d) Fencing by timber off cuts; Do the pigs or piglets ever escape from the fence? (YES__; NO_)

(e) What is the fence quality? Good_, Medium_, Bad_ (If the piglets can escape). Other remarks.....................

16. What do you feed your pigs ?

(a) Pasture_

(b) Other feeds (mention) ....

17. What problems have you encountered as far as pig management is concerned ? (Rank them)

Cysticercus cellulosae, other diseases _, No problems_, other problems (mention).....................................

POSSIBLE TRANSMISSION FACTORS

18. Do you (any member in the family) consume pork? (YES _, NO _)

19. If "Yes", in what form?

(a) Boiled _

(b) Fried _

(c) Barbecue_

(d) Raw _

(e) Any other (Mention) ....

20. Have ever slaughtered a pig at home? (YES _, NO _)

21. If "Yes", how did you know whether or not it was fit for human consumption?

(a) An official meat inspector inspected the meat _

(b) Meat was not inspected _

22. Presence and use of latrine to be assessed by direct observation

(a) Present and used _

(b) Present but not used _

(c) Absent _

AWARENESS OF TAENIASIS AND/OR CYSTICERCOSIS

23. Have you ever heard of tapeworm infection in human? (YES_, NO_) (If "No" go to question 29)

24. Have you heard of anyone said to have tapeworm infection in the village? (YES_, NO_)

25. How can people acquire tapeworm infection?

(a) By consuming raw or inadequately cooked pork _

(b) By consuming raw or inadequately cooked beef _

(c) the respondent does not know _

(d) Any other explanation..

26. Can you mention any obvious signs of tapeworms in humans?

(a) Expulsion of proglottids in faeces _

(b) Presence of skin nodules _

(c) the respondent does not know _

(d) Any other explanation..

27. What should people do who have this infection ?

(a) Go to hospital _

(b) Use traditional medicine (mention)....................................

(c) Do nothing _

28. Have you heard of nay one said or complaining to have epilepsy in the village?

(YES__, NO__)

If "Yes", approximately how many?.......................................

Do you regard it as major problem in your village? (YES__, NO__)

29. Have ever seen or heard of white nodules in pig's carcasses ? (YES__ NO__)

(a) Presence of nodules under the tongue _

(b) Can not recognize _

(c) any other explanation..

30. How can a pig acquire an infection?

(a) By eating human faeces _

(b) Does not know _

(c) any other explanation ....

31. What would you do if you discovered your pig had *Cysticecus cellulosae*?

(a) Seek veterinary advice

(b) Use traditional medicine (mention) ....

(c) the respondent does not know _

(d) Any other explanation ....

Appendix 3: The questionnaire for group discussion [Pig farmers, Pubic Health Workers and Butchers] Mgeta Division

Date ____________

1.Village______________ Division:____________

Group Composition and Description

Name	Age	Sex	Occupation	Experience	Ethnicity	Education	Family size/ Land size	No. pigs
1								
2.								
3.								
4.								
5.								
6.								
7.								
8								
9.								
10.								

Questions:

1. Have ever seen pork with this kind of lesions? (With a presentation of clear picture of cyst infected pork Fig. 5, 6 and 7) (YES_ , NO_). If yes :-

(a) In which Village? ....

WHEN?

(b) From which household did the pig(s) come from?..............................

(c) Is the pork always inspected at home (YES____, NO.____)................

(d) What did the farmer/pig trader/butcher did with the pork?

(Sold it_, Ate it _Was condemned and buried ___) Other (please specify)

