Porcine cysticercosis in northern Tanzania

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Financial efficiency of health and pig management education intervention in controlling porcine cysticercosis in Mbulu District, northern Tanzania

to determine the financial efficiency of health and pig management education intervention in reducing the incidence rate of porcine cysticercosis to smallholder pig farmers in Mbulu District, northern Tanzania.

Abstract

The objective of this study was to determine the financial efficiency of health and pig management education intervention in reducing the incidence rate of porcine cysticercosis to smallholder pig farmers in Mbulu District, northern Tanzania. We used investment appraisal analytical method (a simple form of cost-benefit analysis) in an Excel® spreadsheet model. Sensitivity analyses were also conducted to identify the effects of uncertainty on costs and benefits as well as disease incidence rate.

Over a period of 5 years, the health and pig management education intervention would have a significant financial benefit to the smallholder pig farmers in Mbulu District [NPV: US $3507 (95% CI: 3421 to 3591); IRR: 370%]. The sensitivity analysis showed that the health education intervention would remain financially efficient regardless of plausible changes in costs and benefits in the pig production, as well as plausible changes in the incidence rate of porcine cysticercosis.

It is recommended that smallholder pig farmers in Mbulu District be educated on how to control porcine cysticercosis in order to improve their economic well being.

Keywords:
Financial efficiency, health and pig management education, Taenia solium control

Introduction

Taenia solium
is a zoonotic helminth affecting primarily pigs and humans. The adult
Taenia solium
is found in the small intestine of human beings and lays thousands of eggs in the environment. Pigs are the natural intermediate hosts of
Taenia solium
and get infected by ingesting eggs of the tapeworm in human faeces. Porcine cysticercosis has been reported in many developing countries of Latin America, Asia and Africa. Human beings can also get infected with the eggs of the parasite and may develop severe neurological disorders if the larvae migrate to the brain, a condition called neurocysticercosis (NCC). Human NCC is considered as the most dangerous form of

Taenia solium
infection in human and has been diagnosed worldwide (DeGiorgio et al 2004). Most symptomatic cases of NCC will manifest with recurrent seizures or epilepsy.

Porcine cysticercosis has been reported in Tanzania. In Mbulu District, an overall prevalence of 17.4% was established in 21 villages based on lingual examination methods in 1998 (Ngowi et al 2004). In the same district, an incidence rate of 68.6 per 100 pig-years using antigen enzyme-linked immunosorbent assay (Ag-ELISA) was estimated from 21villages in 2003-2004 (Ngowi 2005). Unfortunately, there is no data available on the human aspect of
Taenia solium
infection in Tanzania. The infection in both pigs and humans could lead to high economic losses by smallholder pig producers in Mbulu District as well as high treatment and opportunity costs for people suffering from NCC, in addition to high health risk to the public.

Financial losses due to porcine cysticercosis have been reported by several studies elsewhere. Annual losses due to porcine cysticercosis have been estimated to 25 million Euros in 2002 in ten Western and Central African countries (Zoli et al 2003), US$5.0 million in the Eastern Cape Province of South Africa in 2004 (Carabin et al 2006), US $121 million for 0.2 billion kg of pork meat in China in 2002 (Engels et al 2003), and US$164 million in all Latin America in 1991 (Murrell 1991). Most analyses were based on strong assumptions that may not be realistic and have not been based on data collected in the field. Also, the effects of endemic porcine cysticercosis in terms of productivity losses and control costs should be dealt with at the producer level. The decision in question depends on the relative costs of developing a control strategy as compared to the gains associated with reducing the infection in pigs. 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).

There are no previous field studies that had directly measured the economic impact of porcine cysticercosis or the efficiency of any measure directed to the control of the parasite in Tanzania. The primary objective of this study was to conduct a financial benefit-cost analysis of a health and pig management education intervention to smallholder pig farmers in Mbulu District in northern Tanzania.

Materials and methods

Study area

This study was conducted in Mbulu, a mostly agricultural District located in north-eastern Tanzania. In 2002, the District had 72 villages and the National census counted 237882 people living in 38729 households with an average of six persons per household. In 1997, Mbulu District pig population was estimated at about 35000. Most of the District inhabitants practice mixed farming: crop and livestock production. Pigs are raised in many homes as a source of income and animal protein for the household (Meindertsma and Kessler 1997).

