EFFECTIVENESS OF HEALTH EDUCATION INTERVENTION IN REDUCING THE INCIDENCE RATE OF PORCINE CYSTICERCOSIS IN MBULU DISTRICT, NORTHERN TANZANIA

BY

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ABSTRACT

A study was conducted to investigate the effectiveness of health and pig management education intervention in reducing the incidence rate of porcine cysticercosis caused by larvae of *Taenia solium* in Mbulu District, northern Tanzania. A random sample of 827 pig-keeping households was selected from 42 randomly selected villages to participate in the study, which lasted for about 2 years. Baseline data were collected on the prevalence of porcine cysticercosis based on lingual examination of live pigs; history of human taeniosis, and related knowledge and practices based on questionnaire interviews and observations. The health education intervention, developed with community participation, was allocated to 21 of the 42 study villages by randomisation. A note-based analysis was used to analyse qualitative data, while quantitative data were analysed using Stata 8.0 for Windows. Knowledge of smallholder pig farmers on how a pig acquires cysticercosis and how to prevent it, improved significantly in both the intervention and control groups 6 months after the intervention, showing a significant effect attributable to the intervention [improvement by the intervention: 27.4% (95% CI: 7.0, 48.0) and 37.7% (95% CI: 13.0, 62.0), respectively]. The effect of the intervention 10-12 months post-intervention was not significant [improvement by the intervention: 0.7% (95% CI: -11.0, 12.0) and 1.1% (95% CI: -13.0, 15.0). There were no significant improvements in observed practices by the intervention throughout the study period. The incidence rate of porcine cysticercosis as measured by antigen ELISA in tracer piglets in the control group was about 1.6 that in the intervention group (95% CI: 0.928, 2.707). The effectiveness of the education intervention in reducing the incidence rate of porcine cysticercosis was 35.9%. Educating pig farmers in Mbulu District on how to control porcine cysticercosis would have a significant financial benefit to them [NPV: TZS 4 034 030.4 (95% CI: 3 719 614.0, 4 368 169.0); IRR: 370%]. Health education would have an important contribution to the control of ***Taenia solium*** transmission, if implemented in Mbulu District. Demonstration studies are needed in order to educate smallholder pig farmers on how to improve the traditional pig rearing system using locally available resources.

DECLARATION

I, HELENA AMINIEL NGOWI, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and has neither been submitted nor concurrently being submitted for a degree award in any other institution.

Signature ....

Date 13/11/2005 ....

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DEDICATION

This work is dedicated to my beloved husband Robinson Mdegela, my daughter Margreth Lightness, my parents, and relatives for their patience, motivation, and prayers during my absence for my PhD studies.

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LIST OF ABBREVIATIONS AND SYMBOLS

Ag-ELISA	Antigen enzyme-linked immunosorbent assay
C	Control
CI	Confidence Interval
CNS	Central nervous system
CT	Computerised tomography
CWGESA	Cysticercosis Working Group in Eastern and Southern Africa
DANIDA	Danish International Development Agency
DBL	Danish Bilharziasis Laboratory
DevCom	Development Communications
DVD	Digital Versatile Disc
EITB	Enzyme-linked immunoelectrotransfer blot
ELISA	Enzyme-linked immunosorbent assay
ENRECA	Enhancement of Research Capacity
FAO	Food and Agriculture Organisation
FGD	Focus group discussion
H_2SO_4	Sulphuric acid
HT	Human taeniosis
ICTs	Information and Communication Technologies
IgA	Immunogobulin A
IgE	Immunoglobulin E

IgG	Immunoglobulin G
IgM	Immunoglobulin M
ILRI	International Livestock Research Institute
IND	In-depth interview
IRR	Internal rate of return
ITFDE	International Task Force for Disease Eradication
LFEO	Livestock field extension officer
MOH	Ministry of Health
MRI	Magnetic Resonance Imaging
Na_2CO_3	Sodium carbonate
$NaHCO_3$	Sodium bi-carbonate
NBCS	New borne calf serum
NIMR	National Institute for Medical Research
NPV	Net present value
O	Observed
oPD	o-Phenylenediamine Dihydrochloride
OUHSC	Oklahoma University of Health Sciences
PBS	Phosphate buffered saline
PCC	Porcine cysticercosis
PV	Present value
R	Reported
r	Real discount rate

RMA	Rural medical assistant
RR	Rate ratio
SUA	Sokoine University of Agriculture
t	Time period from the present date
T	Intervention
TCA	Tri-choloroacetic acid
TZS	Tanzanian shilling
USA	United States of America
WHO	World Health Organization
X_t	Amount of money in Year t

CHAPTER ONE

INTRODUCTION

1.1. Background information

Porcine cysticercosis is an infection of pigs caused by larvae of *Taenia solium*, a zoonotic tapeworm that is transmitted between humans and pigs. The human being is the natural definitive host carrying the adult parasite in the small intestine, a condition known as taeniosis. The pig is the most common natural intermediate host harbouring the larval form of the parasite in muscles and certain organs. Infection by larvae of *T. solium* is referred to as cysticercosis. Pigs and human beings can acquire cysticercosis by ingesting eggs of *T. solium* through foodstuffs or water that have been contaminated with faeces from a tapeworm carrier or directly with faeces found in the environment. Human beings get taeniosis by ingesting larvae of the tapeworm mainly by eating raw or undercooked infected pork. It has been reported recently that dogs can be an important source of taeniosis in humans in areas where dog meat is consumed by human beings (Okolo, 1986; Ito *et al.*, 2002). Based on epidemiological studies conducted elsewhere, factors such as lack of knowledge of people on the mode of transmission of porcine cysticercosis, lack of latrines, and free ranging pigs have been reported to enhance the transmission of *T. solium* (Sarti *et al.*, 1992; Onah and Chiejina, 1995; Ngowi *et al.*, 2004a). However, these factors cannot be generalised in all community settings (Ngowi *et al.*, 2004a).

Cysticercosis has been reported to occur mostly in developing countries of Latin America, Asia, and Africa (Sarti *et al.*, 1992; Schantz *et al.*, 1992). However, with tourism and increasing migration of people harbouring tapeworms, human cysticercosis is now transmitted worldwide and it is considered as an emerging disease in the United States of America (Schantz *et al.*, 1998). Human cysticercosis has been reported in non-pork consuming communities including Islamic communities in Kashmir and Saudi Arabia (Khan *et al.*, 2000; Al Shahrani *et al.*, 2003), an Orthodox Jewish community in the USA (Schantz *et al.*, 1992), and in some vegetarians in India (Rajshekhar *et al.*, 2003).

In Tanzania, only a few studies to estimate the prevalence of porcine cysticercosis have been conducted in some areas, in the northern, southern, and central regions, where smallholder pig production is popular (Ngowi *et al.*, 2004a). Mbulu District in the northern highlands of Tanzania has so far been shown to have the highest prevalence of porcine cysticercosis in the country and possibly in eastern and southern Africa. A farm-based study conducted in 1998 estimated an overall prevalence of 17.4% in 770 live pigs examined by lingual examination in 21 villages (Ngowi *et al.*, 2004a). The prevalence in individual villages ranged from 3.2-46.7%. The true prevalence of the infection in this area could be twice that detected by lingual examination method due to the low sensitivity of the latter method (Phiri *et al.*, 2003; Dorny *et al.*, 2004). Factors that were likely to facilitate the transmission of porcine cysticercosis in the area were lack of latrines, presence of free ranging pigs, and ignorance of people concerning the parasite and its mode of transmission.

Taenia solium is of particular importance since the larval infection in humans may result in serious and sometimes fatal conditions, particularly when the human central nervous system is infected. The most commonly reported neurological manifestations of neurocysticercosis are seizures. Neurocysticercosis accounts for 30-50% of the cases of late-onset epilepsy in developing countries (Medina *et al.*, 1990; Torres, 1992; Engels *et al.*, 2003). Studies conducted in the Republic of South Africa demonstrated that juvenile cases of neurocysticercosis are also common (Pammenter *et al.*, 1987; Shasha and Pammenter, 1991; Foyaca-Sibat, 2002). Stigmatisation and ostracism of people with epilepsy in many endemic countries is an important socio-economic problem since many epileptic individuals are excluded from educational and productive fields (Diop *et al.*, 2003).

In addition to the public health impact, *T. solium* causes economic losses due to condemnation or reduced value of infected pig carcasses, costs of diagnosis, treatment and disability of neurocysticercotic patients. A very conservative and rough economic estimate indicates that the annual losses due to porcine cysticercosis in 10 West and Central African countries amount to about 25 million Euros (Zoli *et al.*, 2003). A recent study conducted by the International Livestock Research Institute (ILRI) found that porcine cysticercosis was among the top 10 disease conditions that have greater impact on the poor globally because of its impact on livestock productivity and marketing, as well as public health (Perry *et al.*, 2002).

Taenia solium is listed among six disease agents that were declared by the International Task Force for Disease Eradication (ITFDE) to be potential candidates for eradication (Schantz, 1993). This was based on its simple life cycle and the availability of effective tools for surveillance to identify foci of transmission and for mass treatment of humans to eliminate such foci. The ITFDE recommended that the eradication of *T. solium* should be demonstrated in a sizeable geographical area. However, elimination of *T. solium* infections was only achieved in Europe and North America (Gonzalez *et al.*, 2003). Significant improvements in sanitary conditions and developing functional pig slaughterhouse control systems were basically responsible for the control of *T. solium* in these areas. However, these control strategies are not suitable for most developing countries because they need substantial financial investments.

It is thought that any disease eradication programme that considers the economic factor is more likely to be effective and sustainable (Gilman *et al.*, 1999). To date different strategies for controlling *T. solium* have been attempted in some endemic countries. These control strategies include treatment of infected human carriers, treatment of infected pigs, vaccination of pigs, and public health education (Keilbach *et al.*, 1989; Sarti *et al.*, 1997; Gonzalez *et al.*, 1997; Lightowlers, 1999).

Despite the presence of effective drugs for treatment of cysticercosis and taeniosis, some of the previous interventions have been reported to be unsuccessful due to lack of community involvement leading to poor compliance for implementing the interventions (Keilbach *et al.*, 1989). As opposed to the traditional health educational approach whereby an outsider designs, plans, implements, and evaluates the intervention, health education with community participation has been reported to be valuable in reducing the prevalence of porcine cysticercosis (Sarti *et al.*, 1997). To encourage active participation of villagers in community-based programmes, a flexible approach to the process of communication with people about parasite control is needed. The approach should allow both community goals and programme goals to be identified and addressed (Lloyd *et al.*, 1994).

One way to stimulate community participation is by decentralising the design and production of educational materials to include the ecological, social, and cultural characteristics of the community where the programme is being implemented (Lloyd *et al.*, 1994). The resulting materials should have greater impact because they are (a) easily understood using local concepts and terminology, and (b) relevant by considering local conditions and perceptions. It is important to assess the economic viability of the intervention in order to see whether the benefits of the programme outweigh the full costs of the disease. In addition, since most of intervention studies are donor funded, economic analysis would also help to assess the community's ability to sustain the intervention after the project has ended.

Previous studies used the prevalence of porcine cysticercosis before and after an intervention, to assess change in the infection frequency and hence estimate the effectiveness of the intervention. However, the pig population in many endemic areas is very dynamic. Some pigs are sold or exchanged between and within villages especially after weaning, while some are fattened quickly and sold to butchers at lower prices, when they are discovered to be infected with porcine cysticercosis. It is also common, especially in rural areas that some pigs die at different times due to presence of competing risks (e.g. African Swine Fever). Movement of infected pigs from a village removes them from the prevalence pool in that particular village and consequently decreases the prevalence in that village even without any intervention. Measuring the incidence rate of the infection would better reflect the rapidity with which the infection occurs by taking into account the animals moving into and out of the villages. This would enable better comparison of the frequency of the infection between different villages or periods.

None of the previous studies had used a control group when evaluating the effectiveness of the health education intervention in controlling *T. solium* (Keilbach *et al.*, 1989; Sarti *et al.*, 1997). In the absence of a control group, it is not appropriate to attribute any effect on the disease or other outcome variables to the effect of the intervention. This is because in such a case it is not possible to rule out the effect of other factors (including time) on the outcome variables (Glanz *et al.*, 2002; Carabin *et al.*, 1999). The present community-based randomised trial investigated the effectiveness of health education intervention in reducing the incidence rate (porcine cysticercosis in Mbulu District, Tanzania.

1.2. Overall objective

The overall objective of this study was to evaluate the effectiveness of heal education intervention in reducing the incidence rate of porcine cysticercosis safeguard the public against *Taenia solium* infections.

1.3. Specific objectives

(a) To assess human knowledge, perceptions, and practices related to *T. solium* infections in Mbulu District;

(b) To estimate the incidence rate of porcine cysticercosis in the area;

(c) To evaluate the effectiveness of produced health educational materials in improving human knowledge and practices related to the transmission of *T. solium* in the area;

(d) To evaluate the effectiveness of the health educational materials in reducing the incidence rate of porcine cysticercosis;

(e) To carry out a cost-benefit analysis of the health education intervention in the area.

CHAPTER TWO

LITERATURE REVIEW

2.1. Morphology and biology of *Taenia solium*

Taenia solium belongs to the cestode family Taeniidae, which comprises two genera, *Taenia* and *Echinococcus*. Currently the genus *Taenia* consists of more than 30 species (Loos-Frank, 2000). However, only two species are known to infect human beings in their adult stages. These are *T. solium*, *T. saginata saginata* and *T. saginata asiatica* (Eom and Rim, 1993; McManus and Bowles, 1994; Fan *et al.*, 1995; Loos-Frank, 2000).

The adult *T. solium* inhabits the upper part of the small intestine of human and measures between 1.8 and 4.8 m long (Gracey, 1986). This tapeworm is opaque white and has a globular head or scolex that measures about 937 μm in diameter (Loos-Frank, 2000). The scolex is the attachment organ containing four suckers and a rostellum with long and short hooks arranged in two rows of 22 to 36 hooks each (Loos-Frank, 2000). The long and short hooks are arranged alternately around the rostellum, with the long hooks measuring 139 to 200 μm and the short ones measuring 90 to 159 μm (Loos-Frank, 2000). The head is followed by a short neck from which segments or proglottids proliferate forming a long chain known as strobila. One tapeworm can have 800-900 proglottids (Gracey, 1986). The proglottids gradually increase in size and age so that the rear ones are broader, longer, and mature than the front ones (Flisser *et al.*, 2004a). A mature proglottid is hermaphroditic with 375-575 testes (Loos-Frank, 2000). These testes are connected among them by fine sperm ductules that anastomose to form the sperm duct or vas deferens. The vas deferens ends in the genital pore or atrium forming the cirrus, which is a highly muscular body located inside a sac or pouch (Flisser *et al.*, 2004a). The genital atrium is the only marginal external feature and is irregularly distributed on either side of proglottids. The female reproductive system is mostly located in the posterior portion of the proglottid and it consists of vagina, a tube flowing from the genital atrium to the oviduct. Connected to the oviduct are the ootype, Mehlis's glands, the vitellarium, and one ovary. After fertilization the ootype transforms into the uterus that is located centrally and with lateral branches. A gravid uterus of *T. solium* has 7-16 tree-like lateral branches on each side (Loos-Frank, 2000).

Embryonated eggs of *T. solium* are typical taeniid eggs. The eggs are brown and measure 26-34 µm in diameter. They have a double-walled membrane with radiating striae (Schantz, 1996). The six-hooked embryo or onchosphere is usually visible within the egg. The larval form or metacestode of *T. solium* is known as cysticercus. *T. solium* cysticerci are distinctly oval, measuring 20 x 10 mm when mature (Loos-Frank, 2000). Each cysticercus of *T. solium* has a single sac containing one invaginated protoscolex. The metacestode appears like a white vesicle and the invaginated protoscolex is visible from the outside.

Taenia solium should be differentiated from *T. saginata saginata* and *T. saginata asiatica* due to morphological resemblances and possible co-occurrence of the three species in the same locality or individual. Scolices and gravid proglottids are the most important features for the morphological differentiation of these three tapeworms (Flisser *et al.*, 2004a). *T. solium* has a prominent scolex and a protruded rostellum with double row of hooks. *T. saginata saginata* has a retracted rostellum with no hooks, and *T. saginata asiatica* has a rostellum with rudimentary hooklets (Eom and Rim, 1993; Flisser *et al.*, 2004a). As opposed to *T. solium*, each mature proglottid of *T. saginata saginata* and *T. saginata asiatica* has a vaginal sphincter muscle, testes are not confluent posterior to the vitellarium, and the cirrus pouch does not extend up to the longitudinal excretory vessels (Eom and Rim, 1993; Loos-Frank, 2000). The ovary of *T. solium* has three lobes while that of *T. saginata saginata* and *T. saginata asiatica* have two lobes (Eom and Rim, 1993; Loos-Frank, 2000). Externally, only gravid proglottids of *T. saginata asiatica* end in a protuberance on the posterior side (Eom and Rim, 1993).

Metacestodes of the three *Taenia* worms can be differentiated based on their morphological differences of their protoscolices that resemble that of their corresponding adult tapeworm scolices, and on the differences in their predilection sites in their natural intermediate hosts. The metacestodes of *T. solium* are normally found in the skeletal muscles and brain of the intermediate hosts. In humans, the eye can also be infected. Metacestodes of *T. saginata saginata* are mostly encysted in the skeletal muscles of bovine. In heavy infections, they can be seen in liver, lung, kidney and abdominal fat. *T. saginata asiatica* metacestodes are found in pig and cattle liver surfaces and parenchyma. In pigs, also omentum and rarely lungs and serosa of colon can be infected by *T. saginata asiatica* (Eom and Rim, 1993; Loos-Frank, 2000). The outer wall of the metacestodes of *T. saginata asiatica* has wart-like formations (Eom and Rim, 1993). Eggs of all taeniid tapeworms are similar and cannot be distinguished morphologically.

2.2. Epidemiology of *Taenia solium*

2.2.1. Frequency and distribution of *Taenia solium* cysticercosis/taeniosis

Taenia solium has a cosmopolitan distribution (Loos-Frank, 2000). Human cysticercosis caused by this parasite is now a global problem because of tourism and increasing migration of people all over the world (Schantz *et al.*, 1998). These movements increase the chances of transmitting *T. solium*. For example, it is estimated that movement of people in both directions across the USA-Mexico border exceeds 200 million persons per year (Flisser *et al.*, 2004a), and human cysticercosis is now emerging as a problem in the USA (Schantz *et al.*, 1998). On the other hand, porcine cysticercosis due to *T. solium* occurs most often in developing countries of Latin America, Asia, and Africa (Sarti *et al.*, 1992). This focal distribution is mainly associated with poor socio-economic conditions in these countries, which in turn increase the prevalence of infection transmission factors such as poor hygiene, poor meat inspection, and poor pig rearing practices.

Because of lack of standardization of diagnostic techniques for human and porcine *T. solium* infections, it is difficult to have a fair comparison of the prevalence of these infections between countries or studies (Dorny *et al.*, 2003). However, the epidemiology of *T. solium* infections has especially been thoroughly studied in Latin America with many countries including Brazil, Colombia, Mexico, Peru, and Guatemala reported to be endemic (Flisser *et al.*, 2003). Studies conducted in Mexico estimated an overall prevalence of 1% of human taeniosis based on coproantigen enzyme-linked immunosorbent assay (ELISA) or stool microscopy (Flisser *et al.*, 2003). Human cysticercosis in Mexico has been estimated to range from 3.7-12.2% in different villages based on ELISA or western blot. Porcine cysticercosis in this area was reported to range from 1-24% by tongue examination and 4-35% by ELISA or western blot (Flisser *et al.*, 2003).

In Peru, the prevalence of human taeniosis is estimated to be 3% of the general population using stool microscopy, while human cysticercosis ranges from 5-24% using ELISA or western blot (Flisser *et al.*, 2003). Studies of porcine cysticercosis in Peru have reported prevalence of 13-61% using ELISA or western blot. In Asia, seroprevalence studies indicate high proportions of human exposure to *T. solium* in several countries including Vietnam, China, Korea, India, and Indonesia (Rajshekhar *et al.*, 2003). Prevalence of human taeniosis as determined by stool examination of ova is reported to range from 0.1-6% in these countries (Rajshekhar *et al.*, 2003). Human cysticercosis is reported to range from 1.7-13% while porcine cysticercosis ranges from 0.02-40% based on various methods of detection (Rajshekhar *et al.*, 2003).

In Africa, *T. solium* infections have been reported in several countries including Nigeria, Bénin, Cameroon, South Africa, Tanzania, Kenya, Uganda, Zimbabwe, Zambia, Mozambique, Burundi, and Madagascar (Phiri *et al.*, 2003; Zoli *et al.*, 2003; Ngowi *et al.*, 2004a). Most studies in Africa have examined the prevalence of cysticercosis in people manifesting neurological symptoms. In these studies, prevalence of human cysticercosis ranging from 10% to 41% has been reported in some countries in the eastern and southern Africa based on various serological methods for detecting parasite antigens or host antibodies against the parasite (Mafojane *et al.*, 2003). In Burundi, an overall prevalence of 2.8% has been reported in the general population based on serology (Mafojane *et al.*, 2003). Prevalence of porcine cysticercosis has been reported to range from 5-18% by lingual examination and 15-57% by antibody- or antigen-ELISA (Phiri *et al.*, 2003).

In Tanzania, there is scanty information on the prevalence of human taeniosis and cysticercosis. A hospital based study conducted in Mbulu District in the northern highlands of Tanzania estimated an overall annual prevalence of 1.2% of human taeniosis in patients reporting for stool examination in Mbulu District hospital (Ngowi, 1999). These estimates are on the lower side considering that stool microscopy is less sensitive in detecting infected individuals. The overall prevalence of porcine cysticercosis measured by lingual examination was estimated to be 17.4% (95% CI: 12.5 - 22.3) with important clustering by village (range of 3.2-36.7% in different villages) (Ngowi *et al.*, 2004a). These estimates also are on the lower side because the lingual examination method has low sensitivity (Gonzalez *et al.*, 1990; Onah and Chiejina, 1995; Dorny *et al.*, 2004). To date, there are no published reports of human cysticercosis or neurocysticercosis in Tanzania.