2. What do you think this is?.(They don't know _______, they know ________)

3. How can a pig acquire such an infection?

(a) By eating human faeces __

(b) By eating pigs faeces__

(c) By eating garbage__

(d) They don't know__

(e) Any other explanation ____________________

4. What pigs are more likely to acquires this infection/problem?

(a) Those raised indoors__

(b) Those raised under free-range system __

(c) Those, which are, tethered all day__

(d) Those, which are, tethered part of the day __

(e) Any other explanation _________________

5. Which of the above mentioned system is mostly practised in your Village ?

(a) Indoors raring __

(b) Free-range system___

(c) Tethering__

(d) Other ___

6. Why do farmers put their pigs under total confinement?

To avoid destruction of other peoples crops___

To avoid being infected by worms___

Confined pigs grow faster___

Forced by village bylaws___

Any other explanation___

7. What materials do most farmers use to construct pig ties?

Timber off cuts__

Sisal poles___

Tree poles___

"bamboo poles"___

Other Materials___

8. How much does it cost to make an average pig tie from locally available materials:-

Labour costs in Tshs __

Labour in terms of man hours__

Material costs in Tshs__

9. Of what quality are these pig ties?:-

(a) Pigs of all sizes/age categories can not escape____

(b) Only weaners and younger piglets can escape_____

(c) In some even adult pigs can escape____

10. In what villages/wards are pigs :-

(a) Under free range/roaming__

(b) Pigs are in pig ties but even adult pigs can escape__

(c) Pigs of all age categories/sizes can't escape__

11. Did your ever had a government sponsored sanitation project in your village/ward? (YES__, NO.__). If yes:-

(a) What was it about?.

(i) Construction and use of proper latrines___

(ii) Boiling of drinking water to control Cholera__

(iii) Washing of hands after defecation and before eating to control cholera___

(iv) Washing of fruits and salad before consumption__

(v) Importance of keeping water intake clean from faecal contamination__

(b) How was it implemented ?

(i) By education and sensitisation__

(ii) Enactment of village bylaws and their enforcement__

(iii) After education and sensitisation people just adopted the techniques _

(c) What were the successes and failures of the project?

Successes	Failures

12. What were the reasons for establishing Village Public Health Committee?

13. What are the mandates of the committee?.

14. When was it established for the first times (Year....................)

15. What are its successes and failures ?

16. Do farmers in your area do home slaughters? (Yes. ___, No. __)

17. If yes do they call the meat inspectors to inspect the pork? (Yes. __. No. __)

18. If yes what percentage of home slaughters you think pork is inspected? [Estimate]:

(a) 100%__

(b) 75%__

(c) 50%__

(d) 25%__

(e) 0%__

19. For what reasons pork was not inspected?.(Check all that apply & rank them)

(a) Lack of transport___.

(b) Inspection fee is very high thus, farmers can't afford __

(c) Shortage of meat inspectors/public Health Workers? __

(d) Difficult terrain__

(e) Vast areas to cover__

Appendix 4: Questionnaire for group discussions [Meat Inspectors/Agricultural Workers/Medical Personnel]

1. What problems have you encountered as far as pig management is concerned? (Rank them)

Disease/Problem	**Death**	**Full Recovery**	**Recover & Poor Performer**
Cysticercosis			
Lameness			
Fractures			
Abscesses			
Abortion			
Dystocia			
Death during farrowing			
Infertility			
Cannibalism (piglets)			
Mange/Lice/Ticks			
Worms			
Food shortage			
Pneumonia			
Diarrhoea			
Inbreeding e.g. lack of eyes & ears			

2.What are the two most common causes adult and piglet deaths in your swineherd?

(a) Adult: 1...........................2.............................

(b) Piglets: 1.........................2..............................

3. How many slaughter slabs do you have in your area? _____

4. On average how many carcasses per months do you inspect in the all the slabs?___

5. Do farmers in your area do home slaughters? (Yes. ___, No. __)

6. If yes do they call you to inspect the pork? (Yes. __, No. __)

7. If yes what percentage of home slaughters you are called to inspect?:

(a) 100%__

(b) 75%__

(c) 50%__

(d) 25%__

(e) 0%__

8. If you're not asked to inspect to pork why is that?.(Check all that apply & rank them)

(a) Lack of transport___,

(b) Inspection fee is very high thus, farmers can't afford __

(c) Shortage of meat inspectors/public Health Workers? __

(d) Difficult terrain__

(e) Vast areas to cover__

9. Do pi traders export pigs to Dar es Salaam city and Morogoro town from your area?

10. If yes what is the monthly average export? . (Get records where possible).

11.Have you ever seen pork of this kind ?(With a presentation of clear picture of cyst infected [Fig. 5. 6 and 7] (Yes. _ . No. _). If yes :-

(a) In which Village? ....