Estimation of the costs of porcine cysticercosis control strategies

Costs of health education intervention for control of porcine cysticercosis considered for pig farmers in this study included the cost of the farmer to attend the training and costs for implementing intervention measures. The cost of the smallholder pig farmer attending the health education training was considered as ones' opportunity cost for four hours, which were used for the training. This included the travel and the actual training times. The average time used by the farmers to and from the training centre was estimated through interviewing a random sample of farmers who attended the training. The actual costs of transport of farmers to and from the training centres could not be determined because almost all farmers walked, with only a few who travelled by bicycles. The average time used for the actual training of the farmers was calculated from the actual times recorded during the training. The sum of the average values of the travel and actual training times was calculated and considered the total time used by the farmers for participating the health education training, for which opportunity cost was calculated. The next best alternative use of the time by the Mbulu smallholder pig farmer was reported to be working as a casual labour that could earn an average of 140 Tanzanian shillings per hour, equivalent to US $0.12 at the 2005 average exchange rate (Anonymous 2005). This amount of money was therefore considered the opportunity cost for the farmer for one hour, which was then multiplied by the total time used by the farmer for the training.

Costs of the farmer implementing the intervention considered in this study included costs of constructing pig pens and costs for rearing pigs indoors, which were collected in March 2005 by using in-depth interviews of 35 key informants (experienced smallholder pig farmers or pig traders) in the study area. These costs would result from additional feed and labour that would be required. Pig rearing method was considered a key factor with regard to control of porcine cysticercosis despite the presence of other risk factors of the infection, as will be elaborated later in this paper. The cost of constructing a pig pen was calculated as the sum of the average cost of purchasing building materials and labour charge. The cost of rearing pigs indoors was calculated as the sum of the cost of feeding the pig to market weight using various feed combinations as reported by farmers and the charges paid to the labour responsible for feeding the pig and cleaning the pig pen. Farmers reported that it would cost on average about US $21.6 to feed a penned pig to slaughter weight but only about US $6.6 for a free-range/tethered pig. Similarly, farmers reported that a labourer would charge on average about US $11.0 to care for a penned pig per month but only about US $4.3 for a free-range/tethered pig. The above costs were considered regardless of whether the farmer did the work herself/himself or employed someone else.

Estimation of the costs of porcine cysticercosis

To estimate the losses associated with porcine cysticercosis, we first needed to determine the income generated by pig production in the absence of infection. To do this, we considered costs of pig production under the two different rearing systems used in Mbulu District (that is the indoor and the traditional free-ranging/tethering systems) and the impact of porcine cysticercosis to the farmer. Specific data collected included costs and time required to reach slaughter weight when raising pigs under indoor pig-rearing method as compared to the free-ranging/tethering system. To estimate the costs of pigs with cysticercosis, information on the decision criteria used by the farmer when a pig was diagnosed as having cysticercosis was also collected. For example, whether the pig was totally condemned or sold at lower prices. In addition, data on the current market prices for piglets, and finished pigs (both cysticercosis-free and infected pigs) were collected.

Epidemiological data on the effectiveness of control strategy

Incidence rates of porcine cysticercosis were obtained from a large randomised field controlled health education intervention trial, which was conducted in 42 villages of Mbulu District, northern Tanzania between 2002 and 2005 (Ngowi 2005). The public health education intervention was compared with monitoring alone in reducing the incidence rate of porcine cysticercosis as measured by Ag-ELISA in tracer pigs in the area.

Financial analysis of the health education intervention

The analysis was 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. Educating the smallholder pig farmers on how to control porcine cysticercosis was considered an investment that would result into additional costs and benefits to the pig farmers participating in the intervention. Additional costs due to the health education campaign were related to the costs of attending the training, and implementing the parasite control measures. The costs of implementing the intervention would include costs of constructing pig pens and rearing pigs indoors. Such costs would result from additional feed and labour that would be required. Although the transmission of porcine cysticercosis in the study area was likely to be attributable to several factors, the financial analysis of the intervention was focused on pig-rearing method as a key factor. Pig-rearing method was also selected as a key factor based on the researcher's hypothesis that the environment in the study area was already contaminated with
Taenia solium
eggs, thus, susceptible pigs introduced to the area would most likely be protected from infection when reared indoors. Additional revenues from selling cysticercosis-free pigs were considered additional benefits to the smallholder farmer participating in the health education.

Assumptions

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

- The pig farmer keeps a fattener (rather than breeder) pig. This is an option preferred by most smallholder pig farmers in Mbulu District.
- A pig is replaced immediately after the previous one has been sold.
- The health and pig management education is administered once at the end of Year zero.
- The proportion of farmers who adopted the intervention recommendations as observed in the present study remains constant throughout the period.
- The observed incidence rate of porcine cysticercosis in the control and intervention groups remains unchanged throughout the time period.
- Constant prices were used. For planning purposes, prices in the planning year were applied for

all five years and
real
discount rates (discount rates that are free from the effect of inflation) were used in order to make the benefits and costs comparable in terms of the time dimension.