2.2.2. Risk factors for the transmission of *Taenia solium*

The occurrence of *T. solium* is associated with certain risk factors, but there is no reliable information on the statistical or biological association of these factors and the prevalence of *T. solium* infections. It is thought that lack of knowledge of people on how *T. solium* is transmitted, facilitates the transmission of human taeniosis as well as human and porcine cysticercosis. This can be due to the fact that people lacking this knowledge are likely to expose themselves or their pigs to sources of *T. solium* infections, such as contaminated foodstuffs or water. For example, in South Africa, certain traditional healers have been reported to use *Taenia* segment contents as a treatment in cases of severe intestinal tapeworm infections (Kriel and Joubert, 1996). Some risk factors or their interactions are specific for the occurrence of porcine cysticercosis, human taeniosis, or human cysticercosis (including neurocysticercosis).

Both the absence and presence of toilets in households have been reported as risk factors for the occurrence of porcine cysticercosis. For example, one study in Mexico found a high prevalence of porcine cysticercosis when a latrine was present in the house (Sarti *et al.*, 1992), while a study in Tanzania found a high prevalence of porcine cysticercosis when a latrine was absent (Ngowi *et al.*, 2004a). The major difference in the two studies is that, the latrines in the Mexico study were constructed indoors and strategically to allow pigs access human faecal materials. On the other hand, the pit latrines in the Tanzania study were constructed outdoors and there was no information on whether there was any deliberate feeding of pigs with human excreta. This underlines important regional differences in the use of latrines and that one should be careful in generalising risk factors for *T. solium* from one culture to another.

Free ranging of pigs is likely to facilitate the transmission of porcine cysticercosis especially in areas where latrines are not used or are poorly constructed. Letting pigs roam freely increases their chances to access human faeces that are randomly disposed in the environment, mostly when the latrines are not available or are in poor condition.

The presence of a tapeworm carrier in a household can facilitate the occurrence of both porcine and human cysticercosis, particularly when personal hygiene is not observed. This is because the tapeworm carrier can infect himself/herself through faecal-oral route, or infect other people and pigs when handling their feeds. The presence of a tapeworm carrier in a household has caused the introduction of human cysticercosis in areas that were previously free from the disease, or re-introduction of the parasite in areas where it was previously eradicated. For example, human cysticercosis reported in a non-pork-consuming Orthodox Jewish community in the USA, has been associated with the presence of tapeworm carriers from endemic areas of Latin America, and the infections were attributed to food contamination by the tapeworm carriers (Schantz *et al.*, 1992).

Prevalence of certain cultural practices may facilitate the occurrence of human cysticercosis or taeniosis. For example, the use of *T. solium* contents by some women in South Africa to add to beer as a punishment to their unfaithful husbands or lovers is likely to facilitate the occurrence of human cysticercosis (Mafojane *et al.*, 2003). Eating raw or undercooked pork as preferred by some people is likely to facilitate the occurrence of human taeniosis, especially in areas where meat inspection is absent or poorly practiced.

2.3. Life cycle and mode of transmission of *Taenia solium*

The life cycle of *T. solium* includes the human as the only natural definitive host, harbouring the adult tapeworm, and the pig as the common intermediate host, harbouring the larval stage of the parasite (Soulsby, 1982). Other natural intermediate hosts of the tapeworm include bush pigs, humans, dogs, cats, rats, and monkeys (Gracey, 1986). Humans and the other intermediate hosts of *T. solium* are normally dead-end hosts except in areas where their meat is consumed by people. In these occasions these hosts can contribute to the maintenance of the life cycle of the tapeworm. For example, dogs are thought to be an important source of transmission of human taeniosis in Nigeria and Indonesia (Okolo, 1986; Ito *et al.*, 2002).

2.3.1. Porcine and human cysticercosis

The gravid terminal segments of the adult *T. solium* are normally passed out in the human faeces and each may contain up to 60 000 eggs. The eggs released from these segments form the only free-living stage in the life cycle and are immediately infective for the intermediate host (Harrison and Sewell, 1991). Eggs of *T. solium* are known to survive for more than 6 months in the environment (Soulsby, 1982). After the eggs have been ingested by a suitable intermediate host, the six-hooked hexacanth larvae or oncospheres hatch and they are activated under the influence of gastric and intestinal juices before migrating to the development sites via the lymphatic and blood stream (Harrison and Sewell, 1991).

The common predilection sites for the cysticerci in pigs are the skeletal, cardiac, diaphragmatic and lingual musculature as well as the brain. In the human being, the commonly reported sites of *T. solium* metacestodes are the musculature, subcutaneous tissue, and the brain. However, other organs and tissues such as the eye and spinal cord may be infested. The onchospheres require at least 12 weeks to developing into fully infective cysticerci (Harrison and Sewell, 1991). However, the characteristic bladder form may be identified within two to four weeks. The life span of *T. solium* cysticerci in the living host is not well documented.

2.3.2. Human taeniosis

When a human being ingests a viable metacestode from an infected intermediate host, the protoscolex evaginates in the intestinal tract and attaches to the mucosa of the small intestine. The proglottids develop from the neck of the metacestode and further developments occur to their maturity. The life span of the adult *T. solium* is not well known. Some authors have estimated it to be 20-25 years while others have estimated less than 5 years (Pawlowski and Schultz, 1972; Richards and Schantz, 1985; Allan *et al.*, 1996a; Garcia *et al.*, 2003). A recent study established an experimental model in chinchillas (*Chinchilla laniger*) that allowed the development of an infective adult *T. solium* that was capable of infecting the intermediate host (Maravilla *et al.*, 1998). Proglottids obtained from the chinchilla were introduced orally to a cyst-free pig and developed to cysticerci 12 weeks following the oral infection.

2.4. Clinical signs of *Taenia solium* infections

2.4.1. Porcine cysticercosis and human extra-neurocysticercosis

Porcine cysticercosis is rarely associated with symptoms of any kind (Garcia *et al.*, 2003). Clinical manifestation of human cysticercosis depends on the organ infected.

Subcutaneous cysticercosis is characterized by small, movable, painless nodules that are mostly noticed in the arm or chest (Garcia *et al.*, 2003). After a few months the nodules become swollen, tender, inflamed, and gradually disappear (Dixon and Smithers, 1934). In rare cases, massive parasite burdens in human musculature cause enlargement of the infected organ, such as the limb. Cardiac cysticercosis in humans is thought to be asymptomatic and occurs in about 5% of patients with cysticercosis (Rabiela *et al.*, 1982). In areas endemic for *T. solium*, ophthalmic cysticercosis is the most frequent intra-orbital parasite and occurs in 1-3% of all *T. solium* cysticercosis infections (Rahalkar *et al.*, 2000). Visual disturbance depends on the affected part and the degree of damage. Massive infections in the retro-ocular space affect the optic nerve and may cause proptosis (Wadia *et al.*, 1988; Chandra *et al.*, 2000).

2.4.2. Human neurocysticercosis

Neurocysticercosis, an infection of the central nervous system of human being, is the most common neurological condition caused by *T. solium* (Rahalkar *et al.*, 2000). Normally viable cysticerci elicit few inflammatory changes in the surrounding tissues although some symptoms may be due to massive effect of the parasite or blockage of the cerebrospinal fluid circulation (Garcia *et al.*, 2003). Most symptoms of neurocysticercosis are the direct result of the inflammatory process that accompanies cyst degeneration. The common clinical manifestations of neurocysticercosis are epileptic seizures (Sarti *et al.*, 1992; Schantz *et al.*, 1992).

Depending on the location of the cysticerci in the brain, neurocysticercosis may also manifest with other symptoms such as intra-cranial hypertension, hydrocephalus, stroke, and mild cognitive dysfunction. In children and teenagers, an acute encephalitic presentation can happen and it is more likely in female than male patients (Rangel *et al.*, 1987). The period between initial infection and the onset of symptoms varies and can be up to 5 years (Schantz, 1994).

2.4.3. Human taeniosis

The adult *T. solium* causes only mild inflammation at the site of attachment in the small intestine of human being. Human taeniosis is thus characterised by mild symptoms or not at all (Schantz *et al.*, 1998). Symptoms such as abdominal pain, distension, diarrhoea, and nausea have been attributed to the tapeworm infestation, but, there are no controlled studies that have demonstrated their association (Schantz *et al.*, 1998).

2.5. Diagnosis of *Taenia solium* infections

2.5.1. Porcine cysticercosis

Lingual examination, which involves the visualisation of cysticerci of *T. solium* under the tongue of the pig, has been the traditional method for diagnosing porcine cysticercosis in many endemic countries (Gonzalez *et al.*, 1990; Sarti *et al.*, 1992; Onah and Chiejina, 1995; Ngowi *et al.*, 2004b). The observation can be supplemented with palpation of the nodules. A recent study in South Africa found that illumination of the cysticerci using a powerful source of light could increase the likelihood of observing *T. solium* cysts (Krecek, 2003, personal communication). However, there are no quantitative estimates that have been reported regarding the increase in the sensitivity of the test. In Tanzania, lingual examination method is commonly used by pig traders to select cysticercosis-free pigs from farmers (Ngowi *et al.*, 2004a,b). Being of the lowest cost, easily carried out in the field and requiring no formal skills, its accuracy in detecting porcine cysticercosis and ways of improving it should be examined.

Few studies have reported the accuracy of lingual examination using meat inspection as a standard test (Gonzalez *et al.*, 1990; Onah and Chiejina, 1995). One study in Peru estimated the sensitivity and specificity of lingual examination to be 70% and 100% respectively (Gonzalez *et al.*, 1990). In Nigeria, results of an abattoir survey indicate that the sensitivity and specificity of lingual examination was 41% and 100% respectively (Onah and Chiejina, 1995). The study population and evaluation criteria used in the two studies might have contributed to the observed differences in the sensitivity of the tongue examination method. For the study in Peru, the negative controls were pigs from a non-endemic area that tested negative by meat inspection while the positive controls were pigs from an endemic area that tested positive by meat inspection (Gonzalez *et al.*, 1990). This biased sampling might have increased the sensitivity and specificity of the meat inspection as well as that of lingual examination.

On the other hand, in the Nigeria study all the pigs studied came from an endemic area, with previously unknown disease status (Onah and Chiejina, 1995). This nearly reflects the real situation, and in this situation meat inspection is not a gold standard test since it can fail to detect low grade infections. Evaluation of diagnostic tests for porcine cysticercosis using a Bayesian approach was reported recently (Dorny *et al.*, 2004). This analysis allows the proper estimation of parameters of one or more diagnostic tests even when none of them is a gold standard. Using this approach one study in Zambia estimated the sensitivity and specificity of lingual examination to be 21% (95% CI: 14-26) and 100%, respectively (Dorny *et al.*, 2004). This indicates that while the specificity of the lingual examination can be high, its sensitivity can be low.

There is scant information on the accuracy of post-mortem inspection for porcine cysticercosis. Using the Bayesian analysis, Dorny *et al.* (2004) found that the routine meat inspection based on Zambian standard meat inspection had a sensitivity and specificity of 22.1% (95% CI: 15.0-27.0) and 100%, respectively, in detecting porcine cysticercosis. It is apparent from this study that the lingual and standard meat examination methods have approximately equal accuracy in detecting porcine cysticercosis. This may explain an observation in northern Tanzania whereby it was rare to observe infected pig carcasses at slaughter slabs for most pigs from Mbulu, an endemic area. This could be attributed to the pre-screening excise done by pig traders using lingual examination method before they purchased the pigs from the farmers (Ngowi *et al.*, 2004b).

Porcine cysticercosis can also be detected using serological methods (Dorny *et al.*, 2003). Extensive literature is available regarding the performance of serological assays for porcine cysticercosis, especially those directed to the detection of host antibodies against the parasite, such as complement fixation test, radioimmunoassay, ELISA, and immunoblot. The antigens used in the antibody-detection methods have evolved from crude extracts to highly purified, specific fractions and recombinant antigens of the glycoprotein family, increasing both the sensitivity and specificity of the tests (Dorny *et al.*, 2003). Despite these developments antibody-detection methods are not appropriate for clinical use in individual animals since they may indicate exposure to the parasite rather than presence of viable infection (Dorny *et al.*, 2003). Studies also have shown that maternal antibodies transferred through colostrum may persist for most of the pig's life and therefore limit the use of these techniques in endemic areas (Gonzalez *et al.*, 1999). Antibody detection methods are, however, useful in identifying areas where transmission of the parasite is high and therefore, suggest areas where control measures should be directed. Detection of circulating antigens from *T. solium* cysticerci have been found to be a useful method in identifying pigs with active infections (Dorny *et al.*, 2003). The only known limitation of this method is its inability to distinguish *T. solium* from *Taenia hydatigena* cysticerci, and where the later parasite is highly prevalent the method may be of little use (Dorny *et al.*, 2003). Using the Bayesian analytical approach, Dorny *et al.* (2004) found that the sensitivity and specificity of antigen ELISA in detecting porcine cysticercosis was 86.7% (95% CI: 62.0-98.0) and 94.7% (95% CI: 90.0-99.7), respectively. The sensitivity and specificity of antibody ELISA was found to be 35.8% (95% CI: 26.0-41.0) and 91.7% (95% CI: 85.0-99.0), respectively.

2.5.2. Human cysticercosis

A number of serological techniques are being developed for the detection of circulating host antibodies or parasite antigens in cysticercotic individuals (Tsang *et al.*, 1989; Ito *et al.*, 1998; Dorny *et al.*, 2003). However, the validation of these techniques in human is hindered by the lack of a gold standard. In addition, no study has yet used a Bayesian approach to estimate the sensitivity and specificity of different approaches in the absence of a gold standard. The only gold standard would be pathological confirmation through biopsy or autopsy procedures that have ethical limitations (Carpio *et al.*, 1998).

Previous antibody-detection assays had moderate sensitivities and poor specificity because most used crude antigens (Dorny *et al.*, 2003). However, recent developments have led to the production of highly purified antigens that improved the accuracy of the serodiagnostic tests (Dorny *et al.*, 2003). The most specific test developed is the enzyme-linked immunoelectrotransfer blot (EITB). This is an immunoblot of seven cysticercus glycoproteins, purified by lentil lectin-purified chromatography, which gives about 100% specificity and 70-90% sensitivity (Tsang *et al.*, 1989). However, a sensitivity of 28% has been found in cases with single cyst in the brain (Wilson *et al.*, 1991). Ito *et al.* (1998) prepared a highly species specific antigen from cyst fluid using single-step preparative isoelectric focusing. This assay can be used in pigs as well as humans.

Furthermore, several attempts have been done to produce recombinant antigens that can be used in immunoblot and ELISA (Chung *et al.*, 1999; Sako *et al.*, 2000). These synthetic polypeptides have been reported to have high specificity but lower sensitivity than that of native antigens (Dorny *et al.*, 2003). The drawback of the antibody-detection methods is that they indicate exposure to infection, and therefore the tests can detect maternal-transferred antibodies or presence of antibodies without the viable parasite (such as shortly after treatment or exposure without parasite establishment). The assays are not good for clinical purposes as they may lead into unnecessary use of anti-parasitic drugs where the parasites are not viable. However, the antibody-detection techniques have been useful in identifying "hot spots" of the infection where control measures should be directed (Dorny *et al.*, 2003).

Several assays have been developed to detect parasite antigens but only the monoclonal antibody-based tests directed at defined parasite antigens may ensure reproducibility (Correa *et al.*, 1989; Harrison *et al.*, 1989; Brandt *et al.*, 1992; Erhart *et al.*, 2002). Antigen detection may be done on serum as well on cerebrospinal fluid. The sensitivity and specificity of antigen ELISA in detecting human cysticercosis is thought to be high although there are no proper studies that have evaluated this (Dorny *et al.*, 2003).

Greater attention has been directed to the diagnosis of human neurocysticercosis due to its greater impact on public health. Computerised tomographic (CT) scans and magnetic resonance imaging (MRI) are two neuroimaging techniques that have been used to diagnose human neurocysticercosis. The sensitivity of MRI for the detection of calcified lesions is poor, and thus CT remains the best screening neuroimaging procedure for patients with suspected neurocysticercosis (Garcia and Del Brutto, 2003). MRI is the imaging modality of choice for evaluation of patients with intraventricular cysticercosis, brainstem cysts, and small cysts located over the convexity of the cerebral hemispheres and can be the technique of choice in the follow-up of patients following treatment (Garcia and Del Brutto, 2003). While some CT and MRI findings in neurocysticercosis are highly suggestive of this disease, the differential diagnosis with other infectious or neoplastic diseases of the CNS may be difficult (Garcia and Del Brutto, 2003). In such cases, a combination of clinical diagnosis, immunodiagnostic tests, and epidemiological data may improve proper interpretation of the neuroimaging findings (Garcia and Del Brutto, 2003). The big drawback of the use of neuroimaging techniques is their availability in the field and their high cost. This hinders their application especially in poor countries like Tanzania as it costs an individual US $80 to undergo CT scanning. This amount can hardly be afforded by the rural poor, most of who earn below the poverty line of US $1 per day.

2.5.3. Human taeniosis

Until the early 1990s, stool microscopy to visualise *Taenia* eggs was the only diagnostic method available for the diagnosis of human taeniosis (Garcia *et al.*, 2003). This method is still the only one available for clinical use in many developing countries including Tanzania. Stool microscopy has two major disadvantages, the first being its inability to differentiate between *T. solium* and *T. saginata* eggs (Soulsby, 1982). In rare occasions, when the scolex or mature proglottids are found in the human stool, differentiation of the two species can be possible based on their morphological characteristics. The second disadvantage of stool microscopy is its low sensitivity of between 30-40% (Garcia *et al.*, 2003; Allan *et al.*, 2003), probably due to the fact that *Taenia* eggs are excreted intermittently (Allan *et al.*, 1996b).

Progress has been made towards the development of immunodiagnostic tests for the detection of human taeniosis. The most commonly used test in some endemic areas is coproantigen test (Garcia *et al.*, 2003; Allan *et al.*, 2003). Parasite coproantigens constitute parasite specific products in the faeces of the host that are amenable to immunological detection. These products are a result of parasite metabolic activities and are thus present independently of parasite reproductive material such as eggs and proglottids, and they disappear within a week after treatment (Allan *et al.*, 2003).

The antigen detection is genus specific with *T. solium* and *T. saginata* both reacting in the assay, but with no cross-reactions with other parasites (Allan *et al.*, 2003). The true coproantigen test sensitivity and specificity is likely to be greater than 90% and 99% respectively based on micro-plate formats (Garcia *et al.*, 2003; Allan *et al.*, 2003). With dipstick ELISA formats, the test has shown sensitivity and specificity of 76% and 99.9% respectively (Allan *et al.*, 2003).

Recently, Wilkins *et al.* (1999) demonstrated the possibility of diagnosing *T. solium* taeniosis by the detection of species-specific circulating antibodies using the EITB method. Based on studies conducted elsewhere, the test has revealed the sensitivity and specificity of 95% and 100%, respectively (Allan *et al.*, 2003). However, the test is subject to false positive results in individuals who may have been exposed to the parasite, but have not developed the disease or have recovered from the infection. One of the areas that remain to be investigated is the rate at which sera, following removal of the intestinal infection, become negative for circulating antibodies to the diagnostic antigens (Allan *et al.*, 2003).

2.6. Impact of *Taenia solium*

Being a zoonotic parasite, *T. solium* poses both public health and economic problems in endemic countries. However, to date information on the total impact of the parasite is absent. This might partly be attributed to the under-recognition of the parasite in many endemic countries (Tsang and Wilson, 1995), thus little effort has been made to investigate its presence and consequences. The disease burden due to human cysticercosis is especially difficult to estimate due to lack of epidemiological data on the morbidity and health consequences attributed to *T. solium* cysticercosis in endemic countries. Some fragmented information however exists on the public health and financial impact of the parasite in some endemic areas (Engels *et al.*, 2003).

It has been shown through studies elsewhere that neurocysticercosis accounts for 30-50% of the cases of late-onset epilepsy in developing countries (Medina *et al.*, 1990; Torres, 1992). *T. solium* has also been reported to be a common cause of juvenile neurocysticercosis (Pammenter *et al.*, 1987; Shasha and Pammenter, 1991; Foyaca-Sibat, 2002). Apart from human morbidity and mortality due to neurocysticercosis, people with epilepsy or certain disabilities are normally socially isolated and most cannot participate in important activities such as school education and paid jobs. It is also common in many societies that nobody can marry epileptic persons for fear of transmission of the condition to the next generation. In Mexico, it has been estimated that more than US $17 million is incurred annually in hospitalisation and treatment costs for humans with neurocysticercosis (Murrell, 1991).

Financial losses due to porcine cysticercosis have been reported by several studies. A simple economic estimation indicates that the annual loss due to porcine cysticercosis in ten West and Central African countries was about 25 million Euros

(Zoli *et al.*, 2003). In China, one study estimated that 0.2 billion kg of pork was discarded per year due to porcine cysticercosis resulting in a loss of about US $121 million per year (Engels *et al.*, 2003). In Mexico, porcine cysticercosis was responsible for a loss of more than one-half of the national investment in swine production and then for all of Latin America, porcine cysticercosis accounted for an economic loss of US$164 million (Murrell, 1991). No information on financial impact of porcine cysticercosis available for Tanzania. It is thought that any disease eradication programme that considers the economic factor is more likely to be effective and sustainable (Gilman *et al.*, 1999).