(b) From which household did the pig(s) came from?...........................

(c) Is the pork always inspected (Yes.____. No.____)...........................

(d) What did the farmer/pig trader/butcher did with the pork?

(Sold it_. Ate it _Was condemned and buried ___)

12. What do you think this is?.(They don't know ________. They know _________)

13. How can a pig acquire such an infection?

(a) By eating human faeces __

(b) They don't know__

(c) Any other explanation ___

14. Which pigs are more likely to acquire this infection/problem?

(a) Those raised indoors__

(b) Those raised under free-range system __

(c) Those. which are tethered__

(d) Any other explanation___

15.Which of the above mentioned system is mostly practised in your area?

(a) Indoors-raring __

(b) Free-range system___

(c) Tethering__

16. Why do farmers put their pigs under total confinement?

(a) To avoid destruction of other peoples crops___

(b) To avoid being infected by worms___

(c) Confined pigs grow faster___

(d) Forced by village bylaws___

(f) Any other explanation___

17. Of what quality are these pig ties?:-

(a) Pigs of all sizes/age categories cannot escape____

(b) Only weaners and younger piglets can escape_____

(c) In some even adult pigs can escape____

18. In what villages/wards are pigs :-

(a) Under free range/roaming__

(b) Pigs are in pig ties but even adult pigs can escape__

(b) Pigs of all age categories/sizes can't escape__

19. Did your ever had a government/donor sponsored sanitation project in your village/ward?(Yes__, No.__). If yes:-

(a) What was it about?.

(i) Construction and use of proper latrines___

(ii) Boiling of drinking water to control Cholera__

(iii) Washing of hands after defecation and before eating to control cholera__

(iv) Washing of fruits and salad before consumption__

(v) Importance of keeping water intake clean from faecal contamination__

(b) How was it implemented?

(i) By education and sensitisation__

(ii) Enactment of village bylaws and their enforcement__

(iii) After education and sensitisation people just adopted the techniques _

(c) What were the successes and failures of the project?

Successes	Failures

20. Do you have a village Health Committee? (Yes. ___. No.__) If yes:

(a) What were the reasons for establishing Village Health Committee?

(b) What are the mandates of the committee?.

(c) When was it established for the first times (Year....................)

(d) What are its successes and failures?

Successes	Failures

Appendix 5:The questionnaire for Mgeta Division on *T.solium* taeniosis/cysticercosis survey interviews with pig raisers at household level

Number of pigs positive by tongue examination: _____out of ____pigs examined

Date ________.

1.Village_______ Sub-village_______ 10 Cell Leader_________Household Number__________.

HOUSEHOLD DESCRIPTION (A PERSON TAKING CARE OF PIGS)

2.Main income_____ _________

3.Ethnic background_____________

Respondent:

4.Name _________ _________

5.Age ___________________

6.Sex ___________________.

7.Position in the household___________

8.Education level _______________.

9.Occupation________________.

10.Experience in pig management (years)______.

11.Other farm activities or out of farm activities towards family income (mention).

PIG MANAGEMENT

12. How many pigs do you currently have in each of the following categories?

(a) Breeders________

(b) Piglets _________.

(c) Fattener_______

(d) Total

13. How many pigs did you have **ONE MONTH AGO** in each of the following categories?

(a) Breeders _ ______

(b) Piglets _________.

(c) Fattener__ ____

(d) Total___ _ ______

14. Have you ever-bought piglets outside your own farm? (YES_ , NO__)

15. If "Yes". (a) Where? ________

(b) How often? _______________

16. What is the aim of keeping pigs?____________..

For sale at (a) Local market _

(b) Market in another village_

(c) Pig traders _

Where do the pig traders sell the pigs?___________________

(d) For home consumption________________________

(e)Any other _____________________________.

How many pigs do you sell per year?

Where are they sold?

Trader to go to big City What age? What weight? How much does it pay?

Village What age? What weight? How much does it pay?

Other What age? What weight? How much does it pay?