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. The full compliance was 27.2% and 17.4% in the intervention and control (in this case protocol violation) groups, respectively. Hence, an "intention-to-treat" approach was used (Grady et al 2001). Capital costs of the intervention (that is, opportunity costs of farmers attending the seminar and the costs of constructing pigpens) were expressed as an initial lump-sum, occurring at the end of Year zero of the study. The financial analysis was done using an Excel® spreadsheet model.

Comparison of costs and benefits between the intervention and the control groups

When comparing health education intervention with no health education to smallholder pig farmers in Mbulu District, all sequences of events that would be expected to take place along each option were considered, based on the available information as shown in Figure 1.

Figure 1

. A sketch of data analysis to investigate the effectiveness and efficiency of health education intervention in reducing porcine cysticercosis in Mbulu District, northern Tanzania 2004

In calculating the costs and benefits of an option to the pig farmers, the respective sequences of events were taken into account. 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 pigs

Where, revenue from healthy pigs was calculated as product of the number of pigs that would be free from cysticercosis annually, the proportion that would be reared indoors, the proportion that would reach slaughter weight annually under the indoor system, the market price of the healthy pig, added to the product of the number of pigs that would be free from cysticercosis annually, the proportion that would be free-ranged/tethered, the proportion that would reach slaughter weight annually under the free-range/tethering system and the market price of the healthy pig. A similar approach was used to calculate revenue from infected pigs and for the total revenue of the control group.

Analysis of financial efficiency of the intervention in reducing cysticercosis

The financial efficiency of the health education intervention was analysed by computing the incremental net present value. At first, the analysis examined the basic situation by running a base model using average values (e.g. average market prices and disease rates) in order to examine the situations in the intervention and control groups under average conditions. The net benefit of each particular option was calculated using the formula:

Net benefit = Total revenue - Total cost ?????...??????????.....????1

Incremental benefit (Xt) of the intervention was calculated as the net benefit of the intervention group minus net benefit of the control group at each year
t
?????...??????????.....????2

The incremental net present value (NPV) due to the intervention was then calculated from the formula:

NPV = Xt/(1 + r)t ?????...??????????.....????3

Where
Xt
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). The internal rate of return (IRR) was computed in the spreadsheet to reflect a discount rate that would make an NPV equal to zero. The basic analysis used a real annual interest rate of 3% offered by Tanzania National Microfinance Bank (NMB) in 2004 as the opportunity cost of the investment, and assumed total condemnation of pigs infected with cysticercosis as per Tanzania government regulations.

Sensitivity analysis

Sensitivity analyses were performed for different pig prices, bank lending rates, disease incidence rates, and farmers' decision on whether to condemn infected pigs or sell them at a lower price. The analytical model was rerun using different prices of pigs as reported by the farmers, and different incidence rates of porcine cysticercosis as determined by the previous randomised field controlled trial in the area in order to see whether changes in these values would affect the financial efficiency of the intervention. With regard to the pig prices, averages for the minimum as well as the maximum prices reported by the farmers were used in the sensitivity analysis. On the other hand, the lower and upper 95% confidence limits of the incidence rates of porcine cysticercosis were used to examine the variation in the effectiveness of the education programme.

Results

The total cost to the smallholder pig farmer with health education offered was US $9038 and the total benefit was US $10482 over the five-year period. On the other hand, a farmer without health education intervention would incur US $7943 and receive benefits of US $5539 in pig production over the time period. Table 1 describes incremental cash flow with and without health education intervention for each year starting in year 0 by the end of which the education was implemented.

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: US $3507 (95% CI: 3421 to 3591); IRR: 370%]. The internal rate of return of the intervention was very high, probably because only some costs of the intervention (those related to attending the training and confining pigs) were included in the analysis as these were considered most important to the control of porcine cysticercosis.

Table 2 summarises the results of the sensitivity analysis of the intervention under various prices of the finished (slaughter weight) cysticercosis-free pigs, of the average lowest price at which the infected pigs are sold, and of real annual interest rates that the farmer would have to pay if he/she decided to borrow money from the bank in order to invest in the pig business. The basic scenario is also present in the table for comparison.

The sensitivity analysis indicated that the health education intervention would remain financially efficient regardless of the plausible changes in pig prices, bank interest rates, incidence rate of porcine cysticercosis, and whether smallholder farmers sell infected pigs at a lower price or condemn them. However, the incremental NPV would be about two times higher if infected pigs were condemned and the healthy ones sold at their average prices than if the infected as well as the healthy pigs were sold at their average prices (Table 2).