2.7. Control strategies for *Taenia solium*

Based on previous studies that investigated the epidemiology of *T. solium*, several characteristics were identified, which make the parasite vulnerable to control and potential eradication (Schantz *et al.*, 1993). These characteristics include: (a) the life cycle of *T. solium* requires human beings as the only natural definitive host; (b) taeniosis is the only source of infection for the intermediate host; (c) pigs can be monitored, considering the short life span of the animal; and (d) safe and efficacious anti-parasitic drugs against taeniosis are available. Based on these findings, the International Task Force for Disease Eradication in its meeting in 1992 listed *T. solium* among the six diseases (poliomyelitis, mumps, rubella, dracunculiasis, lymphatic filariasis, and cysticercosis) that were candidates for eradication. The elimination of *T. solium* from most European and North American countries is important evidence of potential eradicability of the parasite (Sarti and Rajshekhar, 2003; Gonzalez *et al.*, 2003). The elimination of this zoonosis in those countries was not planned, but it resulted from the process of economic development, which in turn improved the environmental sanitation, pig husbandry and marketing procedures. Unfortunately, these measures are not yet feasible in most developing countries including Tanzania. For these countries, other control measures should be relied on.

2.7.1. Treatment of human tapeworm carriers

The human tapeworm carriers and the infected intermediate hosts, especially pigs, are important in terms of transmission of *T. solium* (Garcia *et al.*, 2003). The strategy for treatment of human carriers of the adult *T. solium* is based on the assumption that if egg dispersion is stopped, then the disease transmission cycle will be broken (Gonzalez *et al.*, 2003). According to Garcia *et al.* (2003), the frequency of human taeniosis can be reduced by either, detection and treatment of tapeworm carriers or by treatment of the whole population. With the introduction of anthelmintic drugs such as praziquantel and niclosamide, both of which are effective against human taeniosis, mass chemotherapy has been tried in several endemic areas, especially in Latin America (Keilbach *et al.*, 1989; Cruz *et al.*, 1989; Sarti *et al.*, 1997). Despite the presence of effective drugs for treatment of taeniosis, some previous interventions directed to the treatment of tapeworm carriers were not successful (Keilbach *et al.*, 1989). It is thought that lack of community involvement leading to poor compliance for implementing the interventions, the type of population examined, and the evaluation criteria used might have contributed to the observed failures (Keilbach *et al.*, 1989; Sarti *et al.*, 1997; Sarti and Rajshekhar, 2003).

Although some studies revealed public benefits of mass chemotherapy with praziquantel, the drug works best in higher doses than 10 mg/kg body weight that pose high risk of causing seizures in asymptomatic individuals harbouring *T. solium* cysts in their brains. For this reason, praziquantel is not recommended for the treatment of human taeniosis (Flisser *et al.*, 1994; Sarti *et al.*, 2000; Sarti and Rajshekhar, 2003). Niclosamide is the drug of choice for the treatment of human taeniosis (Sarti and Rajshekhar, 2003). Some studies have found that although human taeniosis is critical to any control strategy, it is difficult to treat, and re-infection may occur (Gilman *et al.*, 1999). There is also a theoretical risk of increase in human cysticercosis during taeniosis treatment campaigns if the disposal of stools is not carefully controlled (Gilman *et al.*, 1999). Targeting treatment of human carriers instead of mass treatment has been recommended in order to reduce the costs and to avoid exacerbation of neurological symptoms in individuals with neurocysticercosis (Flisser *et al.*, 2003).

2.7.2. Treatment of infected pigs

Several efforts have been made to find drugs for the treatment of porcine cysticercosis in order to prevent human infections from pigs. Anthelmintics such as albendazole and oxfendazole have extensively been investigated (Gonzalez *et al.*, 1995; Gonzalez *et al.*, 1996; Gonzalez *et al.*, 1997; Gonzalez *et al.*, 2001). Although albendazole showed some effectiveness in the treatment of porcine cysticercosis, its association with several side effects and the need for repeated doses limits its application (Gonzalez *et al.*, 1995). On the other hand, oxfendazole at a single dose of 30 mg/kg body weight has been reported to provide close to 100% effectiveness under controlled experiments (Gonzalez *et al.*, 1998). It has also been reported recently that the treatment of pigs with oxfendazole induces protection against re-infection with *T. solium* for at least three months (Gonzalez *et al.*, 2001).

However, it is evident from these studies that at least three months are needed after treatment for the meat to return to about its normal state. These studies indicated that brain cysts are not killed by the drug (Gonzalez *et al.*, 1995; Gonzalez *et al.*, 1997; Gonzalez *et al.*, 2001). Although the authors concluded that the brain cysts could not pose a high risk for human infection because the brain is not normally consumed or at least in an undercooked state, this merits further studies as it might not hold true in some cultural settings. Studies are also needed to examine the withdrawal period of oxfendazole in order to protect the public from intake of drug residues from treated pork.

2.7.3. Vaccination of pigs

An effective vaccine to prevent cysticercosis in pigs would be a valuable option to assist with *T. solium* control. Although to date there has been no vaccine commercially available for porcine cysticercosis, several approaches are being tried towards the development of a *T. solium* vaccine (Lightowlers, 2003). These efforts are based on observed success in developing effective vaccines against similar parasites such as *Taenia ovis* and *T. saginata*. This success has encouraged many scientists to adopt similar strategy to develop a vaccine against *T. solium* (Lightowlers, 2003). An important finding which emerged from previous studies on Taeniid cestodes and their intermediate hosts was that immunity to re-infection plays an important role in the natural regulation of transmission of this group of parasites (Rickard and Williams, 1982). This observation distinguishes taeniids from many other helminth infections and provides an opportunity for scientists interested in vaccine development. Host-protective immune responses are directed towards the oncosphere in the early developing embryo (Lightowlers, 2003). Initial studies demonstrated that protection could only be achieved by exposing hosts to living parasites. High levels of effectiveness were obtained in trials using oncosphere antigens prepared directly from the oncospheres or collected from culture of oncospheres in vitro (Rajasekariah *et al.,* 1980; Osborn and Heath, 1982). However, because of the difficulty in producing sufficient amount of antigen for a widespread use vaccine, current efforts are being directed towards the development of a recombinant vaccine (Lightowlers, 2003).

Two recombinant vaccines for *T. solium* (TSOL18 and TSOL45-1A) have been tested experimentally (Gauci *et al.*, 1998; Gauci and Lightowlers, 2001; Flisser *et al.*, 2004b). These antigens are homologies of host-protective antigens in *T. ovis* (To18 and To45) and *T. saginata* (TSA18 and TSA9) (Gauci *et al.*, 1998; Gauci and Lightowlers, 2001; Flisser *et al.*, 2004b). Recently, three trials (two in Mexico, one in Cameroon) indicated that TSOL18 induced 99.5-100% protection against experimental challenge with *T. solium* eggs in piglets vaccinated at two months of age (Flisser *et al.*, 2004b). In the same trials, TSOL 45-1A induced protection of 0-97.1% while in one trial when the two antigens were combined, the protection was 94.7% (Flisser *et al.*, 2004b). Antigens derived from the rodent parasite *Taenia crassiceps* are also used as a potential source of host-protective antigens for *T. solium*. However, there are no proper studies that have evaluated their efficacy (Lightowlers, 2003). Field trials are needed to examine the effectiveness of these vaccines to protect pigs from natural infection with *T. solium*. The potential use of vaccine will however depend on its availability and cost, considering that the targeted users are poor farmers or pig keepers and the vaccine will have to be repeated due to the short lifespan of pigs (Gilman *et al.*, 1999).

2.7.4. Health education

Health education intervention for *T. solium* is principally a preventive measure and when well adopted, it could prevent a disease-free population from infection or the diseased population from further transmission of the parasite. Health education interventions could also increase the health-seeking behaviour and compliance to other interventions such as those directed to porcine and/or human chemotherapy, or improved hygienic behaviour. Only a few studies have examined the effectiveness of health education interventions in reducing the frequency of *T. solium* infections (Keilbach *et al.*, 1989, Sarti *et al.*, 1997). In one study in a village in Mexico, health education campaigns combined with mass chemotherapy of human tapeworm carriers resulted in an increase in the prevalence of porcine cysticercosis from 6% in the baseline to 11% one year after the intervention (Keilbach *et al.*, 1989). However, the failure of the intervention was attributed to lack of community involvement, which led to poor compliance of people with regard to the chemotherapy. Another community study in Morelos state in Mexico, involved an intensive educational campaign alone with active involvement of the target community in the designing and implementation of the intervention (Sarti *et al.*, 1997). This study reported a positive effect of the intervention since the knowledge of the target population was improved, and the prevalence of porcine cysticercosis was reduced from the baseline levels of 2.6% and 5.2% by lingual examination and immunoblot respectively to post-intervention levels of 0% and 1.2% respectively ($p < 0.05$) (Sarti *et al.*, 1997). Community involvement was thought to have contributed to the observed success.

The above two reported studies have given us some information regarding the use of health education as a possible strategy for reducing *T. solium* infections. However, because they both used a non-experimental evaluation design (i.e. lacking a control group), none of them can be used to confirm the association of the intervention and the observed improvement or worsening of the *T. solium* situation. It could be that time or other events that might have occurred during the study periods caused the observed changes between the baseline and the post-intervention levels of the disease or other outcomes measured by the studies. In addition, the sample size of these studies was of one (i.e. only one community), which obviously was too small to reach any conclusion. Randomised controlled trials are needed to examine the effectiveness of the health education intervention as a strategy in reducing the transmission of *T. solium* in endemic areas.

Community participation, especially in the planning and implementation phases of health education interventions has been found to increase the effectiveness of the interventions (Lloyd *et al.*, 1994). This is because it allows considerations of cultural and socioeconomic factors that affect the compliance of the community to the interventions. The use of local terminology of important factors related to the disease helps the problem to be well understood by the target community. In order to encourage active participation of villagers in community-based programmes, a flexible approach to the process of communication with people about parasite control is needed. This approach should bring about some balance between the community and programme goals (Lloyd *et al.*, 1994).

2.7.5. Combined interventions

None of the control strategies for *T. solium* can stand as a sole strategy, therefore, combined interventions are recommended (Gonzalez *et al.*, 2003; Lightowlers, 2003; Sarti and Rajshekhar, 2003). Intervention programmes combining treatment of human and pig populations have been tried in Peru with little success (Gonzalez *et al.*, 2003). The findings of these studies indicate that it is essential to incorporate health education in any of the control strategy combinations in order to prevent re-infection or further transmission of the parasite in a sustainable way.

2.8. Evaluation of *Taenia solium* control strategies

Most previous community-based studies used the prevalence of porcine cysticercosis before and after an intervention to assess change in the infection frequency and hence estimate the effectiveness of the intervention (Keilbach *et al.*, 1989; Sarti *et al.*, 1997). Under normal circumstances, the pig population in many endemic areas is very dynamic. Some pigs are removed from the prevalence pool because they are either sold or exchanged between and within villages, especially after weaning, sold prematurely to butchers when they are discovered to be infected with porcine cysticercosis, or die from competing risks. Movement of infected pigs out of a village decreases the prevalence in that village even without any intervention. Education programmes on porcine cysticercosis control may even increase the behaviour of early selling of infected pigs for fear of loosing money at a later stage. Measuring the incidence rate of the infection could be a good measure to reflect the rapidity with which the infection occurs, since it takes into account the animals moving into and out of the village in terms of pig-time at risk. This would enable better comparison of the frequency of the infection between different villages or periods.

Since most of *T. solium* control trials are donor funded, and hence time and resource limited, it is important to evaluate the economic efficiency of the interventions in order to see whether it is beneficial to the target population and whether the society can sustain the interventions. As opposed to many parasites, the economic importance of *T. solium* results from both the livestock production and human health impact of the parasite. An economic evaluation of the efficiency of any control strategy directed to the parasite would, therefore, be complete if it took a societal perspective (Perry and Randolph, 1999). However, data on the human aspect of *T. solium* is normally lacking in many endemic areas, making it difficulty to conduct a sound economic analysis of the impact of the parasite. Analysing the economics of the livestock production aspect of the parasite would partially highlight the economic viability of a given control strategy for the parasite.

Like many other parasitic infections, porcine cysticercosis normally results in an endemic situation in infected areas. Its effects in terms of productivity losses and control costs should therefore be dealt with at the producer level. The decision in question should relate to whether it is worthwhile to allocate scarce resources to use or develop a given strategy or technology to control porcine cysticercosis. This should compare the costs of using or developing the strategy or technology to the expected benefits of avoiding the infection to some degree at the farm level. Farm management decisions are based on financial criteria: a given control measure is justified if it improves the farmer's profits (Perry and Randolph, 1999). However, even with a complete financial analysis of a porcine cysticercosis control strategy, the public health impact of the strategy should also be considered.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study area

This study was conducted in Mbulu District (Figure 1), which is located in northeastern Tanzania, between latitude 3.80°S and 4.50°S, and longitude 35.00°E and 36.00°E, with altitude ranging from 1000 to 2400 meters above sea level (Meindertsma and Kessler, 1997). The District has areas of semi-arid and sub-humid climates that receive annual rainfall of below 400 mm and above 1200 mm, respectively. The long rainy season extends from 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 between 15°C and 24°C. Currently, the District has 72 villages and the 2002 National census counted 237 882 people living in 38 729 households with an average of six persons per household. In 1997, Mbulu District pig population was estimated at about 35 000, and crop and livestock production was by far the most-important economic activity employing more than 90% of the total District's labour force. Most of the District inhabitants, who belong to the Iraqw tribe, occupy mostly highland areas and practice mixed farming: crop and livestock production. Pigs are raised in many homes as a source of income and animal protein for the household. Besides pig farming, villagers raise cattle, sheep, goats, and local chickens, and some keep dogs, cats, and donkeys (Meindertsma and Kessler, 1997).

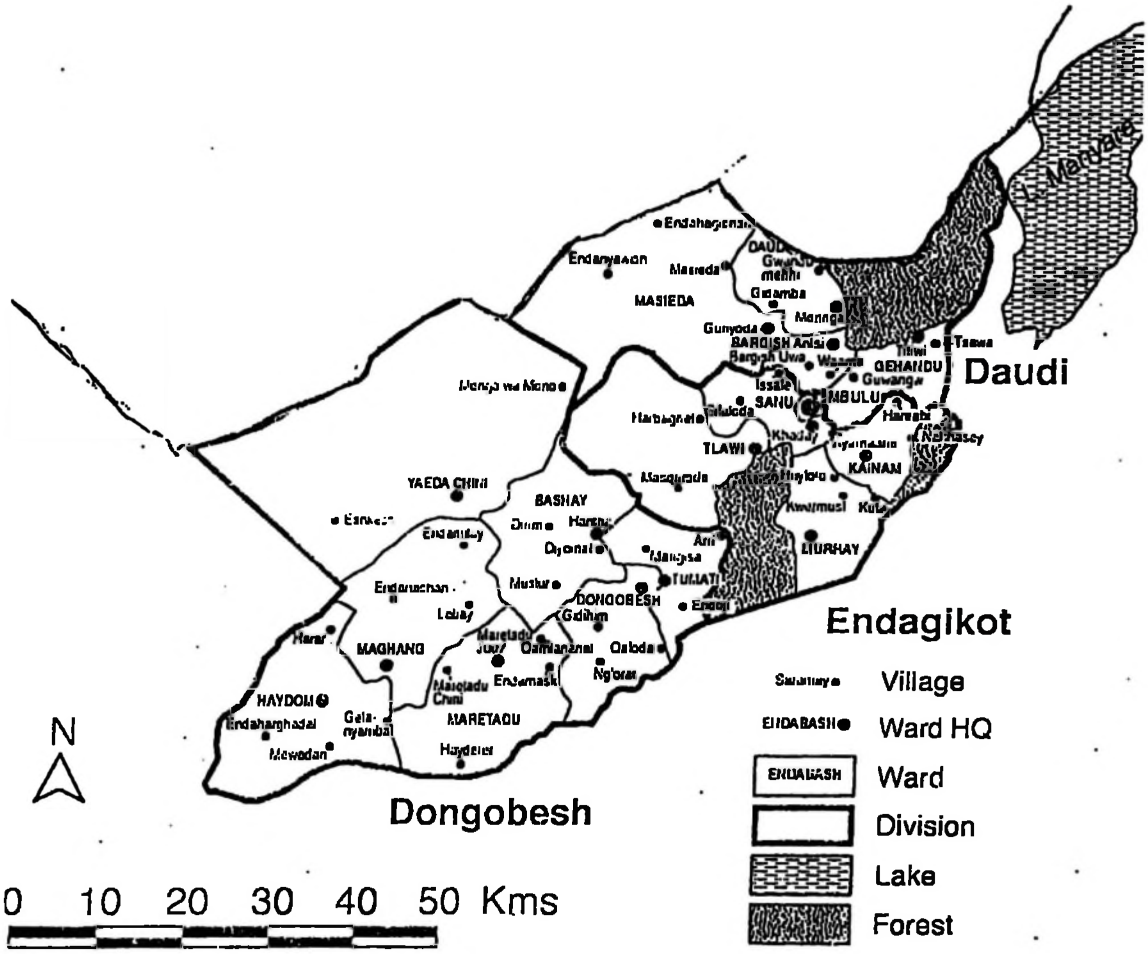

Figure 1. Administrative map of Mbulu District

Source: Mbulu District Livestock Office, 2001

3.2. Study approach

This study had two major phases. The first phase of the study involved the designing and production of health educational materials that were relevant to Mbulu socio-economic and cultural settings. The implementation and assessment of the impact of the health education intervention was done in the second phase of the study. Figure 2 presents the basic steps followed in the approach of this study. Throughout the study, participation of the Mbulu community was a priority in order to increase the effectiveness and sustainability of the intervention.

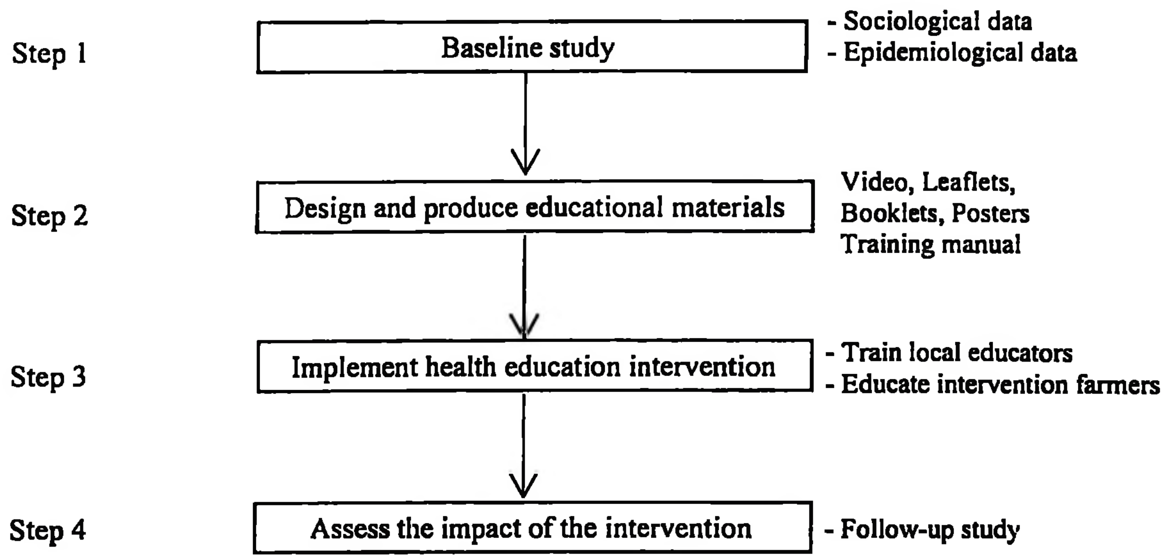

Figure 2. Schematic representation of major steps followed in the health education trial in Mbulu District, northern Tanzania, 2002-2004

3.3. Ethical considerations

Permission to conduct research was obtained from the Tanzania National Institute for Medical Research, Ministry of Health, Sokoine University of Agriculture, and Mbulu District medical hospital, after the relevant authorities had examined and approved the research proposal. Verbal consents were obtained from Mbulu District Executive Director, Livestock Officer; village leaders, and study participants after the researcher had clearly explained the design, purpose, and possible benefits of the study to the target community. Names of respondents in this study were kept confidential. The control group and the pilot study participants received the health education at the end of the study. Smallholder pig farmers who fully participated in the follow up study were offered certificate of participation at the end of the study (see Appendix A).

3.4. Study I: Designing and production of health educational materials appropriate for Mbulu District

The present study was carried out between February 2002 and April 2003. The study involved sociological and baseline surveys that were conducted prior to the production of the health educational materials. The sociological study aimed at providing a deeper understanding of the community's perceptions and practices related to *T. solium* infections, and involving the Mbulu community in designing health educational messages for effective communication strategy. The baseline study aimed at gathering baseline data regarding knowledge and practices related to

T. solium transmission in a more quantitative manner in order to have the basis for the evaluation of the health education intervention. Both the sociological and baseline studies helped the identification of knowledge gaps to be addressed during the development of health educational messages.

3.4.1. Sociological study

3.4.1.1 Study area and selection of study respondents

This qualitative study was conducted in February 2002. Using a table of random numbers and Mbulu District list of villages, Arri village was randomly selected from 45 eligible villages out of 60 villages that were present in the district during that time. The eligibility criteria for a village to be selected were that the village was endemic for porcine cysticercosis, and the villagers consented to participate in the study. Arri village is located in the eastern part of Mbulu District and in 2000 the village had an estimated population of 2,932 people living in 658 households. In 2001, the village pig population was estimated to be 684 (Mbulu District Office, 2001), and the prevalence of porcine cysticercosis in 1998 was estimated to be 23.3% (95% CI: 9.93 - 42.28) by using lingual examination method (Ngowi, 1999). The village was characterised by poor sanitary facilities and pig rearing practices, which was typical for most villages in Mbulu District.

