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REGULAR ARTICLES

Estimating the economic impact of *Trypanosoma evansi* infection on production of camel herds in Somaliland

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Abstract The traditional livestock sector in Somalia is based on nomadic pastoralism where sheep, goats and camels are herded in large numbers. Data from 1609 females (27 % lactating) and 550 males (26 % exported) belonging to 40 pastoralists were analysed in this study. The expected amount of revenue the herders could lose per year in the studied area was estimated at US$404,630 being made up of US$314,630 from decreased milk yield and US$90,000 from reduced market value of exported animals. However, all the camels in Somaliland are at risk of acquiring surra infection, and therefore extrapolating the current findings to the total population could potentially lose US$223,164,000. This highlights the loss in the magnitude of US$164,253,600 from decreased milk yield and US$58,910,400 from body condition loss. Overall, the benefit in controlling *Trypanosoma evansi* infection in the study area was US$398,880 ($n$=2159). On average, US$720 was saved per head per year from improved milk production in treated animals and US$615 from the increased value of exported camels. It is concluded that all three-treatment options evaluated were economically beneficial strategies; however, the biannual treatment of seropositive camels in the herds was the best financial option.

Keywords *Trypanosoma evansi* · Economic impact · Pastoral camel production · Disease control

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Introduction

The livestock sector in Somalia is the major repository of individual and national wealth. Camels represent a significant business in Somalia, generating an annual income of US$250 million through exports (FAO 2012). However, the level of animal productivity is generally low due to diseases and poor management (FAO 2004). Surra and sarcoptic mange are the two most important diseases of camels in the central and northern rangelands of Somalia (Baumann and Zessin 1992). Pastoralists mainly keep camels under a subsistence production system, and these animals are a source of prestige and have cultural importance, as well as being an important source of income (Dirie and Abdurahman 2003). Approximately 60 % of the dromedary camel population in the world is found in Somalia, Sudan, Kenya and Ethiopia with Somalia having the largest dromedary camel population, estimated at over 6 million heads (Farah et al. 2007).

Camel milk is also one of the main components of the pastoralists diet and contributes up to 30 % of the annual caloric intake (Baumann and Zessin 1992). Camels produce more milk and lactate for longer than do any other milking animals raised under similar harsh environmental conditions (Pasha et al. 2013). The daily milk yield ranges between 3 and 10 kg in a lactation period of 12 to 18 months, and this year-long milk production makes the animal the most valuable of all livestock species in Somali pastoral societies. There is the potential for individual camels to produce more than 15 litres of milk a day during the peak of their lactation (Farah et al. 2007).

In the Horn of Africa, surra is one of the most important diseases that reduce camel productivity, particularly through reduced milk and meat production of adult camels (Boid et al. 1985). Economic losses due to surra result in significant social impact to producers, although the actual losses are difficult to estimate (Mochabo et al. 2006; Reid 2002). These losses

include deaths, reduced productivity and the cost of chemotherapeutic interventions (Derakhshanfar et al. 2010; Reid 2002).

Although the economic impact of surra is believed to be significant in Somaliland, data are lacking to confirm the exact losses. There is limited information on the losses associated with reduced milk yield and meat production due to the lack of exact epidemiological data. As well as the direct losses incurred through reduced productivity and deaths, camels infected with surra are often sold for slaughter at lower prices to avoid treatment costs if their production performance decreases substantially (Yusuf Mohamed, personal communication). Several studies in Kenya and Ethiopia have suggested considerable economic losses through the disease's impact on growth, production, productivity and reproduction (Njiru et al. 2004; Zeleke and Bekele 2001). Previously, there has been no attempt to assess the economic impact of surra in camels reared under the Somaliland pastoral system.

Such information would be useful for estimating the economic loss of the disease and to evaluate the financial profitability of a control strategy for the disease. Data from a cross-sectional seroprevalence survey and questionnaire was used to estimate the losses associated with reduced productivity and the financial benefit in adopting control strategies against the disease.

Materials and methods

Description of the study area

The study was conducted in the northern regions of Somalia (Somaliland). Most of Somaliland is arid or semi-arid with unreliable rainfall, and this results in only extensive animal production being feasible. Rainfall is irregular ranging between 100 and 300 mm per annum with an average temperature between 25 and 28 °C (77 and 82 °F). Temperatures fall as low as 0 °C (32 °F) in the mountains of the north and reach as high as 47 °C (117 °F) on the coast. Camels are better suited to this environment than are other domestic animals. Camel herders practice seasonal or annual movement of livestock in search of pasture over a large area of the rangelands. Most natural vegetation types are described as coastal desert, absolute desert, semi-desert grasslands and shrub lands, *Acacia* species, bush land and thickets (Sommerlatte and Umar 2000). Bush lands are favoured for camels and goats because of these animals browsing habits. Use of different zones at different seasons is greatly influenced by the availability of fodder and water and by the seasonal activity of biting flies and ticks (FAO 2004).