17. Which system do you use to feed your pigs?

(a) Indoor_

(b) Free-range_

(c) Tethering_ Is the pig ever freed to roam during part of the day or during certain seasons? If yes, when exactly and for how long?

(d) Fencing by timber off cuts; Is the pig ever freed to roam during part of the day or during certain seasons? If yes, when exactly and for how long?

Do the pigs or piglets ever escape from the fence? (YES__; NO__)

(e) What is the fence quality? Good_, Medium_, Bad_ (If the piglets can escape).

Other remarks______.

18. What do you feed your pigs ?

(a) Pasture_

(b) Other feeds (mention) _______________

19. What problems have you encountered as far as pig management is concerned ? (Rank them) *Cysticercus cellulosae* , other diseases (specify)_, No problems_. Other problems (mention)____________.

POSSIBLE TRANSMISSION FACTORS

20. Do you (any member in the family) consume pork? (YES__, NO.__)

How often? (Any particular occasion – feast?)

Where do the pigs you eat come from?

21. If "Yes", in what form?

(a) Boiled _

(b) Fried _

(c) Barbecue_

(d) Raw _

(e) Any other (Mention) ______________

22. Have ever slaughtered a pig at home? (YES__, NO.__)

23. If "Yes", how did you know whether or not it was fit for human consumption?

(a) An official meat inspector inspected the meat __

(b) Meat was not inspected__

24. Presence and use of latrine to be assessed by direct observation

(a) Present and used __

(b) Present but not used __

(c) Absent__

AWARENESS OF TAENIASIS AND/OR CYSTICERCOSIS

25. Have you ever heard of tapeworm infection in human? (YES_, NO_) (If "No" , go to question 29)

26. Have you heard of anyone said to have tapeworm infection in the village? (YES_, NO _)

27. How can people acquire tapeworm infection?

(a) By consuming raw or inadequately cooked pork _

(b) By consuming raw or inadequately cooked beef _

(c) By consuming raw or inadequately cooked chicken_

(d) By consuming raw or undercooked vegetables_

(e) By lack of washing hands_

(f) The respondent does not know_

(d) Any other explanation____________________________

28. Can you mention any obvious signs of tapeworms in humans?

(a) Expulsion of tapeworm segments (supported by showing segments and round worms specimens) in faeces _

(b) Presence of skin nodules _

(c) Diarrhoea

(d) Coughing

(e) The respondent does not know _

(f) Any other explanation________________.

29. What should people do who have this infection ?

(a) Go to hospital _

(b) Go to the dispensary

(c) Use traditional medicine (mention)____________.

(d) Do nothing _

30. Have you heard of nay one said or complaining to have epilepsy in the village?

(YES__, NO.__) If "Yes". approximately how many?______________

Do you regard it as major problem in your village? (YES_. NO._)

31. Have ever seen or heard of white nodules in pig's carcasses ? (YES__. NO.__)

(a) Presence of nodules under the tongue _

(b) Can not recognize _

(c) Any other explanation______________________

32. What would you do if you discovered your pig had cysts under the tongue?

(a) Seek veterinary advice

(b) Use traditional medicine (mention) _______________.

(c) The respondent does not know _

(d) Any other explanation ___________________.

Appendix 6: Reported cases and mortalities of cholera and bacillary dysentery, Morogoro Rural District, Morogoro Regional Hospital, Tanzania.

Year	Cholera			Bacillary Dysentery		
	Cases	Deaths	Mortality [%]	Cases	Deaths	Mortality [%]
1980	3	0	0	0	0	0
1981	0	0	0	0	0	0
1982	278	38	13.7	572	12	2.1
1983	584	54	9.3	584	7	1.2
1984	122	9	7.4	0	0	0
1985	156	19	12.2	0	0	0
1986	43	8	18.6	723	60	8.3
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	78	0	0
1990	0	0	0	28	1	3.4
1991	0	0	0	0	0	0
1992	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	28	2	7.1
1996	28	1	3.6	6	0	0

Note: Data presented here are previous years outbreaks e.g. 1989 recorded outbreak of dysentery occurred in 1988.