A total of 61 respondents from Arri village participated in the sociological study. The study unit was the household. Out of these 61, 59 were smallholder pig farmers, representing different gender and age categories. A smallholder pig farmer in this context was defined as an individual pig keeper living in a rural area of Mbulu District. These respondents were purposively selected to ensure gender and age group representation in order to have a representative of the pig-keeping community in the area. Prior information was obtained from the village leaders, and the respondents were selected using the village list of smallholder pig farmers. Also included in the list were the rural medical assistant (RMA) and the livestock/agricultural field extension officer (LFEO) serving the study village. The latter two officials were purposively selected considering the medical and agricultural importance of the parasite.

3.4.1.2. Exploration of people's knowledge, perceptions, and practices related to *Taenia solium* infections in Mbulu District

The sociological study was undertaken in the porcine cysticercosis endemic areas to ascertain if pig keepers were aware of how the infection was transmitted. In addition, because porcine cysticercosis normally does not cause any observable health effect in pigs, many pig keepers may not believe that the parasite is dangerous to their health. Such perceptions hinder the preventive efforts one could take against the parasite. This study, therefore, assessed the local knowledge on the causes, transmission, impact, treatment, and prevention of porcine cysticercosis as well as the perceived importance of keeping pigs in Arri village in Mbulu District. To achieve this, qualitative methods of data collection comprising in-depth interviews and focus group discussions were conducted with pig keepers.

An interview check-list was developed, which had key questions reviewed from a previous survey of porcine cysticercosis in Mbulu District. Additionally, in each interview, probing was done to obtain more information (see Appendix B). The RMA, LFEO, and 11 smallholder pig farmers (five women, six men) ranging in ages from 32 to 52 were involved in the in-depth interviews. The other 48 smallholder pig farmers (24 women, 24 men) were involved in the focus group discussions, and were divided into four age-gender categories (Plate 1).

The age of the respondents was not predetermined. However, those who represented older women ranged in ages from 41 to 89, while those representing younger women ranged from 21 to 30 years old (see Plate 1a and 1b). Older men ranged in ages from 49 to 72, while younger ones ranged from 22 to 40 years old (see Plate 1c and 1d). Two focus group discussions each with six respondents were conducted in each of the four age-gender categories. The different group categories allowed free conversations among respondents and helped to ascertain whether there was any difference in views between the groups. The results of this study were used to determine whether porcine cysticercosis was perceived as an important infection, and what actions the smallholder pig farmers, and other villagers took to control the infection.

a

b

c

d

Plate 1. Focus group discussion (a) younger women, (b) older women, (c) younger men, and (d) older men group in Mbulu District, northern Tanzania, 2002.

The researcher gave the village executive officer the list of smallholder pig farmers selected for interviews, who in turn informed them that they would be interviewed the following day. Both in-depth interviews and focus group discussions with farmers were conducted in the village meeting room at different times. The RMA was interviewed in her office, while the LFEO was interviewed in a village tearoom. All places for the interviews had minimal disturbances. The interviews were scheduled between 1:00 PM and 3:00 PM, when most of the smallholder farmers had spare time. In-depth interviews of the smallholder pig keepers lasted for 30-60 minutes each, while that of the RMA and LFEO lasted for about 20 minutes each. Focus group discussions lasted for 60-90 minutes. All in-depth interviews were hand-recorded, and the focus group discussions were hand- and tape-recorded. All the interviews and discussions were conducted in Kiswahili, the national language, which both the interviewer and most respondents understood well. Where it was necessary, a local assistant translated the interviews to Iraqw, the local language, after which the assistant back-translated them to Kiswahili.

In order to stimulate the discussions, every focus group participant was first asked to look at a variety of photographs of the common livestock including pigs kept in Mbulu District, and each was asked to sort out pictures of animals in the order of importance one preferred to keep if she/he was to start a new animal business. Smallholder pig farmers gave their opinions on six areas: the importance of pig farming in the community, importance of porcine cysticercosis, local knowledge about the infection, and practices that facilitated transmission of the parasite in the area, constraints to changing practices that facilitate the transmission of porcine cysticercosis, and their recommendations for changing the practices.

The LFEO gave his opinions about his awareness of porcine cysticercosis and actions that he took when he found an infected pig during meat inspection. The RMA was asked about her awareness and presence of taeniosis and epilepsy in the village, how they were diagnosed, treated, and their possible link to porcine cysticercosis.

3.4.2. Baseline study

3.4.2.1. Selection of villages and households to be included in the baseline study

At the time of the baseline study, Mbulu District had a total of 72 villages, 69 of which kept pigs. On average one village in Mbulu District had about 500 households although there were some with more than 1000 households. The decision on the number of villages and households to include in this main study was not based on actual statistical calculations, but on actual field observations. Because health education intervention was to be randomised at the village level, whereas the measurement of the variables were to be done at the household level, it was decided to include as many villages and households as possible. The large sample size would reduce the estimated variance of the measured variables within and between villages.

Maximising the number of villages was meant to allow for the detection of the smallest possible reduction in the incidence rate of porcine cysticercosis.

Using the list of Mbulu District villages with pig population estimates of 2001, the table of random numbers was used to select 44 villages out of the 69 villages that kept pigs in the District. The sociological study village was excluded from the baseline study. In April 2002, a census of all pig keeping households was conducted in each of the 44 villages in order to obtain the actual number of pig-keeping households in each village as the 2001 estimates could have changed. The eligibility criteria for a village to be included in the baseline study were (a) the village to had at least 20 eligible smallholder pig farmers at the time of the census, and (b) the village leaders agreed to participate in the study.

Forty-two out of the 44 villages met the inclusion criteria and they were recruited into the study. During the pig census, information on the number, ages and sexes of pigs owned by the farmer was also collected. Using the list of pig keeping households in the selected villages, 20 smallholder pig farmers were randomly selected from each village using the table of random numbers. In the villages in which the eligible smallholder pig farmers were only 20, all the farmers were included in the study. The eligibility criteria for a smallholder pig farmer to participate in the baseline study were (a) the smallholder pig farmer had at least one pig that was between two and twelve months of age, and (b) the farmer agreed to participate in both the baseline and follow-up studies. This exercise gave a total of 827 households because nine households refused participation because of lack of interest in the study, and in some villages the number of eligible households decreased to less than 20 during the time of the baseline data collection. Therefore, the 827 households were included in the baseline, and agreed to participate in the follow-up study. This was an average of about 20 households per village. The baseline study was carried out in a series of steps as described below.

3.4.2.2. Training and pre-testing of interviewers and pig examiners

Two laboratory assistants were trained in order to assist in interviewing the smallholder pig farmers. One of the two individuals was also trained to help with the examination of pigs for cysticercosis using the lingual examination technique. The training and pre-testing of the assistants was carried out in the study area for three consecutive days. The researcher and the trained tongue examination assistant exercised the actual field work by independently examining 43 pigs for cysticercosis, and the inter-observer agreement was analysed using *kappa* statistic as suggested by Altman (1991). This analysis indicated that there was a perfect agreement ($\kappa = 1$) between the two observers.

3.4.2.3. Questionnaire survey and pig examination

Between July 2002 and April 2003, cross-sectional studies were conducted in the selected households. The studies involved face-to-face interviews of smallholder pig farmers (Plate 2), observations of environmental factors, and examination of live pigs. On visiting a selected pig-keeping household, the interviewer gave a self-introduction to the household owner(s), explained the purpose of the study and asked permission to administer the questionnaire and examine a pig. If the pig owner was not around, any person living in the household (preferably a family member), who was able to answer the questionnaire, was interviewed. The questionnaire was designed to collect information on farmer's knowledge on *T. solium*, its transmission, impact, prevention and control, and the presence in the family of cases of human taeniosis. The questionnaire supplemented with observations also helped to elicit information on risk factors associated with the transmission of *T. solium* such as the households not using latrines, eating infected pork, and drinking un-boiled water. The detailed questionnaire is presented in Appendix C.

A pig to be examined was identified prior to visiting the study household. This was achieved by using the information collected during the pig census and the table of random numbers. The baseline study included pigs between two and twelve months old to correspond to the expected 12 months post-intervention follow up period. Pregnant sows that were near term were excluded from the examination. Only one pig was studied per household to minimise any clustering of infection at the household level. The decision to examine one pig per household was based on the fact that pigs reared in one household shared similar environmental factors. Therefore, pigs in the same household were likely to be more similar to one another than pigs from different households. Standard statistical techniques always assume that study individuals are independent from one another, which would not have been the case if more than one pig from the same households had been included in the study. In addition, pigs in the same household share similar risk factors, reducing the natural variability in these factors.

Plate 2. Face-to-face questionnaire interviews in Mbulu District, northern Tanzania, 2002-2004.

After the interviewer had finished collecting information from the smallholder pig farmer using the questionnaire, the selected pig was then examined for the presence or absence of *T. solium* cysts by examining the tongue visually, supplemented with palpation when necessary. The sex, age, and origin of the pig were recorded. The age of the pig was based on the history of its birth date or when first brought to the household. For example, if a pig was reported to be born during month x, the examiner started to count the following month (i.e. $x + 1$) to be the pig's first month of age in order to avoid situations whereby a pig was born at the end of month x. For those pigs that were introduced into the household from a different origin, if the pig was introduced during month x the examiner assumed that during month x the pig was two months old as it was a common practice in Mbulu District for piglets to be sold or given to neighbours when they were about two months old. If the selected pig was no longer in the household during the day of the visit, another pig from a reserve list was examined. If there was no eligible pig present during the visit or the farmer refused participation, the household was replaced by another household from a reserve list. The primary objective of estimating the prevalence of porcine cysticercosis at the baseline was to later use the information to balance the intervention and control groups with regard to disease magnitude when allocating the intervention to the study villages.

3.4.2.4. Collection of economic data

The economic data were collected in order to enable analysis of the financial efficiency of the health education intervention in Mbulu District. These data were recollected in March 2005 by using in-depth interviews of 35 key informants (experienced smallholder pig farmers or pig traders). Data collected involved costs related to raising pigs under indoor pig-rearing method, the traditional free-range and tethering method, and current market prices for piglets and finished pigs.

3.4.3. Analysis of the sociological and baseline data

The interviews recorded from the sociological data were transcribed using the Microsoft Word processing programme. In order to ensure the reliability of the interpretation of the data, two independent experienced analysts coded the eight focus group discussion transcripts. The analysts independently analysed the transcribed data and compared their results to determine if they arrived at similar interpretations of the data. The agreement between the two analysts was 90.5%. The remaining 11 transcripts from the in-depth interviews were coded by one of the two analysts.

A note-based analysis of responses was done across all focus group discussion sessions and then across all in-depth interview results. In the responses to each question, clusters were identified and assigned a code. A cluster consisted of a group of similar ideas. Themes were then identified from the discussions. A theme was the most important idea (or cluster of ideas) identified under each question in the discussion. In this study, a theme was identified if an idea or cluster was presented in the majority of the focus group discussion sessions or in-depth interviews. For questions that were asked in both the focus group discussions and in-depth interviews the information from the two different approaches was used to cross-check the consistency of the information.

Each response was assigned a reference number with an indication as to whether it originated from the in-depth interviews (IND) or focus group discussions (FGD) followed by a serial number. For the quotations originating from the focus group discussions, the age-gender category was specified, while for the ones from the in-depth interviews the gender and age of the respondent were specified. Thus reference numbers such as "IND 01, male, 40 years" or "FGD 02, younger man" were used to identify quotations from the in-depth interviews and focus group discussions, respectively. Some of the important quotes from the respondents are given in the results section.

Data from the baseline study were analysed using Stata 8.0 for Windows. Baseline proportions and their 95% confidence intervals (CI) were computed for important variables to analyse the knowledge, practices, and prevalence of porcine cysticercosis and human taeniosis at the household level.

3.4.4. Development of recommendations for behaviour change

The study used information from the sociological, baseline, and previous studies in Mbulu District to identify important factors that could affect the behaviour of the community regarding changing various practices related to transmission of *T. solium*. The information was used as a guide in the development of recommendations for behaviour change. Three major factors were considered in this study: (a) the importance of each of the identified risk practices in facilitating the transmission of *T. solium* in the area; (b) the perception of the community as to whether a particular practice was a risk factor. The principle behind this was that if the community did not regard a particular practice as a risk factor, efforts in changing the practice would not be successful. Therefore, this study considered educating the community on the importance of each of the risk practices; (c) feasibility of changing a particular risk practice. For example, if the study recommended that pig farmers house their pigs permanently, then the farmers would have to incur costs related to indoor pig rearing method, such as a farmer building a pig house, and growing or buying feeds for pigs throughout the pigs' life.

3.4.5. Development and production of health educational materials

After deciding which practices to recommend, the messages were put in a form appropriate for the target group. This study considered the community's recommendations concerning appropriate control measures and the target group for the messages. However, the final decision was based on the relevance, feasibility, and sustainability of a particular control action as well as the experience from similar studies conducted elsewhere. Once educational messages had been developed, appropriate media for their dissemination were considered.

3.5. Study II: Implementation and evaluation of the health education intervention

3.5.1. Selection of the experimental design

One of the objectives of this study was to measure the effect of the health education intervention on reducing the incidence rate of porcine cysticercosis. This led to adoption of a pre-post randomised experimental design with a control group. This involved allocating the health education intervention randomly to the control and intervention groups and comparing the situation of interest before and after the intervention between the two groups. The aim was to balance known and unknown confounding factors between the groups as well as enable the researcher to disentangle the effect of the intervention from the effect of monitoring alone. A village was selected as the unit of intervention allocation because the intervention was information-based, and people within village were likely to communicate more frequently than people between villages. This helped to minimise the spill over of the information from the intervention to the control group. A description of the experimental design is shown in Table 1.

Table 1. Health education evaluation design with pre- and two post-intervention observations of the treatment and the control groups used in Mbulu District, northern Tanzania, 2002-2004

Baseline data Collection	Random allocation of villages to groups	Health education	6 months after education	10-12 months after education
First observation	Intervention (T) group	Done	Second observation	Third observation
First observation	Control (C) group	Not done	Second observation	Third observation

3.5.2. Implementation of the health education intervention

The health education intervention was implemented in the first half of July 2003 and consisted of all the educational materials administered as one package. The intervention was randomly allocated to 21 of the study villages and the 21 other villages served as controls (received no intervention). The control and intervention villages were balanced based on the baseline prevalence of porcine cysticercosis. This was done by grouping the villages according to whether their overall baseline prevalence of porcine cysticercosis was below, within, or above the median. Villages from each of the three groups were randomly allocated to either the control or intervention group using the table of random numbers. As a result of this randomisation, a total of 409 households were assigned into the intervention group and 418 into the control group.

In order to increase sustainability and community participation in the intervention, the implementation of the health education was conducted in two stages as explained below.

3.5.2.1. Training and pre-testing of local educators

A two-day training workshop was conducted involving a total of nine local individuals who were purposively selected (Plate 3). Seven out of the nine people were livestock/agricultural field extension officers and the other two were health workers. The purpose of training these individuals was to use them later as educators for the pig farmers. The training involved a one-day introduction to the life cycle, transmission, impact, control and prevention of *T. solium*. The current status of porcine cysticercosis with more focus on Mbulu District was presented. A training manual was presented and workshop participants were asked to comment on it. Participants gave various opinions on how to improve the manual to fit the situation and it was later revised accordingly. During the second day, each participant practiced on how one would educate farmers using the training manual, posters, and video. During this time, the other participants listened to the presenter. The training of educators lasted for about three hours per day.

Plate 3. Training of the local educators for pig farmers in Mbulu District, northern Tanzania, 2003

3.5.2.2. Seminars for smallholder pig farmers

The second stage of the health education intervention was to educate the pig farmers. A total of 409 pig keeping households in the 21 intervention villages were invited to participate in the health education intervention. Of these, 253 (62%) presented at least one member to the training session and received a leaflet and a booklet, while the leaflets and booklets for the 156 (38%) households that did not attend the training session, were sent to them through their neighbours or leaders. The village leaders of the 21 intervention villages were also invited to the training seminars. Most of these leaders attended the seminars. A few who did not attend sent their representatives.

During seminar, the LFEO trained farmers using the training manual, poster, and the video and later distributed leaflets and booklets to each household owner (Plate 4). The seminar for farmers took place in village offices, school classrooms, churches, or any other available place, and each took an average of two hours. The farmers' seminars were carried out from 10:00 a.m. to 12: 00 noon and from 2:00-4:00 p.m., and during the seminars farmers were allowed to ask questions and/or give their opinions.

Seminar participants were advised that in order to prevent the transmission of porcine cysticercosis eight things were important: (a) pig farmers should build pigpens and keep all pigs indoors all the time; (b) each household should dig a pit latrine, use it, and it should be enclosed and have a closing door; (c) children's faeces should immediately be disposed of in the pit latrines; (d) people should wash hands thoroughly after using latrines and before eating anything; (e) people should boil water for drinking purposes; (f) people should never eat or sell infected pork; (g) one should consult a medical personnel whenever has signs of worm infection or epilepsy; and (h) farmers should consult a livestock extension officer whenever they discover that their pigs are infected with cysticercosis.

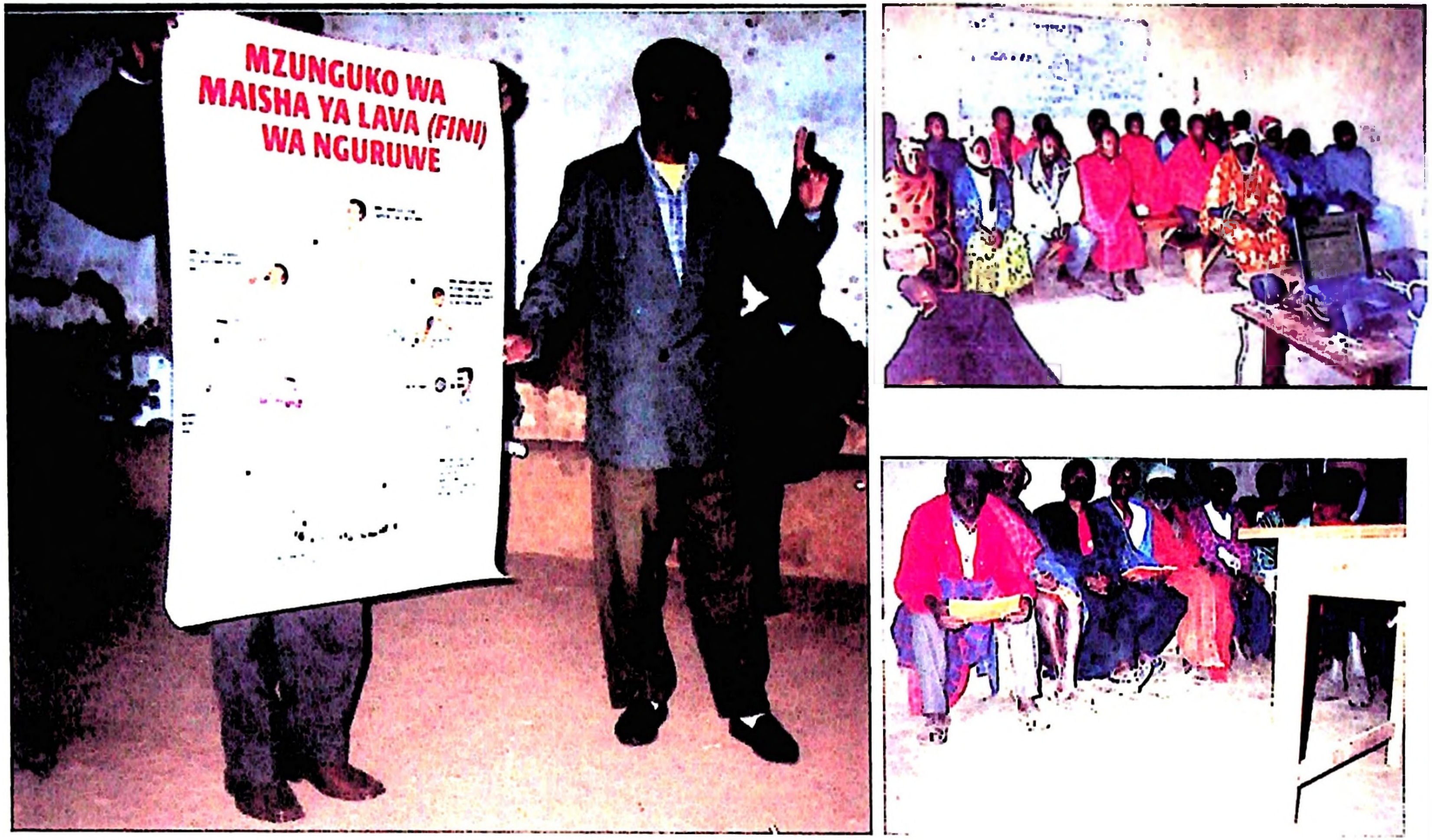

Plate 4. Seminar for pig farmers in Mbulu District, northern Tanzania. 2003.

3.5.3. Follow-up study

The follow-up study came immediately after the health education intervention, and was aimed at measuring the incidence rate of porcine cysticercosis and farmers' knowledge and practices related to porcine cysticercosis over one year period. In order to assess the incidence rate of porcine cysticercosis, tracer pigs had to be introduced over a period of time since there were no reliable methods for detecting new infections in the already infected pigs. The tracer piglets were purchased from local farmers and one piglet was introduced to each study household to be reared by the household owners for one year. Smallholder farmers were promised that they would own the pigs free of charge after the end of the study. Smallholder pig farmers who participated in this study were blinded with regard to the actual objective of the study in order to avoid bias that could be introduced by possible modification of their usual practices. This was achieved by informing the smallholder pig farmers that it was a small project aimed at benefiting smallholder pig farmers in Mbulu District by offering them piglets. In addition, the farmers were informed that the project team consisted of students who were interested in learning about pig husbandry therefore the students would visit the pig farmers from time to time to ask them some questions. In this respect, the intervention group differed from the control group only on the education that the former group received with regard to the cause, transmission, impact, and control of porcine cysticercosis.