Study design

A questionnaire survey was conducted from 2011 to 2012 in different ecological zones used for rearing camels in Somaliland. A total of 40 participants who owned camels and were familiar with their husbandry were selected using a purposive sampling technique in order to collect data on the economic impact of surra on camels raised under a nomadic pastoralist system. The impact of surra on milk production and the export market was investigated. Financial modelling was based on estimates of the average values for a range of production parameters generated through a questionnaire (Table 1).

Economic loss assessment

The importance of camels for Somalis is primarily associated with their provision of milk and meat within the subsistence economy. They are very reliable milk producers during dry seasons, particularly in drought years when milk from cattle, sheep and goats is scarce. At such times camels can contribute up to 50 % of the nutrient intake of the pastoralists (Farah 2004). Camel meat is also an important by-product, mainly as a source of income and export of live camels, and the slaughter of males and unproductive females at local butcheries is very common in Somalia. However, it is difficult to evaluate the economic contribution made by camels as most of their products are traded in the informal market sector. A large proportion of a herd (70 to 80 %) is female. This high number is needed to satisfy the large milk requirement of the nomadic community (Farah et al. 2007). Loss of production is the most significant economic impact of animal disease. Parasitic diseases can affect animals through various physiological processes and result in reduced value of animals and their products. These processes can result in reduced liveweight gain, and reduced quantity and quality of milk produced (Perry and Randolph 1999). In this study, the economic loss due to infection with *Trypanosoma evansi* on milk and meat products per year was determined for camels from data collected by interviewing camel herders and through field data collected during a seroprevalence survey. This study only

Table 1 Definition of effect, population size, production loss and benefits of treatment

Effect	Population size	Loss of production	Benefit of treatment
Loss of milk yield	Number of females lactating	Loss of milk yield per camel	Price of milk yield
Loss of live animal exports	Number of males exported	Loss of value per camel exported	Price of camel exported

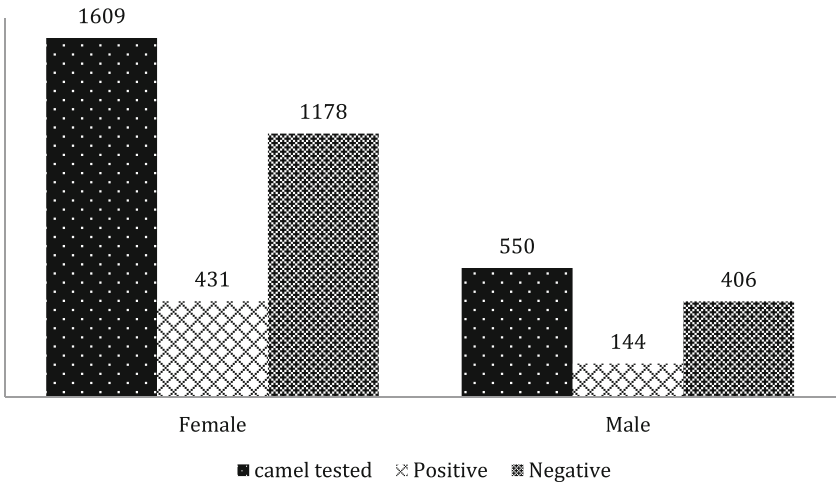

Fig. 1 Camels included in the study to determine the impact of *T. evansi* on camel production

examined productive male and female camels between the ages of 5 and 20 years old. Females are sexually mature at the age of 4 to 5 years and they can remain fertile up to the age of 25 years (Farah 2004).

Data were collected from 2159 camels belonging to 144 herds. The division of these animals into groups is summarised in Fig. 1. On the basis of these figures, the effect of infection with *T. evansi* on the milk and meat yield was investigated. The total value of the live camel export market, the total value of milk produced per camel each year, the total loss per year if animals were not treated, the total value per year if animals were treated and the total production losses were evaluated. The effects of surra on production were calculated by multiplying the total number of clinically affected camels in each category by the reduced value of the affected camels. The annual loss from milk and meat products were the key parameters assessed as these had previously been identified as key outputs of camels in Somaliland (Farah et al. 2004). Data on the overall annual milk production from a healthy camel and the losses associated with surra and the retail market price of camel milk were collected (Table 2). In the present study, the average milk yields in camels with and without disease were estimated at 2 and 6 l per day, respectively. The local unit price of camel milk was recorded as US$0.50. The average market price of a camel exported to the UAE was estimated at US$820 (FAO 2012). The cost of treatment due to disease was estimated at US$10 (M.F. Dirie, personal communication), and the total herd cost was estimated by multiplying this value by the number of animals in the herd.