Discussion

This is the first study that has examined the economic efficiency of health education intervention for control of porcine cysticercosis in an endemic rural situation. Since the present study only examined the economic benefit of the health education intervention in terms of pig production, results of this study should be considered the minimal actual benefit of the intervention. This is because the reduction of human disease morbidity, particularly NCC, which is anticipated to occur as a result of reduced incidence rate of porcine cysticercosis by the intervention, is likely to add significantly to the benefits of the health education intervention to the smallholder pig farmers in Mbulu District and the general public in Tanzania. In fact, in a study conducted in the Eastern Cape Province of South Africa, the proportion of the overall societal costs of cysticercosis associated with NCC varied from 66% to 84% (Carabin et al 2006). This calls for further studies to determine the full economic impact of the health education and other intervention strategies for *Taenia solium* to enable adoption of cost effective control strategies for this zoonotic parasite. In order to be able to conduct a thorough economic analysis of any control strategy for *Taenia solium,* data on the frequency and burden of the disease and the impact of the parasite to both the pig production and the human health are necessary. In many countries, these data are available for only one sector (agricultural or human).

Although most participants in the intervention group in the present study did not comply or only complied partially to the intervention recommendations, particularly with regard to the construction of pigpens and housing their pigs, and the fact that some participants in the control group implemented the intervention recommendations (probably due to 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 by the farmers if they were educated to control porcine cysticercosis. This may be a reflection of the observed important reduction of the incidence rate of porcine cysticercosis by the intervention (prevented fraction of 42.5%). The double incremental benefit of the intervention observed when infected pigs were condemned as compared to if they were sold, emphasizes the need to reinforce government regulations with regard to total condemnation of infected pigs. This would safeguard public health and enable the smallholder pig farmers to see more financial benefit of having a healthy pig as compared to having an infected one. This could probably encourage the smallholder pig farmers in Mbulu District to implement disease preventive measures. These conclusions are based on the assumption that the effectiveness of the training would remain high for a period of 5 years. The effectiveness estimate was based on a follow-up of a median of 4 months (Ngowi 2005), so we cannot guarantee that the effectiveness would remain high. However, since the net present value was still positive even using the lowest confidence bound of the estimate of the effectiveness, these results are believed to be robust.

In this study, the adoption of indoor pig rearing method by the smallholder pig farmers in Mbulu District was very poor. This could be attributed to seasonal availability of pig feeds as mentioned by some respondents during a sociological study (Ngowi 2005). This became apparent in the present study when about 52% of the baseline study farmers dropped out of the follow up study due to hunger situations that were faced by their families during the time, which made them unable to raise study piglets that they had to keep for one year. A few farmers were also worried about an outbreak of African Swine Fever that was occurring in the neighbouring region of Arusha. The present study recommends demonstration activities combined with educational packages to educate smallholder pig farmers in Mbulu District on how to rear pigs indoors with minimal financial inputs. 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.

Due to its zoonotic aspect, the economic impact of *Taenia solium* includes both livestock production losses and economic losses due to human infection and disease. However, access to imagery of the brain, essential for the diagnosis of NCC, is lacking from several African countries (Dorny et al 2003). Consequently, data on the human aspect of the parasite is lacking in many endemic areas because most studies have only examined the livestock aspect of the parasite. This has made it difficult to carry out a thorough economic analysis of the impact of *Taenia solium*. Analysing the economics of the livestock impact of the parasite would nevertheless highlight on the economic viability of a given control strategy for the parasite. However, even with a complete analysis of the impact of *Taenia solium* on the livestock production, its public health importance should be considered. In South Africa, one of the rare African countries with access to imagery, a recent analysis revealed an important economic burden to the country due to *Taenia solium* infections despite the fact that data on the animal side of the disease was scant (Carabin et al 2006). It is important in the future to examine the distribution of the costs of *Taenia solium* infections in different sectors to raise awareness of extent of the problem and promote inter-sectoral approach to the control of the parasite.

Conclusions

- Educating smallholder pig farmers in Mbulu District, northern Tanzania, on the health and management of pigs, would have a significant financial benefit to them.
- The health education intervention would remain financially efficient to smallholder pig farmers in Mbulu District regardless of plausible changes in costs and benefits in the pig production, as well as plausible changes in the incidence rate of porcine cysticercosis.
- The incremental benefit of the health education intervention would be doubled if infected pigs were condemned as compared to if they were sold at a lower price, emphasizing the need to reinforce government regulations with regard to total condemnation of infected pigs, in order to encourage farmers to implement disease preventive measures.

Acknowledgements

We are grateful to the Danish International Development Agency (DANIDA) for financial support of this study through the ENRECA Livestock Helminths Research Project in Eastern and Southern Africa. We thank the Tanzania National Institute for Medical Research and Ministry of Health for offering the research ethical clearance. The cooperation of the study participants and their authorities is highly acknowledged.

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Regional status, epidemiology and impact of
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How to cite this article

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