3.5.3.1. Selection of piglets free from porcine cysticercosis

The screening test used to select a cysticercosis-free piglet was the lingual examination method. This was done by examining sows and their piglets under their tongues for the presence of *T. solium* cysts. If both of them had no *T. solium* cysts, the piglets were used to trace infection. In cases where a sow was not in a household for examination, piglets were examined. The choice of this screening method was based on its feasibility in the field. The aim of using piglets from cysticercosis-free sows was to avoid possible vertical transmission of the infection from the sow to the piglet, an observation that has been reported recently (Kisakye and Masaba, 2002). Blood samples were also collected from the sows and piglets for further confirmation of *T. solium* cysticercosis.

3.5.3.2. Introduction of the tracer piglets to the study farmers

During the introduction of piglets to the study farmers 434 of the 827 farmers (about 52%) dropped out of the study. The main reason was that most farmers could not afford to raise pigs due to food scarcity in their households. A few farmers were worried about an outbreak of African Swine Fever that was occurring in the neighbouring region of Arusha. Therefore, only 393 (about 48%) of the baseline farmers participated in the follow-up study, for which tracer piglets were offered in three batches: in late July 2003; November 2003; and January to March 2004. The variation in the introduction of piglets to participating pig farmers was due to shortage of piglets.

3.5.3.3. Post-intervention assessment of knowledge and practices related to *Taenia solium* infections

A questionnaire similar to one used in the baseline study, was used to re-assess farmers' knowledge and practices related to *T. solium* after the intervention. However, some minor modifications were made to the questionnaire to suit the situation. The follow-up assessment was done in January, May, and July 2004, which corresponded to about 6, 10, and 12 months post-intervention. A schematic presentation of pig recruitment and sampling is shown in Figure 3. These piglets were about equally divided into the intervention and control villages. The piglets were introduced village by village, mostly due to logistics reasons. This means that some households in the villages were followed for longer periods. However, care was taken to alternate between intervention and control villages. The letter x, marks the specific month when the re-examination was done in the pigs, household factors, and respondents' knowledge. The number after the letter x is the exact number of pigs examined during that visit. Nevertheless, some of the pigs were lost to follow-up mainly due to deaths. For example, in January 2004 a total of 69 piglets were introduced into the study, 27 of which were re-examined in May, 14 in July 2004, and 28 were lost to follow up. Therefore, the lengths of the bars give an indication of the number of months that each pig was followed following its introduction into the study household. The examination of pigs was done in the same visit when the farmers were interviewed, and the environment observed.

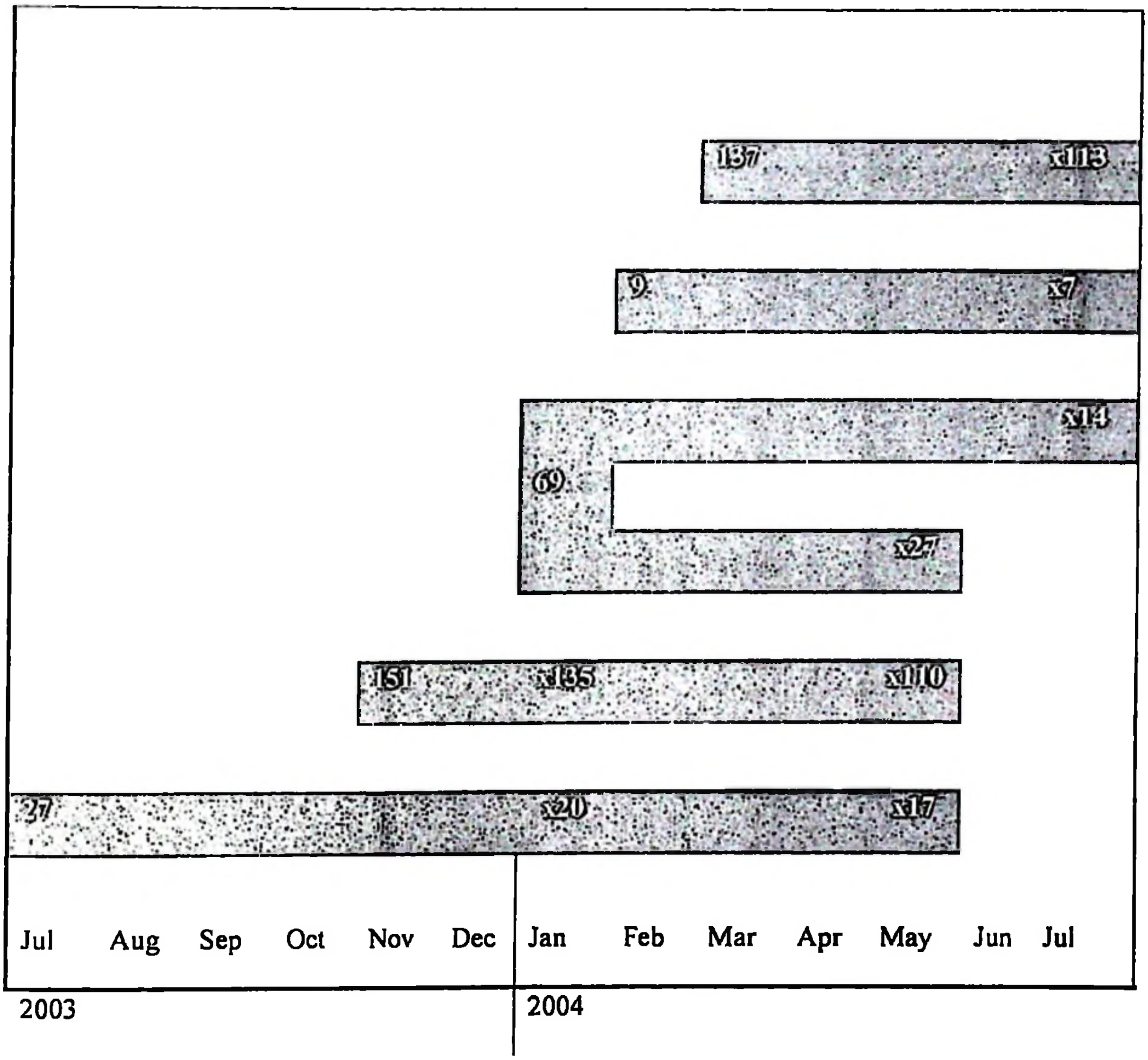

Figure 3. Plan for the introduction of piglets to the follow-up study and post intervention reassessment of pigs, people's knowledge and household factors in Mbulu District, northern Tanzania, 2003-2004.

Key: The numbers at the beginning of the bars indicate the number of pigs introduced during the month indicated below it. The letter x followed by a number indicates specific month when the pigs were re-examined and the exact number of pigs examined during that month.

3.5.3.4. Post-intervention assessment of the incidence rate of porcine cysticercosis

The study pigs were examined for cysticercosis by lingual examination method and blood samples were collected from each pig for serological analysis. The lingual examination for porcine cysticercosis was done in the same way as in the baseline study. A blood sample of about 3 ml was collected from the jugular vein of each pig for enzyme-linked immunosorbent assay to detect circulating antigens (Ag-ELISA) that are excreted or secreted by viable *T. solium* larvae in the host. The blood samples were centrifuged and the serum samples separated into vials and frozen at around -20°C until their use. The Ag-ELISA, also referred to as sandwich ELISA, was performed as described by Dorny *et al.* (2003) with slight modification. The details of the procedure are given in Appendix D.

3.5.3.5. Analysis of the follow-up data

Stata 8.0 for Windows computer programme was also used to analyse the follow-up data in this study. Because of the important drop out of the baseline participants from the study, three preliminary statistical analyses were carried out to determine whether the losses to follow up had introduced a selection bias in the remaining participants. In the first analysis, the baseline characteristics of the dropout participants were analysed to assess if there was any important difference between those who dropped out of the intervention and those who dropped out of the control groups. A total of 15 different variables were examined all of which were balanced between the two groups. In the second analysis, differences in baseline proportions of the variables between the dropout and full participant households were directly compared. One out of the 15 variables examined was significantly different between the two groups (percent difference: -0.08; 95% CI: -0.14, -0.03). In the final analysis, households that participated fully in the study were analysed to examine the distribution of the same baseline variables between the intervention and control group. One variable was significantly different between the intervention and the control group (percent difference: -0.19; 95% CI: -0.34, -0.04). Results of the three analyses are presented in Appendix E and F. Because only two out of the 45 observations were significantly different within or between the groups, it was assumed that these could have occurred by chance. This assumption was based on the statistical principle that for 95% confidence level, one would expect five out of 100 (and hence two out of 40) observations to be statistically significant by chance alone (Altman, 1991). Further statistical analyses were, therefore, carried out according to the study objectives.

3.5.3.5.1. Analysing changes from the baseline knowledge and practices related to *Taenia solium*

Change in proportions from the baseline was computed for selected knowledge and practice variables and compared between the intervention and the control groups for significance. Because the village was the unit of intervention randomisation, averages were calculated for the baseline and follow-up proportions of each variable by village. Changes in mean proportions of each variable from the baseline were compared between the intervention and control villages using two-sample *t*-test. One variable, whose change from the baseline was not normally distributed, was analysed using non-parametric Mann-Whitney two-sample ranksum test. The intervention effect on a variable was computed as the difference between the intervention group mean change from the baseline and the control group mean change from the baseline. Statistical significance of the intervention effects were examined under 95% confidence level or *p*-value for the non-parametric test.

Variables re-examined in this analysis included respondent's knowledge on how a pig acquires cysticercosis, how one could prevent a pig from contracting cysticercosis, how a person acquires taeniosis, how one could prevent taeniosis infection, and the relationship between porcine cysticercosis and human taeniosis. Considering that pig management in the household is a shared responsibility, and because everyone in the household could contribute to the transmission of *T. solium*, this study considered an innovation for *T. solium* control to be effective and sustainable if it diffused at least within the household. Therefore, the change in knowledge was measured regardless of whether the same respondent answered the questions in the different surveys. Practice variables re-assessed included whether the household was using a pit latrine, whether the pit latrine had an enclosure and a closing door, and whether the pig was roaming at the time of the examiners' visit. The effects of the intervention on the reported practices such as eating infected pork, boiling water for drinking, and washing hands after using a latrine were not analysed as the reported information could not be relied upon.

3.5.3.5.2. Calculation of the incidence rate of porcine cysticercosis

Thirteen out of the 393 of the tracer piglets (i.e. 3.8%) were later discovered to be positive for cysticercosis at the time of their introduction to study households. This confirmation was done by Ag-ELISA that was carried out in Zambia at the end of the field data collection due to the fact that the assay was not then available in Tanzania. Antigen ELISA is currently known to also detect cases of *Cysticercus tenuicollis*, metacestode of *Taenia hydatigena* that commonly infects sheep and goats and to a lesser extent pigs. Therefore, some of the observed 3.8% positive reactors may be due to infection with *C. tenuicollis*. This was because a slaughter-slab survey of 56 pigs from Mbulu District detected one case of this parasite (Ngowi *et al.,* 2004b). However, in order to be confident, all the 13 serologically positive pigs, and 49 pigs whose serological states were not known at the time of their introduction to the study due to failure to obtain blood samples from the pigs, were excluded from further analyses. Therefore, a total of 331 pigs were included in the final analysis.

A farmer in the intervention group was considered to have fully complied with the intervention recommendations if one kept his pig indoor during the examiner's last visit to the household. Although participation in the health education training by the full study participants in intervention group was high (71.4%, n = 169), and those who did not attend the training were given the pamphlets through their neighbours, the full compliance to the intervention recommendation was only about 27.2%. On the other hand, although none of the control group participants (n = 162) attended the health education training, about 17.4% of them kept their pigs indoors during the examiners' last visit (see Figure 4).

Due to the observed protocol violations in both the intervention and control groups, and the fact that the full-compliant sub-group in the intervention group was very small, analysis by "intention-to-treat" was found to be a practical approach for analysing the biological effectiveness of the intervention. Analysis by intention-to-treat compares outcomes between groups, with every participant analysed according to his randomised group assignment, regardless of whether he received the assigned intervention (Pocock, 2000; Hulley *et al.*, 2001). Analysis by intention-to-treat mostly likely reflects the actual field situation. Following this approach, the incidence rate of porcine cysticercosis was calculated using the formula by Martin *et al.* (1987) as follows:

IR = Total number of new cases / Total pig-months at risk of infection 1

Where, IR is the incidence rate of porcine cysticercosis. The period at risk of infection for a pig that did not acquire cysticercosis during the study was calculated as the total number of months starting from the month following that when the pig was introduced to the farmer, to the month before the month of its death or termination of the follow-up. The risk period for a pig that was re-examined once and found to have cysticercosis was estimated to be half the number of months from the month following the month of its introduction to the farmer to the month before the month of cysticercosis detection. On the other hand, the risk period for a pig that was found to have cysticercosis in the second re-examination was calculated as the number of months of the first interval plus half the number of months in the second interval. Only the first infection was measured for a pig. The exclusion of the months of its introduction and re-examination from the period of risk was to avoid situations whereby a pig was introduced at the end of the month or re-examined at the beginning of the month. Considerations of the halfway intervals for infected pigs was based on the epidemiological principle that if the exact time of occurrence of an event is not known and the events can be assumed to occur uniformly over time, the event is likely to occur about halfway through the follow-up period (Smith and Morrow, 1996).

Incidence rates were calculated for each village and the mean rates for the intervention and control groups calculated. The incidence rate ratio (RR) of the control to the intervention group, and its 95% confidence interval were computed using Bayesian analysis in WinBUGS®, taking into account that the intervention was allocated at the village level. The percentage of the incidence rate of porcine cysticercosis among households exposed to the health education intervention, which had been prevented by the intervention, was calculated using the formula by Smith and Morrow (1996) as shown below.

PF = 1-RR... 2

Where, PF is the Prevented fraction and RR is the ratio of the incidence rate of the intervention group to that of the control group.

3.5.3.5.3 Analysing changes from the baseline prevalence of porcine cysticercosis

Changes from the baseline prevalence of porcine cysticercosis was analysed only for the lingual examination results because Ag-ELISA was not performed during the baseline study. Because the changes from the baseline prevalence of porcine cysticercosis were not normally distributed in both the intervention and control villages, comparison of the changes between the intervention and control groups was analysed using Mann-Whitney test.

3.6. Financial analysis of the health education intervention

The primary objective of the financial analysis in this study was to assess whether the health education intervention would have any additional financial benefit to the pig farmers if implemented in Mbulu District in northern Tanzania. The analysis was therefore done from the farmer's perspective. Investment appraisal, a simple form of benefit-cost analysis was used to analyse the financial efficiency of the health education intervention to the smallholder pig farmers in Mbulu District. Educating pig farmers on how to control porcine cysticercosis was considered an investment that would result into additional costs and benefits to the pig farmers.

The costs and benefits are related to the implementation of the parasite control measures, and reduction of disease morbidity, respectively. Costs and benefits considered to be associated with the health education intervention to pig farmers in Mbulu District are presented in Table 2.

Table 2. Farmer's benefits and costs considered to be associated with the health education intervention for controlling porcine cysticercosis in Mbulu District, northern Tanzania, 2004

Benefits	Costs
Additional revenue from selling pigs that are free from cysticercosis	Cost of the farmers attending the health education training
	Cost of constructing pigpens
	Cost of rearing pigs indoors

Although the transmission of porcine cysticercosis is caused by several factors such as random disposal of human faecal materials, eating raw or undercooked pork infected with *T. solium* larvae, drinking contaminated water, allowing pigs to roam freely, and feeding pigs with feedstuffs that are contaminated with *Taenia* eggs; epidemiological data for most of these factors are not reliable because they are normally based on interviews rather than direct measurement or observations by the investigator. It would therefore be difficult to assign reliable financial values to such variables. Therefore, although several factors were addressed during the farmers' education, the financial analysis of the intervention was focussed on pig-rearing method as a key factor. Another reason for choosing pig-rearing method as a key factor was based on a hypothesis that the environment in the study area was already contaminated with *T. solium* eggs, thus, susceptible pigs introduced to the area would mostly be prevented from infection if they were reared indoors.

3.6.1. Assumptions and formulas used in the financial analysis of the intervention

Based on the questionnaire interviews it was estimated that a pigpen constructed then would last for at least 5 years before it was repaired. The time span of 5 years was therefore used in the financial analysis of the intervention. In addition, the following assumptions were used in the analysis:

(a) The pig farmer keeps a fattener pig. This is an option preferred by most smallholder pig farmers in Mbulu District;

(b) A pig is replaced after the previous one has been sold;

(c) The health education is administered once in the time period;

(d) The adoption rate of the intervention observed in the present study will remain constant throughout the period;

(e) The observed incidence rate of porcine cysticercosis in the control and intervention groups and their 95% confidence limits will remain unchanged throughout the period; and

(f) Constant prices for goods and services will be used;

Like for biological data analysis, financial analysis of the health education intervention was done using intention-to-treat approach. Therefore, costs and benefits of housing pigs that resulted in both the intervention and control groups were included in the respective groups. Capital costs of the intervention (i.e. opportunity costs of farmers attending the seminar and the costs of constructing pigpens) were expressed as an initial lump-sum, occurring in the year zero of the study. The financial analysis was done using an Excel spreadsheet model (see Appendix G). When analysing health education intervention with no health education to farmers in Mbulu District, the sequence of events that would be expected to take place along each option were considered based on the findings from the present study (Figure 4). For example, total revenue from pigs allocated to the intervention group was calculated using the following formula:

Total revenue = Revenue from healthy pigs + Revenue from infected (cysticercotic) pigs

Revenue from healthy pigs was calculated as [(the number of pigs that would be free from cysticercosis annually x the proportion that would be reared indoors x the proportion that would reach slaughter weight annually under the indoor system x the market price of the healthy pig) + (the number of pigs that would be free from cysticercosis annually x the proportion that would be free-ranged/tethered x the proportion that would reach slaughter weight annually under the free-range/tethering system x the market price of the healthy pig)]. From Figure 4 this calculation would be:

Revenue from healthy pigs in the intervention group = (56 x 0.272 x 1.2 x TZS 51 250) + (56 x 0.0.728 x 0.71 x TZS 51 250). Appendix G shows the details of the calculations.

The net benefit of a particular option was calculated using the formula:

Net benefit = Total revenues – total costs..3

Incremental net benefit due to the intervention was calculated as the net benefit of the intervention group minus net benefit of the control group 4

The present values (PV) of incremental net benefits for various years were calculated using the formula:

$PV = X_t/(1 + r)^t$ 5

Where, PV is the present value of incremental net benefit due to the intervention, X_t is the incremental benefit of the intervention obtained in year t, r is the real annual interest rate in proportion, and t is the number of years from the present date (Rushton *et al.*, 1999).

Incremental net present value (NPV) of the intervention for the study period was calculated from the formula:

NPV = Sum of present values of incremental net benefits from Year 0 to Year 5 6

The internal rate of return (IRR) was computed in the spreadsheet to reflect a discount rate that would make the NPV equals zero 7

3.6.2. Analysis of the basic scenario of the intervention efficiency

Analysis of the basic efficiency of the health education intervention in controlling porcine cysticercosis was done using average market prices for goods and services, a real annual interest rate of 3% offered by Tanzania National Microfinance Bank (NMB) for depositing money in the bank, and assumed total condemnation of pigs infected with cysticercosis as per Tanzania government regulations. In addition, the overall incidence rates of porcine cysticercosis estimated in the intervention and control groups in the present study were used.

3.6.3. Sensitivity analysis

Analysis of the sensitivity of the health education intervention financial efficiency to changes in market prices and the intervention's effectiveness in reducing porcine cysticercosis was performed for different pig prices, interest rates, disease incidence rate confidence limits, and farmers' decision on whether to condemn infected pigs or sell them at a lower price. The NMB interest rates analysed were 7.1% and 13.5%, which are the real annual rates that the bank charges people who borrow TZS 500 000/= and 1 000 000/=, respectively.

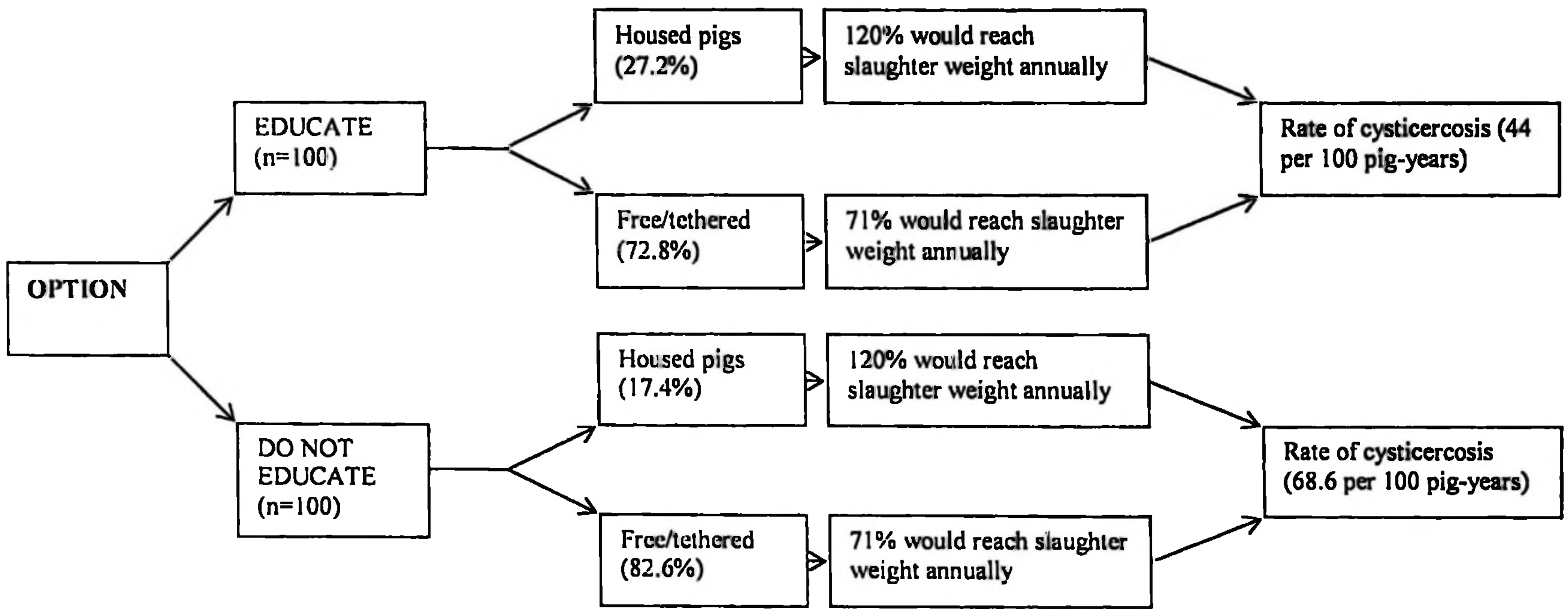

Figure 4. A sketch of the course of events considered when analysing the financial efficiency of health education intervention for porcine cysticercosis control in Mbulu District, northern Tanzania, 2004.

CHAPTER FOUR: RESULTS

4.1. Sociological study results

4.1.1. Demographic characteristics of the respondents in the sociological study

Out of the 61 respondents in the in-depth interviews and focus group discussions, 30 (49.2%) were women while 31 (50.8%) were men. The age of these respondents ranged from 21 to 89 years, with a median age of 39.5 years. Apart from the LFEO and RMA, the respondents were smallholder farmers. Of these, about 21.4% did not have any formal education while about 78.6% had attended some or completed primary school education. The LFEO completed an ordinary level secondary school education, while the RMA completed primary level education.

4.1.2. Importance of pig raising and porcine cysticercosis

Raising pigs was generally more preferred than raising cattle, goats, or chickens. This preference was observed among women and younger men. However, the older men preferred raising cattle mostly. Management and money themes were identified as the reasons for preferring pigs. The consensus was that pigs were comparatively easy to manage, requiring less production costs, and generating more money. For example, three farmers said that:

> "Pigs are easy to manage taking into account that we women have many other responsibilities (FGD 01, older woman)."

"I selected pigs as my first choice because I can afford to raise them and they generate money fast. If properly managed, it can take only nine months to raise a pig to slaughter weight (FGD 02, younger man)."

"I prefer pigs because their production costs are less and I can feed them using kitchen leftovers (FGD 03, younger man)."

Porcine cysticercosis is known as *fini* in the Iraqw language, and it was the most frequently mentioned problem with regard to raising pigs. A theme idea on issues related to failure to sell infected pigs because of porcine cysticercosis emerged as many smallholder pig farmers presented the issue. Respondents said that when a pig was infected with cysticercosis, the farmer was highly affected economically since pig traders would not buy the pig or if they did, at lower price. The importance of porcine cysticercosis to farmers was also revealed by their past and current efforts to control the infection. Different local methods were used to prevent and treat porcine cysticercosis. Although the effectiveness of the local control methods had not been investigated, information from the study population suggested that most of these had not been effective. Some farmers commented that:

"If we discover that a pig is infected with cysticercosis, we put more effort in feeding the infected pig so that we can sell it fast at a lower price and get rid of it. Pig traders can buy the infected pig at a lower price, but only after bargaining (FGD 04, younger man)."

"We have done a lot since porcine cysticercosis emerged. This includes using traditional herbs and removing the cysts. We have lost a lot of money with no success (FGD 09, older man)."

"What puzzles us most is that even tethering the pig outside does not prevent it from cysticercosis. We need to conduct research on this (FGD 10, younger man)."

4.1.3. Local knowledge about porcine cysticercosis, its cause, treatment and prevention

There were various thoughts about the causes of porcine cysticercosis among Mbulu communities. A theme idea that emerged from these opinions was lack of awareness of the source of porcine cysticercosis as illustrated by the following respondents' quotes:

> "I just see a pig with cysts but I do not know how it acquired it (FGD 11, older woman)."

> "My first time to hear about porcine cysticercosis was when pig traders came to buy my pig and after examining the tongue of the pig they told me that it had cysticercosis. I do not know the source of it (FGD 13. older man)."

> "Previously I thought that porcine cysticercosis was something falling from the sky (FGD 15, younger man)."

Although several local methods were used to treat pigs infected with cysticercosis as respondents reported them during the focus group discussions, the most common way used to treat infected pigs was the removal of the cysts. Respondents reported that when a live pig was diagnosed as having porcine cysticercosis, the visible cysts were removed using a sharp object such as a nail. Smallholder pig farmers said that cysts in a live pig were found under the tongue or in the eyelids. When respondents in the in-depth interviews were asked how one could prevent a pig from getting porcine cysticercosis there were several ideas suggested such as tethering the pig outside, building a pigpen, feeding the pig with soda ash, and selecting cyst-free piglets. Nevertheless, none of these emerged as a theme idea. However, the focus group discussion respondents reached a consensus that confining pigs in houses or pens was an important measure for preventing porcine cysticercosis. One farmer stated that:

> "In order to prevent my pig from cysticercosis I would build a pen for my pig so that it would not roam about, and would also add soda ash in the pig's feed (FGD 16, older man)."

4.1.4. Practices that facilitate the transmission of porcine cysticercosis in Mbulu District

On investigating factors facilitating the transmission of porcine cysticercosis in the study area, four themes emerged:

Theme 1: The traditional pig rearing method. There were three major methods of rearing pigs in Mbulu District. This study found that the most common method in Arri village was tethering. Tethering involves tying pigs in the backyard from morning to evening, with the pigs eating grass in the surrounding area, and sometimes farmers supplement them with some feed such as pumpkins, potatoes, and kitchen leftovers. Pigs are taken into the farmer's living house at night or placed in a pigpen if available. This study was conducted during the planting season when most pigs were tethered to restrict them from eating other peoples' crops. Discussions with farmers indicated that tethering was mostly practised during the cropping season.

The other two pig-rearing methods are the indoor method whereby the pig is totally penned, and the free range method in which the pig is let to roam freely (Plate 5), which is commonly practiced after harvesting. Although most of the pigs were tethered during the period of this sociological study, all focus group respondents agreed that the best method for raising pigs was the indoor method. Three farmers gave the following statements:

> "Tethering pigs outside and bringing them inside during the night is our tradition (FGD 19, older woman)."
>
> "Tethering is common here, but you find that pigs can escape and go to other people's compounds (FGD 20, older man)."
>
> "Some people tether their pigs some let them free during the dry season (after harvesting) while others house them (FGD 21, younger man)."

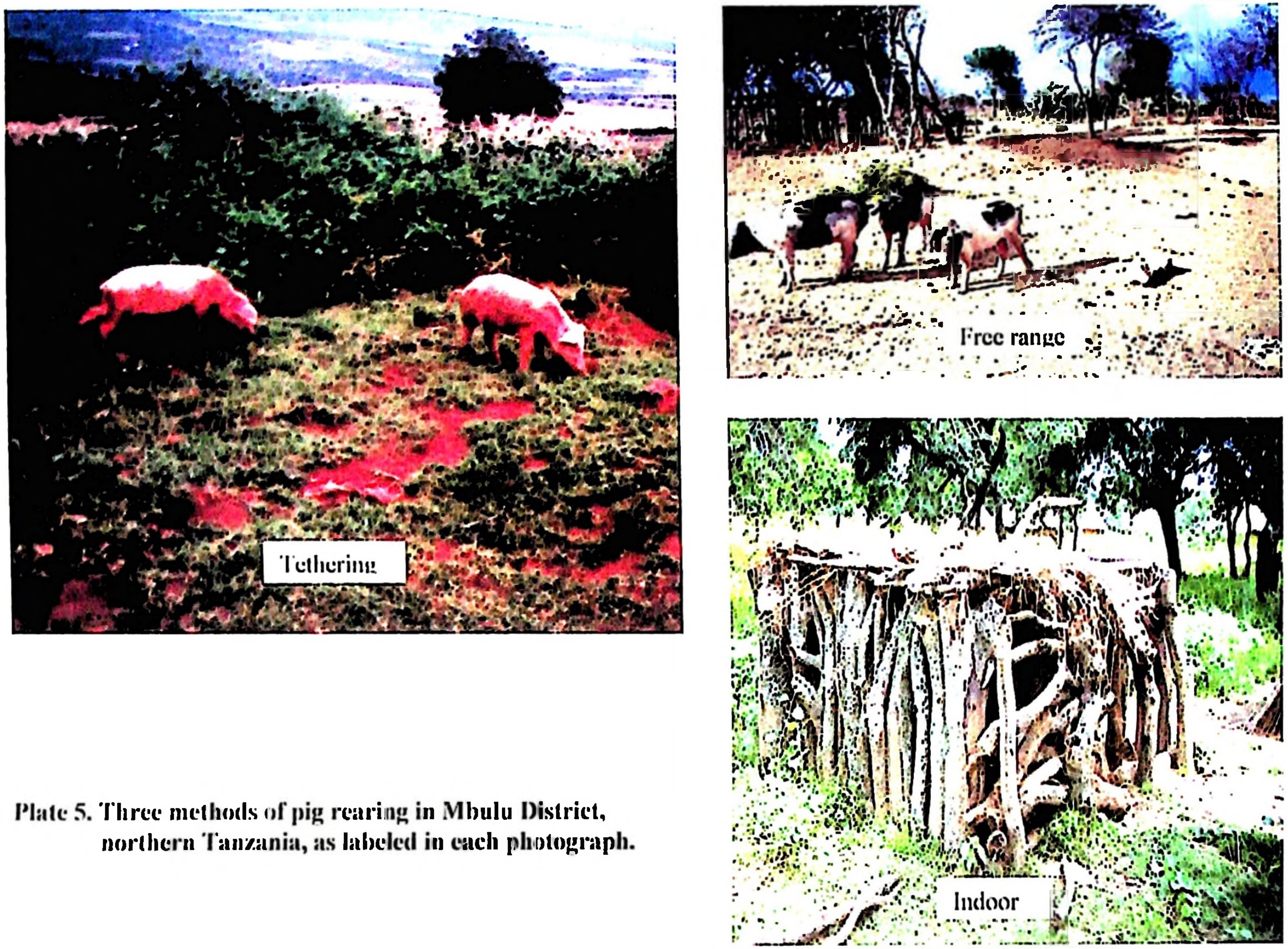

Plate 5. Three methods of pig rearing in Mbulu District, northern Tanzania, as labeled in each photograph.

Theme 2: Eating/selling infected pork. Focus group discussion respondents agreed that if pork was heavily infested with cysts, it was disposed of and that lightly infested meat was cooked and consumed. Respondents said that boiling infected pork and later selling it was a common practice. The following statements illustrate this theme:

> "Frankly speaking, infected pork is just roasted and consumed (FGD 23, older woman)."

> "You know, a human being cannot throw away meat. If a person found that pork had too many cysts, one selected the better and lightly affected areas and consumed the meat (FGD 24, older man)."

> "In our tradition we do not throw away meat, we boil the infected meat and sell it (FGD 25, older man)."

Theme 3: Drinking un-boiled water. The main source of water for villagers' home consumption was reported to be the river. It was common across focus group discussions that only a few people in the village boiled the water before drinking it, while the majority did not. Some farmers commented that:

> "Water needs to be boiled before one drinks it but in this village people do not do that (FGD 27, younger woman)."

> "There are some people who are a little bit developed and boil water for drinking. This is a small percentage (FGD 28, younger man)."

> "Sometimes I come from work very tired, I just drink un-boiled water (EGD 29, older woman)."

Theme 4: Not washing hands after using the pit latrine. The researcher asked the respondents to mention the three most important occasions during a day that they must wash their hands, for example, before a meal, after using the pit latrine, or both.

Although washing hands after using the pit latrine was identified as important, further probing of its practicality revealed that washing hands after using the pit latrine was done infrequently. The quotes below illustrate this observation:

> "Washing hands after using the pit latrine is not done in this village (FGD 31, younger woman)."

> "It (washing hands after using the latrine) is possible, but it is not practised (FGD 32, older man)."

> "This practice of going to the latrine and washing hands later is the most difficult one (FGD 33, younger man)."

4.1.5. Knowledge of LFEO and the RMA on porcine cysticercosis, human taeniosis and epilepsy

The LFEO said that there were no slaughter slabs in the 14 villages that he supervised, and that when a pig was found to be infected with five or fewer cysts, the meat was boiled and could then be consumed by people. On the other hand, when the number of cysts on a pig exceeded five, the entire carcass was condemned. The RMA reported that among the top ten disease conditions reported most frequently at the local health centre during the previous year (that is 2001), intestinal worm infection was ranked as the number five complaint. She also said that the health centre did not have diagnostic facilities, but based on patients' history of clinical signs patients were suspected to suffer from tapeworm infections, and were treated with mebendazole. The RMA said that the source of tapeworm infection was hand contamination, and that there were few epileptic patients reported in the local health centre. The few epileptic patients seen at the health centre were treated with anticonvulsant drugs including phenobarbital and phenytoin.

4.1.6. Farmers' recommendations for changing practices related to *Taenia solium* transmission

Respondents in both the focus group discussions and in-depth interviews gave several recommendations for the control of porcine cysticercosis. Although no theme idea emerged from the comments, some of them were useful with regard to designing educational messages for effective and sustainable control of the parasite. Some of the recommendations included: (a) provide people with a container to place in their pit latrines in which they could put water for washing hands after using the pit latrines; (b) educate some pig farmers who could later educate others and could demonstrate in their homes the best practices; and (c) teach pig farmers to confine piglets as well as adult pigs. Other comments were that (d) health education should be supplemented with persistent enforcement of by-laws that each household should build a pit latrine and use it; (e) assist pig farmers to secure improved pig feed, medication, and breeds since most of them could not afford or access them; (f) educate pig farmers on better pig husbandry and management. Furthermore, farmers suggested that (g) the educational programme should make use of existing community committees; (h) women should also be targeted for health education as they are mostly involved in pig rearing; and (i) the health educator be one from or outside the community. However, older women suggested that the educator be a man and not a woman in order for their husbands to accept recommendations.

4.1.7. Barriers to changing practices that facilitate the transmission of porcine cysticercosis in Mbulu District

In both the in-depth interviews and the focus group discussions, no important constraint emerged as a theme idea with regard to possible barriers to the farmers changing practices that facilitate *T. solium* transmission. However, several pig farmers mentioned some factors that could hinder the adoption of the indoor pig rearing method. These farmers said that rearing pigs indoors throughout their lives was difficult to adopt due to food seasonality, poor growth of indoor-fed pigs, and the heavy workload for removing the accumulated manure.

4.2. Baseline study results

Table 3 shows the general characteristics of respondents and pigs examined during the baseline study. About 98% of the respondents were smallholder farmers. The study interviewed more women than men, suggesting that, in addition to being more responsible for rearing pigs, women are more available at home than men. The baseline study revealed an illiteracy rate of about 30% in Mbulu District.

Table 3. General characteristics of respondents and pigs examined during the baseline study in Mbulu District, northern Tanzania, 2002-2003

Individuals and characteristics	Relevant statistic
Questionnaire respondents	
Gender (n = 799): Female respondents (percent)	63.3
Age (n = 800): Median and range (years)	30 (13-113)
Level of education (n = 798)	
➢ No formal education (percent)	29.6
➢ Some primary school education (percent)	68.8
➢ Secondary school or college (percent)	1.7
Occupation (n = 777)	
➢ Smallholder farmers (percent)	97.6
➢ Others (employees etc.) (percent)	2.4
Position in the household (n = 797)	
➢ Mother (percent)	52.1
➢ Father (percent)	27.4
➢ Children (percent)	16.8
➢ Others (in-laws) (percent)	3.8
Pigs examined	
Sex (n = 781): Female (percent)	47.0
Age (n = 775)): Median and range (months)	8 (2-12)

The quantitative baseline knowledge and practices related to *T. solium* transmission is presented in Table 4 and Table 5. Less than 50% of the respondents knew about porcine cysticercosis transmission. The knowledge of the respondents about the link between porcine cysticercosis and human tapeworm was negligible (Table 4). The prevalence of risk factors for the transmission of *T. solium* was high ranging from 24-94% (Table 5).

The findings of the quantitative data analysis support the findings from the qualitative data in the sociological study, which revealed lack of knowledge of porcine cysticercosis transmission, and presence of risk behaviours for the transmission of *T. solium*, such as poor personal hygiene and eating infected pork.

Table 4. Baseline knowledge related to *Taenia solium* transmission based on questionnaire interviews in Mbulu District, northern Tanzania, 2002-2003

Factor	Number of respondents*	Positive responses	Percentage	95% CI
Knowledge on how a pig acquires cysticercosis (PCC)	585	272	46.5	42.4, 50.6
Knowledge on how to prevent PCC	581	265	45.6	41.5, 49.8
Knowledge on how human tapeworm (HT) infection is acquired	256	52	20.3	15.6, 25.8
Knowledge on how to prevent HT	256	36	14.1	10.0, 18.9
Knowledge of at least one relationship between PCC and HT	208	14	6.7	3.7, 11.0

*Note that many questions were conditional to some previous questions. This led to observed variations in the total number of respondents.

Table 5. Baseline practices related to *T. solium* transmission based on investigator's observation (O) or respondent's report (R) in Mbulu District, northern Tanzania, 2002-2003

Factor	Observations or respondents	Positive responses	Percentage	95% CI
The household was not using a latrine (O)	818	193	23.6	20.7, 26.7
The used latrines did not have closing doors (O)	625	586	93.8	91.6, 95.5
The pig was roaming freely* (O)	779	223	28.6	25.5, 32.0
The respondent eats pork infected with cysticercosis (R)	522	198	37.9	33.8, 42.2
The respondent does not wash hands after using the latrine (R)	800	235	29.4	26.2, 32.7
The respondent does not boil drinking water from the(R):				
• River	342	166	48.5	43.1, 54.0
• Well (bore hole)	333	183	55.0	49.4, 60.4
• Tap	102	43	42.2	32.4, 52.3

*Most of the observed pigs were tied outside and a few were kept indoors.

The baseline prevalence of porcine cysticercosis based on lingual examination and of at least one case of human taeniosis based on respondents' reports is presented in Table 6. While only about 8.5% of households reported to have at least one current case of tapeworm infection, 33.1% of the remaining households reported to had experience at least one case previously. This suggests possible self-cure of tapeworm carriers using traditional medicine as reported by some respondents. It could also be lack of transparency by some respondents to report current cases as the information is likely to be sensitive.

Table 6. Baseline prevalence of porcine cysticercosis based on lingual examination of live pigs (two to twelve month old), and of at least one case of human taeniosis based on respondent's report in Mbulu District, northern Tanzania, 2002-2003

Factor	Households Examined	Positive observations	Percentage	95% CI
Porcine cysticercosis	784	57	7.3	5.6, 9.3
Human taeniosis				
• Current (believed to have it on the day of our visit)	258	22	8.5	5.4, 12.6
• Recovered (experienced previously but not currently)	236	78	33.1	27.1, 39.4
• Total (current or recovered)	258	100	38.8	32.8, 45.0

4.3. Educational messages and the target groups

Based on the sociological and baseline study findings, it was found appropriate to educate pig farmers on the importance of (a) building better pigpens using locally available materials; (b) confining all pigs (adults and piglets); (c) not to eat or sell infected pork; (d) thoroughly cooking meat; (e) building good pit latrines using locally available materials; (f) washing hands after using the pit latrine and before eating anything; and (g) boiling water for drinking purposes. Other messages included (h) the importance of adhering to the government regulations regarding disposal of infected pork, i.e. whenever there is evidence of cysticercosis infection in a pig carcass, the entire carcass should be condemned (URT, 1962).

From the sociological study it was possible to understand that the control of each of the risk factors was the responsibility of the family as a whole although women were mostly involved in pig rearing. The family was therefore identified as the target for the messages. This study identified a trained LFEO as an appropriate person to educate pig farmers on health and pig management.

4.4. Development and production of health educational materials

Respondents suggested using videos, training sessions, field demonstrations and penalising people who would not house their pigs or use latrines. All these approaches were considered as possible means of disseminating information to control *T. solium* in the area. After considering the demographic structure of the

Mbulu community in addition to the feasibility and sustainability of all the recommendations. use of training sessions. a video, and a variety of health educational pamphlets was found to be appropriate for this community. Thus a video, a leaflet, a comic booklet, two posters, and a training manual were together considered to be a sufficient package to use for the health education campaigns. A video produced in 2001, a year before this study was found appropriate for this campaign. This video was filmed in Mbulu District involving local farmers acting in various roles in a story line regarding *T. solium*. The video was edited and produced at the Danish Meat Research Institute in Roskilde, Denmark. Two versions of the video were made- one in Kiswahili and one in Iraqw language. This decision was based on the findings that a few residents could not understand Kiswahili. Therefore, it was found important that the two versions be shown to the farmers in order to address the language problem. The two versions were in a digital versatile disc (DVD) so that it was easy to switch from one version to another.

Modified templates of posters and leaflets made by the Cysticercosis Working Group of Eastern and Southern Africa (CWGESA) in their annual meeting held in Nairobi, Kenya in February, 2001 were also used. In addition, a comic booklet and a training manual were designed to complement the other materials. The leaflet, comic booklet and posters were assembled by an artist and printed by Development Communications Company (DevCom) in Nairobi, Kenya. The training manual was printed at Sokoine University of Agriculture, Tanzania. The video, leaflet, and training manual explained the life cycle of *T. solium*, its public health and financial importance, and ways to prevent infection or transmission. The comic booklet emphasised the financial importance of the parasite especially with regard to pig condemnation. One of the two posters described the life cycle of the parasite, while the other demonstrated important sites where a farmer could see *T. solium* cysts in both live and slaughtered pigs. The posters and the training manual were intended for use during farmers training sessions. All the pamphlets were in Kiswahili and pre-tested in the study area for clarity and relevance before their final production.

4.5. Follow-up study results

4.5.1. Change in knowledge and practices related to porcine cysticercosis transmission

Table 7 shows the general characteristics of the full-participants in the intervention and control groups at the end of the follow-up study. The two groups were well balanced in terms of possible factors that could confound the effect of the intervention. Results of the knowledge- and practice-change comparison between the intervention and control groups are presented in Table 8 and Table 9. Six months after the intervention there was a significant improvement in the knowledge of the respondents about how a pig acquires cysticercosis and how to prevent it, in both the intervention and control groups (Table 8). The control group also improved significantly on the use of latrines. During this period, the net effect of the intervention was statistically significant with regard to the improvement of knowledge on how a pig acquires cysticercosis, how to prevent it, and the relationship between porcine cysticercosis and human taeniosis (Table 8). The improvement was 27.4%, 37.7%, and 18.0%, respectively. At the end of the follow-up study (10-12 months after the intervention) there was no significant effect on the improvement of knowledge, attributed to the intervention, because the control group improved more than the intervention group during this time (Table 9). Throughout the follow up study, the intervention did not have any significant improvement on the practices related to the transmission of *T. solium* (Table 8 and Table 9).

Table 7. General characteristics of the full-participant intervention (T) and control (C) groups at the end of the follow-up study in Mbulu District, northern Tanzania, 2003-2004

Factor	T - group	C – group	Total
Villages included	21	21	42
Households included that completed the study	201	192	393
Pig age when entered into the study (months) – median and (mean in brackets)	2 (2.2)	2 (2.4)	2 (2.3)
Pig gender ratio (percentage of females)	50.6	56.9	53.8
Number of months followed up – median and (and range in brackets)	4 (1-9)	4 (1-9)	4 (1-9)
Total pig-months of follow-up – ELISA and (tongue in brackets)	650.5 (721.5)	593.5 (690)	1244 (1411.5)
Losses of pigs to follow-up due to deaths and other causes (percentage)	24.3	22.5	23.4
New cases of porcine cysticercosis detected – ELISA (and tongue in brackets)	23 (8)	34 (15)	57 (23)
New pigpens constructed (number and percentage from originally without one)	15 (15.5)	11 (10.7)	26 (13.0)

Table 8. Change (mean proportions) from the baseline knowledge and observed practices related to porcine cysticercosis between the intervention, T (n = 7) and the control, C (n = 9) villages six months after the intervention in Mbulu District, northern Tanzania, 2002-2004

Factor	T-village change	T-village 95%CI	C-village change	C-village 95%CI	Intervention effect (T-C)	95%CI of T effect
Knowledge on how a pig acquires PCC	0.4801	0.35, 0.61*	0.2064	0.04, 0.37*	0.2737	0.07, 0.48*
Knowledge on how to prevent PCC	0.5543	0.40, 0.71*	0.1775	-0.02, 0.38	0.3768	0.13, 0.62*
Knowledge on how a person acquires HT	-0.0065	-0.14, 0.13	0.0418	-0.15, 0.06	0.0352	-0.12, 0.19
Knowledge on how to prevent taeniosis HT	0.0639	-0.09, 0.22	-0.0121	-0.13, 0.11	0.0760	-0.10, 0.25
Knowledge on PCC-HT relationship†	0.1373	-0.09, 0.36	-0.0412	-0.10, 0.01	0.1785	-0.00, 0.36*
The household was using a latrine	0.0506	-0.03, 0.13	0.1353	0.02, 0.26*	-0.0846	-0.23, 0.06
The latrine did not have a closing door or wall	0.0590	-0.06, 0.17	0.0746	-0.03, 0.18	-0.0155	-0.16, 0.12
The pig was roaming about	-0.0986	-0.32, 0.12	-0.0932	-0.23, 0.04	-0.0054	-0.23, 0.22

* Statistically significant since the 95% CI of the difference does not include zero

†This was re-tested non-parametrically using Mann-Whitney test because of non-normality. It was significant at $P = 0.0312$.

Table 9. Change (mean proportions) from the baseline knowledge and observed practices related to porcine cysticercosis between the intervention, T (n = 21) and the control, C (n = 21) villages 10-12 months after the intervention in Mbulu District, northern Tanzania, 2002-2004

FACTOR	T-village change	T-village 95%CI	C-village change	C-village 95%CI	95%CI of T effect
Knowledge on how a pig acquires PCC	0.4440	0.38, 0.52*	0.4373	0.34, 0.53*	-0.11, 0.12
Knowledge on how to prevent PCC	0.4443	0.35, 0.54*	0.4334	0.32, 0.55*	-0.13, 0.15
Knowledge on how a person acquires HT	0.0199	-0.08, 0.12	0.0872	-0.02, 0.19	-0.21, 0.07
Knowledge on how to prevent HT	0.0850	-0.02, 0.19	0.0475	-0.03, 0.13	-0.09, 0.16
Knowledge on PCC-HT relationship	0.0025	-0.08, 0.08	0.0075	-0.04, 0.06	-0.09, 0.08
The household was using a latrine	0.0634	-0.01, 0.14	0.0974	0.03, 0.17*	-0.14, 0.07
The latrine did not have a closing door	0.0644	0.02, 0.11*	0.0875	0.04, 0.14*	-0.09, 0.04
The pig was roaming about	-0.0673	-0.17, 0.03	-0.1174	-0.22, -0.01*	-0.09, 0.19

4.5.2. Change in the incidence rate and prevalence of porcine cysticercosis transmission

Table 10 presents the comparison of the incidence rate of porcine cysticercosis between the intervention and the control groups 10-12 months after the intervention in Mbulu District. The incidence rate of porcine cysticercosis in the control group was 1.6 and 2.2 that in the intervention group as detected by Ag-ELISA and lingual examination methods, respectively. However, the incidence rates ratios were not statistically significant (95% CI: 0.93, 2.71 and 0.84, 4.92, respectively). The fraction of the incidence rate in the intervention group that was prevented by the intervention was 35.9% and 52.9% by Ag-ELISA and lingual examination, respectively. Table 11 shows changes from the baseline prevalence of porcine cysticercosis between the intervention and control groups as detected by lingual examination in Mbulu District. The prevalence of porcine cysticercosis in the control group increased by 3.1% while that in the intervention decreased by 1.6%. However, there were no significant statistical differences in the change from the baseline prevalence between the control and the intervention groups (Table 11).

Table 10. Mean incidence rate of porcine cysticercosis in the intervention (T) and the control (C) villages ($n_1 = 21$ and $n_2 = 21$), 10-12 months after the intervention in Mbulu District, northern Tanzania, 2004

Diagnostic test	T – group (per 100 pig-years)	C – group (per 100 pig-years)	RR	95% CI	Prevented fraction (percent)
Ag-ELISA	44.0	68.6	1.6	0.93, 2.71	35.9
Lingual exam	12.0	25.5	2.2	0.84, 4.92	52.9

Table 11. Change from the baseline prevalence of porcine cysticercosis between the intervention (T) and control (C) group as detected by lingual examination in Mbulu District, northern Tanzania, 2002-2004

	Prevalence before intervention (percent)	Prevalence after intervention (percent)	Change from baseline (percent)	Rank sum	Z	P
T - group	6.6	5.0	-1.6	421.5		
C - group	6.6	9.7	3.1	481.5	0.792	0.4282

4.5.3. Results of the financial analysis of the health education intervention

Table 12 shows the NPV and IRR for the basic scenario. The basic financial analysis of the intervention indicated that there would be a significant financial gain to the smallholder pig farmers in Mbulu District, if they were offered education to control porcine cysticercosis (NPV: TZS 4 034 030.4; IRR: 370%). Table 13 shows results of the sensitivity analysis. The health education intervention would remain financially efficient regardless of the possible changes in pig prices, bank interest rates, decrease in the effectiveness of the intervention in reducing the incidence rate of porcine cysticercosis, and whether smallholder farmers sell infected pigs at a lower price instead of condemning them (Table 13). However, the incremental NPV would be about two-times higher if infected pigs were condemned than if they were also sold.

Table 12. Net present values (NPV) and internal rates of return (IRR) of the health education compared to no health education to pig farmers, under the basic scenario in Mbulu District, northern Tanzania, 2004

Item/Year	0	1	2	3	4	5
Net benefit with health education	-603024.0	-107147.3	592852.7	592852.7	592852.7	592852.7
Net benefit without health education	-360180.0	-1041022.4	-341022.4	-341022.4	-341022.4	-341022.4
Incremental net benefit discounted*)	-242844.0	906674.8	880266.8	854628.0	829735.9	805568.8
NPV =						4034030.4
IRR =						370%

*Discount rate is 3%

Table 13. Net present values (NPV) and internal rates of return (IRR) of the health education compared to no health education to pig farmers, under various scenarios in Mbulu District, northern Tanzania, 2004

Scenario	NPV (TZS)*	IRR (percent)
When pigs infected with cysticercosis are condemned and:		
• Healthy pigs are sold at their average price of TZS 51250 (basic scenario)	4 034 030.4	370
• Healthy pigs are sold at their minimum price (TZS 45 000)	3 398 840.9	315
• Healthy pigs are sold at their maximum price (TZS 100 000)	8 988 508.4	803
• When the incidence rates of porcine cysticercosis in the intervention and control groups are at their lower 95% confidence limits	3 719 614.0	343
• When the incidence rates of porcine cysticercosis in the intervention and control groups are at their upper 95% confidence limits	4 368 169.0	400
• The farmers borrow money from the bank and pay a real annual interest rate of 13.5%	3 002 131.6	327
When infected as well as healthy pigs are sold at their average prices (TZS 24 500 for infected)	2 087 413.2	200

CHAPTER FIVE

DISCUSSION

This study has for the first time reported results of a randomised, controlled, community-based health education intervention trial for the control of porcine cysticercosis in an endemic situation. The study has also intensively involved the target community in the planning and implementation of the health education intervention for effective and sustainable control of the parasite. By working with the community groups in the preparation and dissemination of the health educational materials, members were able to participate in different ways and this was considered a key output of the programme. This approach addressed a concern among some professionals that health education focuses too much on implementing interventions and too little on designing interventions that are strategically planned to meet demonstrated needs (Glanz *et al.*, 2002).

The use of a control group in this study helped to disentangle the effect of time or other factors, including the "Hawthorne effect", which could have changed the levels of knowledge, practices, or frequency of the infection. The Hawthorne effect in educational studies is similar to the "placebo effect" seen in clinical trials. It can be defined as a situation whereby an individual's behaviour is altered because the individual knows that he is being studied (Glanz *et al.*, 2002; Carabin *et al.*, 1999). The mere act of showing people that someone is concerned about them usually spurs them to better task performance. This influences the outcome of interest in some proportion that cannot be attributed to the planned intervention. By comparing changes from the baseline between the intervention and the control group, many unexplained effects could be controlled.

From the sociological and the baseline studies it is apparent that pig production is an important enterprise especially for women, which provides fast and adequate money to solve their common problems. However, porcine cysticercosis has been an obstacle for accessing local and outside markets. Control of porcine cysticercosis in Mbulu District would, therefore, improve the economic well being of the poor rural women and consequently improve the family living standards. This is because women, especially those living in rural areas, play an important role in the family livelihoods including taking care for children's health and education.

This study has also revealed that porcine cysticercosis is locally recognised as a financial rather than a public health problem. This can partly be attributed to the poor knowledge of people on the parasite's public health consequences. The observed negligible knowledge of people on the human aspect of the parasite supports this observation. Lack of knowledge about how the parasite is transmitted and the high prevalence of transmission risk factors are likely to facilitate the transmission of *T. solium* in Mbulu District.

The prevalence of 8.5% of at least one active case of human taeniosis at the household, estimated in this study is relatively high. Although the estimation was based on the respondents' recall, it should be fairly reliable since the question as to whether the family had a case of tapeworm infection was conditional on whether the respondent identified the tapeworm correctly when shown roundworm and tapeworm samples in two different transparent bottles. Nevertheless, because consumption of beef is also common in the study area, and the fact that *T. saginata saginata* proglottids are more motile than those of *T. solium*, most of the reported taeniosis may be due to *T. saginata saginata*. Specific diagnostic tests such as immunoblot are needed to confirm cases of taeniosis that are caused by *T. solium* infection in Mbulu District.

There are limited reports on the prevalence of human taeniosis in rural communities elsewhere. In Kenya, the prevalence of human taeniosis in the rural population was estimated to be 2% (Githigia *et al.*, 2002). In Nigeria, a higher prevalence of up to 8.6% has been reported in some rural areas (Onah and Chiejina, 1995), which is comparable to the estimate of the present study. In Latin America, prevalence of human taeniosis based on either coproantigen ELISA or stool microscopy have been reported to range from 0.2 to 2.8% (Flisser *et al.*, 2003). The present study found that about 38.8% of the study households had experienced at least one case of human taeniosis in their life. This proportion of people can pose serious environmental contamination with *Taenia* eggs, considering that a good proportion of the households do not use pit latrines.

The present study used different types of educational materials to disseminate health messages to smallholder pig farmers. This approach was appropriate since each medium has advantages and disadvantages (Lloyd *et al.*, 1994). In Mbulu community, one disadvantage of the pamphlets is that about 30% of the population is illiterate, and therefore, cannot read. This problem was considered during designing the materials so that the pictures were made as illustrative as possible to enable an illiterate individual to follow the story line. In the present study, one observed advantage of the pamphlets is that they can be dispatched to the target group through their neighbours or friends if the individuals in the group did not attend the health education training sessions. This increases the coverage of the intervention. Other advantages of the pamphlets are that they can be kept for further reference and can be borrowed by neighbours and friends, therefore, increasing information dissemination. The advantage of the video is that even illiterate individuals can easily understand it and the residents may be more interested, especially after recognising the people and the areas they know. In our study, the use of the local and national languages at different times enabled every participant to follow the story. One disadvantage of the video is that it cannot easily be shown in areas without electricity supply. This was the case in Mbulu District, where we used specialized equipment to show the video in the villages.

Six months after the health education intervention, there was a rapid increase in the knowledge about how a pig acquires cysticercosis, how to prevent it, and the relationship between porcine cysticercosis and human tapeworm in both the intervention and control groups. The improvement in knowledge was maintained to a strong degree throughout the study, with the control group showing further improvement than the intervention group. This gives an indication of possible spill over of the health educational messages from the intervention to the control villages and might have contributed to the lack of statistically significant net effects of the intervention on the knowledge at the end of the study. The positive side of this observation is its indication of the possible high rate of diffusion of information in the area and emphasizes that education of only a few farmers may result in a significant change in knowledge in the community.

In the present study, despite the fact that the participating farmers were blinded with regard to the actual objectives of the study, the Hawthorne effect might have occurred in both the intervention and control groups because the smallholder pig farmers were given piglets and monitored over time. Slower rate of improvement in knowledge in the intervention group from 6 months to the end of the study, suggests possible presence of a stronger Hawthorne effect in this group. The presence of a stronger Hawthorne effect in the intervention than the control group may be due to the fact that smallholder pig farmers in the intervention group were more aware that they were being followed up because they were exposed to the health education.

The health education intervention did not show any improvement in the practices related to the transmission of *T. solium*. Lack of improvement of practices especially on the pig rearing methods suggests that the knowledge was not put into practice and this might have been attributed to poverty and some cultural beliefs. It is worth mentioning here that the observed method of pig rearing at the time of the examiner's visit to a household may not be a permanent practice as it could depend on the time of the day that the household was visited. If the household was visited early in the morning the practice was likely to be less permanent since most pigs were taken outside during the daytime. It was not possible due to time constraint for the most permanent practice to be determined due to the large number of households that had to be visited. However, it was expected that the confounder would be distributed equally between the intervention and the control groups. Failure to observe permanent pig rearing practices has led to failure of studies elsewhere to be certain about the true association between the prevalence of porcine cysticercosis and pig rearing methods (Sarti *et al.*, 1992). This could be overcome by studies employing participant observation method, whereby an investigator lives with the target community and participates while observing their daily activities for longer periods.

The present study estimated an incidence rate of porcine cysticercosis of 68.6 cases per 100 pig-years in the control group (95%CI: 39.0 – 98.2). This implies that if 100 piglets that are free from cysticercosis were introduced to farmers in the study area and observed for 1 year, about 69 of them would be diagnosed as having cysticercosis by Ag-ELISA at the end of the year. Because the sensitivity and specificity of the Ag-ELISA are 86.7% and 94.7%, respectively (Dorny *et al.*, 2004), the observed incidence rate of porcine cysticercosis can be an underestimate or overestimate of the true value. The same situation could have also occurred because the pigs were examined at longer time intervals and it was not possible to know exactly when a pig acquired the infection. The arbitrary halfway-interval used to estimate the possible time of infection might have been too long or too short for some pigs.

Unfortunately there is not a single study conducted elsewhere that has properly estimated the incidence rate of porcine cysticercosis under field conditions. One study in Peru attempted to examine the incidence of porcine cysticercosis in sentinel pigs (Gonzalez *et al.*, 1994). However, because of the small sample size included in the analysis (n = 28), which resulted from 82.2% losses of pigs to follow-up, and the fact that the authors tried to measure new infections in infected and non-infected pigs using antibody-detection method, their findings cannot be compared with the findings of the present study. Therefore, the incidence rate of porcine cysticercosis observed in the present study should be judged on its own, and it seems to be very high, especially given the very short period during which each pig was observed. The observed high incidence rate of porcine cysticercosis is an indication of environmental contamination with *T. solium* eggs and therefore indicates high risk of human infection with cysticercosis (Gonzalez *et al.*, 1994).

The incidence rate of porcine cysticercosis in pigs allocated to the intervention group was 44.0 per 100 pig-years (95% CI: 17.7 – 70.2), when measured by Ag-ELISA. Lack of statistical significance in the difference between the control and the intervention group rates of porcine cysticercosis, may be due to the short follow up period of pigs (median 4 months), and the small sample sizes in many villages studied, which resulted from pig farmers withdrawing from the study. Both situations reduce the power of the study to detect a difference as statistically significant. Nevertheless, the observed attributable fraction of about 36%, which is the intervention's effectiveness in reducing the incidence rate of porcine cysticercosis, is of clinical and economic importance.

As in this study, a study in Mexico found a trend towards reduction in the prevalence of porcine cysticercosis after health education of farmers despite the fact that the related practices did not improve (Sarti *et al.*, 1997). It can be learned from these findings that what is needed to reduce porcine cysticercosis incidence is creating pig farmers' awareness on the parasite's mode of transmission, and ways for preventing it. From this knowledge farmers are likely to implement unnoticeable measures to prevent their pigs from the infection.

Although most smallholder pig farmers in the intervention group partially complied with the intervention recommendations, particularly with regard to the construction of pigpens and housing the pigs, and the fact that there was an evidence of spill-over of information from the intervention to the control group, financial analysis indicated that there would be a significant monetary gain in the long run for the pig farmers. This may be a reflection of the observed important reduction of the incidence rate of porcine cysticercosis induced by the intervention, and it emphasizes the need for considering the clinical importance of an intervention effect even when the statistical effect is not significant. The double incremental benefits of the intervention observed when infected pigs were condemned as compared to when they were sold, emphasized the need to reinforce government regulations for total condemnation of infected pigs. This would not only safeguard the public health, but also enable the smallholder pig farmers to see the financial benefit of selling a healthy pig as opposed to selling an infected one. This could probably encourage them to implement disease control measures in the future. Unfortunately there are no studies that have examined the economics of porcine cysticercosis in a randomised field trial to compare with this study.

Lack of control of experimental conditions, including protocol violations observed in this study, merits further controlled studies to determine the true association between porcine cysticercosis and risk factors such as type of rearing practices and use of latrines. Such studies should include incentives to smallholder pig farmers to enable them follow the protocols. For example, farmers could be assisted on pig feeds to be able to rear their pigs indoors throughout the study period.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

This study has developed specific educational packages for the control of *T. solium* in Mbulu District, northern Tanzania. The packages can be used in other areas inside and outside the country, where there are similar socio-cultural settings. However, preliminary sociologic studies are needed to examine the relevance of the materials to the areas before implementing them.

As opposed to laboratory experiments, this randomised field trial has revealed difficulties in controlling experimental conditions such as treatment coverage, losses to follow-up, and contamination between the experimental and control groups. Most of these factors reduce the sample size, the effect size, and hence the power of the study. Based on these factors it is recommended that the health education intervention be considered based on its clinical and economic importance.

The shorter follow up time for pigs in this study, was due to the fact that the study was carried out as part of a degree programme, which was time limited. This study recommends future intervention studies for porcine cysticercosis be planned independent of a particular time limited programme, in order to allow a reasonable follow up time for pigs to increase the power of the study.

The present study recognised the role of women in pig rearing, and therefore, recommends that women be encouraged to participate in the control programme for *T. solium*. The presence of Hawthorne effect in this study suggests that monitoring of pig management practices may encourage the farmers to take more care in raising their pigs. Therefore, veterinary/agricultural extension officers should be encouraged to make routine visits to pig farmers and offer information on pig management. Government authorities should considered facilitating the extension officers in terms of transport ad other related costs to be able to conduct outreach programmes to the farmers. The feasibility of using information and communication technologies (ICTs) such as radio programmes, television, and telephones as well as including school children as an important target for the educational messages should be investigated in order to facilitate the easy and wider dissemination of agricultural information to farmers in Mbulu District. The study also recommends that the veterinary and medical personnel be updated with regard to *T. solium* transmission and control methods. This was based on the observations that the RMA had incorrect knowledge concerning how the human tapeworm infection is acquired, while the LFEO took incorrect actions when he encountered a pig infected with cysticercosis during meat inspection.

In this study, care was taken ensure that financial investments in the intervention by the project were minimal. This was to see the real responses of the pig farmers taking own initiatives to the intervention, which was thought to increase the intervention effectiveness and sustainability. For example, in the sociologic study farmers requested that they be given containers for washing hands after using the pit latrines, and be assisted with securing adequate feed for their pigs. None of these requests were fulfilled in the present study for fear that such actions would not be sustainable after the end of the study. However, farmers were advised to use better local resources for building pigpens and pit latrines. Although the actions recommended for the control of *T. solium* required little financial investment, commitment of the farmers was needed as most of the actions were labour demanding. For example, total confinement of pigs needed that additional feed and labour were available for feeding the pigs and cleaning their sties. Smallholder pig farmers should be informed about the additional benefits accrued from adopting the interventions for controlling porcine cysticercosis.

In any control programme directed to *T. solium* control, health education should be a necessary component. The health education should be implemented before other components of the control programme in order to prevent re-infection and further transmission of the parasite, by creating peoples' awareness on the preventive measures for the parasite. Furthermore, demonstration activities combined with educational packages are needed to educate smallholder pig farmers in Mbulu District on how to rear pigs indoors with minimal out-of-pocket expenditures. Emphasis should be put on the use of locally available materials for building pigpens and pit latrines, proper formulation of local feedstuffs for feeding indoor-reared pigs and methods of storing feeds for use throughout the year. Positive results from these studies would promote the adoption of the indoor pig rearing method, which seemed to be poorly adopted in Mbulu District.

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APPENDICES

Appendix A. A sample of certificate offered to smallholder pig farmers who participated fully in the study for controlling porcine cysticercosis in Mbulu District, northern Tanzania, 2002-2004

(Written in Kiswahili language)

CHETI CHA KUSHIRIKI KATIKA UTAFITI

Hii ni kuthibitisha kwamba

MATEO JOSEPH

Ameshiriki katika utafiti wa kupambana na tegu wa nguruwe na binadamu (*Taenia solium*) uliofanyika katika Wilaya ya Mbulu, mkoani Manyara, 2002-2004

Prof. A. A. Kassuku
Mkuu wa Mradi

Dr. H. A. Ngowi
Kiongozi wa utafiti

Appendix B. A guide for the in-depth interviews and focus group discussions during a sociologic study for porcine cysticercosis control in Mbulu Distirct, northern Tanzania, 2002

1. Who is responsible for pig management in your family?
2. Where do your pigs stay during the day? (Probing questions such as "Why do you prefer this method? Do you keep your pigs this way everyday?").
3. If you were advised to keep and feed your pigs indoors permanently, would you face any problem? (Probing questions such as "What problems? Why?").
4. Do you have a latrine at your home? (Probing questions: Who in the family uses the latrine? What do you do for children who cannot use the latrine?)
5. Where do you obtain water for your home consumption? (Probing question: How do you prepare water for drinking after fetching it from the source?)
6. What are three important occasions in a day that you must wash your hands?
7. Do you eat pork?
8. How do you prepare pork before eating it?
9. Do you know porcine cysticercosis (the local name is *fini*)?
10. How can a pig acquire porcine cysticercosis?
11. Is there any problem if your pig is infected with cysticercosis? (Probing question "What problem?")
12. How could you prevent your pig from getting cysticercosis?
13. Do you know human tapeworm (the local name is *girirq*)?
14. How could you know that a person has tapeworm infection?
15. How can a person acquire tapeworm infection?
16. Is there any member of your family that has or has had tapeworm infection? (Probing questions such as "When? What measure did you take?")

17. What problems can the human tapeworm cause?

18. How could you prevent from becoming infected with tapeworm?

19. Is there any relationship between the human tapeworm and porcine cysticercosis (if yes, what is the relationship?)

20. Do you know human epilepsy?

21. What symptoms could be found in an epileptic patient?

22. Is there any member of your family who has/has had epilepsy? (If yes, when? What measures did you take?).

23. If you were offered an education about porcine cysticercosis and its control, what would you think about the idea?

24. A short education was given to the informant about porcine cysticercosis and after that the informant was welcome to give comments, suggestions and/or ask questions.

Appendix C. A questionnaire to explore farmer's knowledge, perceptions, and practices related to *T. solium* infections, and the economics of pig production in Mbulu District, northern Tanzania, 2002-2004*

*Notice that there were no multiple-choice questions

1. Date of interview..
2. Ward...
3. Village...
4. Sub-village..
5. Name of the household head...

Part A. Respondent's Particulars

6. Age of the respondent (years)...
7. Gender of the respondent
    - Male
    - Female
8. Level of education of the respondent
    - No formal education
    - Within primary school education
    - Secondary school education or higher level
9. Occupation of the respondent
    - Smallholder farmer
    - Others (mention) ....

10. Position of the respondent in the household
    - Father
    - Mother
    - Daughter or son
    - Others (mention) ....

Part B. Exploring pig production and practices related to porcine cysticercosis transmission

11. How many pigs do you have in this household?..
12. Who is the owner of the pig(s)?...
13. Who owns the income from pig sale? ....
14. Who takes care of the pigs? ....
15. How do you normally rear the following categories of pigs during daytime?
    - Lactating sows ....
    - Lactating piglets ....
    - Weaners ....
    - Fatteners ....
    - Others (mention) ....
16. How do you generally rear your pigs during the following periods:
    - After harvesting your crops from the field?..
    - When there are crops in the field?...
17. Who does the construction of the pigpen for this household?
18. How much would the construction of a pigpen approximately cost? (in monetary or other terms) ....

19. For how long would a pigpen last since its construction to the time that you must replace or repair it? ....

20. Where do you obtain water for home consumption?

- River
- Well (bore hole)
- Tap
- Others (mention) ....

21. How do you prepare water for drinking after fetching it from the source?

- River ....
- Well ....
- Tap...
- Others (mention)..

22. Which among the following situations do you wash your hands? (Check all that are relevant):

- Before eating some food using your fingers ....
- Before eating some food using a spoon ....
- After using the latrine...

23. Do you eat pork?

- Yes
- No (skip question 24)

24. How do you prepare pork before eating it?...

Part C. Exploring the knowledge of the respondent on porcine cysticercosis and human Taeniosis

25. Do you know porcine cysticercosis (*fini* in the local language)?
    - Yes
    - No (go to question 31)
26. What is porcine cysticercosis?..
27. How can a pig acquire cysticercosis?..
28. Can porcine cysticercosis cause any problem to human being?
    - Yes (explain)..
    - No
29. How do you prepare pork infected with cysticercosis:
    - Before you eat it?...
    - Before you sell it?...
30. Is there any way you could prevent your pig from getting cysticercosis?
    - Yes (how?)...
    - No
31. Do you know human tapeworm (*giririq* in the local language)?
    - Yes
    - No (go to question 40)
32. How would you know that a person has a tapeworm infection?...........................
33. Which among these two bottles contains something that looks like the tapeworm you are referring to?
    - Bottle labelled A (had tapeworm segments)
    - Bottle labelled B (had a roundworm)

- Other explanations………………………………………………………………….

34. How can a person acquire tapeworm infection?………………………………………

35. Is there any member of this household whom you believe to have tapeworm infection:

    - Currently?……………………………………………………………………………..
    - In the past but has recovered? …………………………………………………...

36. What action do/did you take with the tapeworm carrier?

    - Consulted a medical doctor
    - Used traditional medicine
    - Other measures (mention) ……………………………………………………….

37. What problem(s) can human tapeworm cause? ………………………………………..

38. Is there any way to prevent someone from getting tapeworm infection?

    - Yes (explain)…………………………………………………………………….
    - No
    - I don't know

39. Is there any relationship between human tapeworm and porcine cysticercosis?

    - Yes (explain)…………………………………………………………………….
    - No
    - I don't know

40. (The interviewer should observe presence and usage of latrine in the household):

    - Present and being used
    - Present but not used
    - The construction started
    - Absent

41. For families that are using latrines, the examiner should assess the following:

- Whether the latrine wall is complete
- Whether the roof is complete
- Whether the latrine has a closing door
- Material composing the floor of the latrine
    - Earth
    - Timber
    - Cement
- Human faeces found on the floor or elsewhere around the latrine

42. Who in the family (including visitors) uses the latrine? ....

43. What if a child who is unable to go to the latrine needs that service? ....

44. Who does the construction of a latrine for this household?

- Father
- Mother
- Others (mention) ....

Name of the interviewer ....

Appendix D. Enzyme-linked immunosorbent assay for detecting circulating antigens (Antigen-ELISA) for porcine cysticercosis

Reagents and solutions used and their preparation

PBS-TWEEN 20

The phosphate buffered saline (PBS) was prepared according to the manufacturer. In this study five of PBS tablets (P-4417 LOT 112K8200) were dissolved in one litre of distilled water. The PBS-TWEEN 20 was then prepared by adding 555 µl of TWEEN 2O in one litre of the PBS solution.

Five percent tri-chloro-acetic acid (TCA)

A 5% TCA was prepared by dissolving one gram of TCA crystals into 20 ml of distilled water.

Coating buffer (0.06 M pH 9.6)

The coating buffer was prepared from two solutions: solution **A** prepared by dissolving 0.159 g of Na_2CO_3 into 25 ml of distilled water and solution **B** prepared by dissolving 0.504 g of $NaHCO_3$ into 100 ml of distilled water. The coating buffer was then prepared by mixing 10 ml of solution **A**, 50 ml of solution **B**, and 175 ml of distilled water. The pH of the final solution was adjusted to 9.6 using either solution **A** (to raise the pH) or **B** (to lower the pH). The volume was finally adjusted to 250 ml with distilled water.

Neutralisation buffer (0.61 M pH 10.0)

The neutralisation buffer was prepared from two solutions: **A** prepared by dissolving 3.233 g of Na_2CO_3 into 50 ml of distilled water and **B** prepared by dissolving 2.562 g of $NaHCO_3$

into 50 ml of distilled water. The neutralisation buffer was then prepared by mixing 5 ml of solution A, 7.5 ml of solution B, and 30 ml of distilled water. The pH of the final solution was adjusted to 10 using either solution A or B. The volume was finally adjusted to 50 ml with distilled water.

Coating solution

A coating solution was prepared by mixing 65 µl of the first monoclonal antibody (Mab B158 C11 A10 LOT number D with a concentration of 6.5 µl / ml CO_3^-) into 10 ml of coating buffer.

Blocking solution (PBS-20 + 1% NBCS)

The blocking solution was prepared by mixing 0.6 ml of new born calf serum (NBCS) with 59.4 ml of PBS-TWEEN 20.

Streptavidine HRP (conjugate)

Streptavidine HRP was prepared by mixing 1 µl of streptavidine HRP with 10 ml of the blocking solution.

o-Phenylenediamine Dihydrochloride (oPD)

The oPD (substrate) was prepared as follows. A phosphate-citrate buffer was prepared by dissolving the contents of two capsules of phosphate-citrate buffer with sodium perborate capsules (P-4922 100 caps LOT 013 K 8200) into 200 ml of distilled water. A 30mg oPD tablet (P-8412 Lot number 016H8913) was dissolved in 180 ml of the phosphate-citrate buffer.

Sulphuric acid (4N)

Four normal sulphuric acid was prepared by adding 100 ml of sulphuric acid into 150 ml of distilled water.

Pre-treatment of the serum samples

The control and unknown serum samples were pre-treated as follows. One hundred and fifty micro-litres of the positive control or unknown serum sample were mixed into an equal volume of 5 % TCA. For the negative control samples 75 µl was used. After an incubation of 20 minutes at room temperature the precipitate was centrifuged at 12 000 revolutions per minute for nine minutes. One hundred and fifty micro-litres or 75 µl of the supernatant was mixed into an equal volume of the neutralisation buffer respectively.

Antigen-ELISA

- A 96-well plate was coated with 100 µl of first monoclonal antibody (Mab B158 C11 A10) in each well and incubated at 37°C for 30 minutes while shaking
- The plate was washed once with PBS-TWEEN 20
- All wells were blocked by adding 150 µl of blocking solution (PBS-TWEEN 20 + 1% new born calf serum) and the plate was incubated at 37°C for 15 minutes while shaking
- Without washing the plate, 100 µl of each of the unknown and positive control pre-treated serum samples were added to the plate in duplicates. Eight wells were added with 100 µl each from eight negative control serum samples. Two wells served for substrate and two for conjugate controls and both were added with 100 µl of the blocking solution
- The plate was incubated at 37°C for 15 minutes while shaking

- The plate was washed five times with BPS-TWEEN 20
- A 100 µl of second monoclonal antibody [MAB/BIOT (B60 H8 A4)] was added to all wells except for the substrate control wells where blocking solution was added
- The plate was incubated at 37°C for 15 minutes while shaking
- The plate was washed five times with PBS-TWEEN 20
- A 100 µl of conjugate (streptavidine HRP) was added to the plate except for the substrate control wells where the blocking solution was added
- The plate was incubated at 37°C for 15 minutes while shaking
- The plate was washed five times with PBS-TWEEN 20
- A 100 µl of substrate [oPD (o-Phenylenediamine Dihydrochloride)] was added to the plate
- The plate was incubated at room temperature (around 26°C) for 15 minutes
- The reaction was stopped using 50 µl of H_2SO_4 (4N)
- The plate was read and printed at 492 nm filter.

Appendix E. Comparison of the baseline characteristics between or within the households that dropped out of the study and those that participated to the end of the study in Mbulu District, northern Tanzania, 2002-2003

Factor	Within drop-outs (T- and C-group)	Between drop-outs and full participants	Within full participants (T- and C-group)
Number of villages involved	42	42	42
Households involved (prop. Difference & 95% CI)	0.03 (-0.04, 0.10)	Not-valid	-0.03 (-0.10, 0.04)
Knowledge on porcine cysticercosis (PCC)	-0.02 (-0.10, 0.07)	-0.070 (-0.13, -0.01)	-0.06 (-0.14, 0.03)
Knowledge on how a pig acquires PCC	0.04 (-0.07, 0.15)	-0.01 (-0.09, 0.07)	0.00 (-0.11, 0.12)
Knowledge on how to prevent PCC	0.02 (-0.10, 0.13)	0.02 (-0.07, 0.10)	-0.10 (-0.22, 0.01)
Knowledge on human taeniosis (HT)	-0.01 (-0.13, 0.12)	0.07 (-0.02, 0.17)	-0.09 (-0.23, 0.05)
Knowledge on how a person acquires HT	-0.01, (-0.13, 0.11)	-0.10 (-0.20, -0.00)	-0.19 (-0.34, -0.04)*
Knowledge on how to prevent HT	-0.07 (-0.18, 0.04)	-0.03 (-0.11, 0.06)	-0.09 (-0.21, 0.03)
Knowledge on PCC-HT relationship	0.02 (-0.06, 0.10)	-0.04 (-0.11, 0.03)	-0.02 (-0.13, 0.09)

Appendix F. **Comparison of more baseline characteristics of households that dropped out of the study and those that participated to the end of the study in Mbulu District, northern Tanzania, 2002-2003**

Factor	Within drop-outs (T- and C-group)	Between drop-outs and full participants	Within full participants (T- and C-group)
Household using latrine	0.02 (-0.06, 0.11)	-0.08 (-0.14, -0.03)*	0.06 (-0.02, 0.14)
Pigs that were found roaming	-0.01 (-0.10, 0.08)	0.05 (-0.02, 0.11)	0.03 (-0.06, 0.12)
Prevalence of porcine cysticercosis	0.01 (-0.05, 0.06)	0.01 (-0.03, 0.04)	-0.02 (-0.07, 0.03)
Pig gender ratio (% female)	0.05 (-0.04, 0.15)	-0.00 (-0.07, 0.07)	-0.02 (-0.12, 0.08)
Pig age (mean difference)	0.31 (-0.26, 0.89)	-0.06 (-0.47, 0.36)	-0.19 (-0.80, 0.41)
Who takes care of the pigs at home (mother)	0.01 (-0.07, 0.10)	0.06 (-0.00, 0.12)	-0.02 (-0.11, 0.07)

Appendix G. An Excei spreadsheet model used in the analysis of financial efficiency of health education intervention for controlling porcine cysticercosis in Mbulu District, northern Tanzania, 2004

TABLE 1. WORKING TABLE			
COMMON EPIDEMIOLOGICAL AND ECONOMIC DATA			
Base population	100		
Average market price of a piglet (TZS)	7000		
Average market price of a finished cysticercosis-free pig (TZS)	51250		
Market price of a finished cysticercotic pig (TZS)	0		
Time taken for an indoor-reared pig to reach slaughter weight (months)	10		
Time taken for a free-range/tethered pig to reach slaughter weight (months)	17		
Proportion of the indoor-reared pigs that would reach slaughter weight annually	1.2		
Proportion of the free-range/tethered pigs that would reach slaughter weight annually	0.71		
Cost of constructing one pigpen (materials + labour)	20700		
Cost of feeding an indoor-reared pig annually (various feed combinations)	24900		
Cost of feeding a free-range/tethered pig annually (various feed combinations)	7600		
Annual interest rate for depositing money in the Tanzania National Microfinance Bank (proportion)	0.03		
Annual interest rate for borrowing money from the Tanzania National Microfinance Bank (proportion)	0.135	0.071	
COSTS			
(i) Training costs			
	Cost (TZS)	**Intervention**	**Control**
Opportunity cost for a farmer to attend the training (4 hours)	560		
Households that would attended the training (proportion)		0.714	
Total (TZS)		39984	
(ii) Costs for constructing one pigpen			
Households that would construct pigpens (proportion)		0.272	0.174
Total (TZS)		563040	360180

TABLE I (CONTINUED)

(iii) Piglet initial investment costs (for Year 1)	**Intervention**	**Control**
Total (TZS)	**700000**	**700000**
(iv) Replacement of finished pigs annually (both healthy and infected ones)		
Introduced pigs that would be reared indoors (number)	27.2	17.4
Indoor-reared pigs that would reach slaughter weight annually (number)	32.6	20.9
Introduced pigs that would be free-ranged/tethered (number)	72.8	82.6
Free-ranged/tethered pigs that would reach slaughter weight annually (number)	51.4	58.3
Total number of pigs that would need to be replaced annually (number)	84.0	79.2
Total (TZS)	**588197.6**	**554301.2**
(v) Feed costs		
Costs of feeding indoor-reared pigs annually (TZS)	677280	433260
Costs of feeding free-range/tethered pigs annually (TZS)	553280	627760
Total (TZS)	**1230560**	**1061020**
REVENUES		
(vi) Selling cysticercosis-free finished pigs		
Incidence rate of porcine cysticercosis (per 100 pig-years)	44	68.6
Pigs that would be free from cysticercosis annually (number)	56	31.4
Cysticercosis-free finished pigs that would be reared indoors (number)	15.2	5.5
Cysticercosis-free finished indoor pigs that would reach slaughter weight annually (number)	18.3	6.6
Cysticercosis-free finished pigs that would be free-ranged/tethered (number)	40.8	25.9
Cysticercosis-free finished free-range/tethered pigs that would reach slaughter weight annually (number)	28.8	18.3
Total number of cysticercosis-free finished pigs that would be sold annually	47.1	24.9
Total (TZS)	2411610.4	1274298.8
(vii) Selling cysticercotic pigs		
Cysticercotic finished pigs that would be reared indoors (number)	12.0	11.9
Cysticercotic finished indoor pigs that would reach slaughter weight annually (number)	14.4	14.3
Cysticercotic finished pigs that would be free-ranged/tethered (number)	32.0	56.7

TABLE I (CONTINUED)

Cysticercotic free ranged/tethered pigs that would reach slaughter weight annually		22.6	40.0			
Total number of cysticercotic finished pigs that would be sold annually (number)		37.0	54.3			
Total (TZS)		0.0	0.0			
Total revenue		**2411610.4**	**1274298.8**			
TABLE II. CASH FLOW WITH EDUCATION						
ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**
COSTS						
Training costs	39984.0	0.0	0.0	0.0	0.0	0.0
Pigpen construction costs	563040.0	0.0	0.0	0.0	0.0	0.0
Piglet initial investment costs	0.0	700000.0	0.0	0.0	0.0	0.0
Piglet replacement costs	0.0	588197.6	588197.6	588197.6	588197.6	588197.6
Feed costs	0.0	1230560.0	1230560.0	1230560.0	1230560.0	1230560.0
Total (TZS)	603024.0	2518757.6	1818757.6	1818757.6	1818757.6	1818757.6
REVENUE						
Total revenue from selling finished pigs	0.0	2411610.4	2411610.4	2411610.4	2411610.4	2411610.4
TABLE III. CASH FLOW WITHOUT EDUCATION						
ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**
COSTS						
Pigpen construction costs	360180.0	0.0	0.0	0.0	0.0	0.0
Piglet initial investment costs	0.0	700000.0	0.0	0.0	0.0	0.0
Piglet replacement costs	0.0	554301.2	554301.2	554301.2	554301.2	554301.2
Feed costs	0.0	1061020.0	1061020.0	1061020.0	1061020.0	1061020.0
Total (TZS)	360180.0	2315321.2	1615321.2	1615321.2	1615321.2	1615321.2
REVENUE						
Total revenue from selling finished pigs	0.0	1274298.8	1274298.8	1274298.8	1274298.8	1274298.8

TABLE IV. INCREMENTAL CASH FLOW						
ITEM/YEAR	0	1	2	3	4	5
Net benefit with health education intervention	-603024.0	-107147.3	592852.7	592852.7	592852.7	592852.7
Net benefit without intervention	-360180.0	-1041022.4	-341022.4	-341022.4	-341022.4	-341022.4
Incremental net benefit (undiscounted)	-242844.0	933875.1	933875.1	933875.1	933875.1	933875.1
Incremental net benefit (discounted)	-242844.0	906674.8	880266.8	854628.0	829735.9	805568.8
NPV						4034030.4
IRR						370%