Direct financial costs and benefits of *T. evansi* treatment strategies

In this study, the cost of the disease was estimated by quantifying the direct and indirect losses due to the disease. The total cost (C) of a disease is thus the sum of the production losses (L), both direct and indirect, and the control expenditures (E): $C=L+E$ (Rushton et al. 1999). The losses due to surra included the reduction in the revenue value of milk and export

Table 2 Components of the estimated benefit-cost analysis for evaluating treatment strategies

Parameter	Value	Range	Units	Source
Herd risk of infection	38.2[a]	1.7–56.2	%	(Baumann and Zessin 1992)
Expected animal losses	30	1.0–30.2	%	(Dirie et al. 1989)
Herd size	80	30–100	#	Field data
Female herd size	70	60–80	#	(Farah et al. 2004)
Value of a female camel	900	600–1200	US$	Field data from 2011 to 2013
Value of a male camel	820	500–1000	US$	(FAO 2012)
Treatment cost per camel	10.1	10.0–10.5	US$	Quinapyramine (triquin) (personal communication)
Cost of diagnosing disease per camel	1	–	US$	(Soumare 2006)
Average milk production per day	6	5–15	Litres	(Farah et al. 2004)
Reduction in milk production	27	–	%	Field data from 2011 to 2012
Reduction in value of camels	26	–	%	Field data from 2011 to 2012

[a] Value % indicate the real prevalence of camels infected with surra

products and losses from the animal's resultant poor body condition.

Risk of *T. evansi* infection

The annual risk of infection with the disease was determined as the probability that any herders would have an outbreak in a given year. Among the parasitological methods used to detect *T. evansi* in the blood stream, the micro-haematocrit centrifugation technique (MHCT) is recognised as the most sensitive test. Examination of the blood samples with MHCT in the field showed that 7.2 % of the camels were newly infected with trypanosomes. MHCT identified 80.5 % of these were infected with *T. evansi* in central Somalia (Baumann and Zessin 1992). Similar studies have reported that 5 % of camels from herds examined in Sool and the northwest regions of Somalia were infected with *T. evansi* (Dirie et al. 1989). Serological tests can effectively complement parasitological methods to improve the diagnosis of surra and determine the disease's prevalence. Nevertheless, surra has been found to be endemic in Somalia, with an estimated prevalence of 56 % when using an ELISA (Baumann and Zessin 1992). It has also been reported that higher levels of infections are present in the long wet season in the riverine zones (Baumann and Zessin 1992). Most importantly, surra generally is chronic and infected animals survive for up to 3 to 4 years, resulting in heavy production losses (Ngaira et al. 2003). Taking all of this into consideration, a conventional estimate of the risk of infection with *T. evansi* in camels from Somalia is between 1.7 and 56.2 % (Baumann and Zessin 1992). In the present study, a seroprevalence of 38.2 % was used to investigate the financial impact of surra on camel production (Table 2).

Components of the treatment strategies to control infection with *T. evansi*

The components of different control strategies for surra were evaluated through calculating the benefit-cost ratio in Somaliland (Table 3). The anticipated financial impacts of adopting the treatment strategies are dependent upon their costs and benefits and the probability of an outbreak. The strategy of no treatment or doing nothing was compared to the other treatment strategies. For the biannual treatment strategy of all camels, it was assumed that 99 % of the camels received treatment. For the monthly-targeted treatment of all clinically sick camels, it was assumed that 26.5 % of the camels were treated. Biannual treatment of seropositive camels was assumed to involve treatment of 38.2 % of the camels—the number of camels infected with surra in a given year. This assumed a 68 % sensitivity and 100 % specificity for the card agglutination test (Ngaira et al. 2003). A benefit-cost analysis was evaluated to determine the financial profitability of implementing different control strategies against surra.

Data analysis

A spreadsheet was constructed in Excel 2011 (Microsoft) to quantify the benefits and costs of controlling *T. evansi* under a variety of strategies. Losses due to the production effects and prevalence of *T. evansi* were estimated from the seroprevalence survey data conducted over 2 years in Somaliland, and special emphasis was given to milk production and the market value of exported camels. These data were used to estimate the economic value of milk loss each year and losses associated with reduced exports of camels. The total cost of treatment was calculated by multiplying the cost of treatment, including the cost of implementation, by the number of animals treated. The cost components of treatment included the unit cost of the drugs, the number of camels dosed, the number of times camels were dosed per year and the cost of veterinary services and transport. Costs of treatment also included diagnostic and treatment of clinically affected camels. Benefits of the treatment components were estimated using gains from the disease control strategies and revenue obtained from the production. Similarly, the annual production loss due to disease prevalence was estimated.

The benefit-cost ratio (B/C) was then calculated (Ramsay et al. 1999). A sensitivity analysis was conducted to determine the sensitivity of the results to the parameter estimates used in the study (Table 2).

Results

This study analysed data from all females (1609) of which 27 % (431) were lactating and 550 males of which 144 (26 %) were exported. The results indicate that the majority

Table 3 Control strategies against *Trypanosoma evansi* in camels evaluated in Somaliland

Strategy	Description	Population treated
No treatment	No camels are treated and no control strategy is adopted	–
Biannual treatment of all camels in the herd	Camels are treated during two consecutive wet seasons	2137
Monthly treatment of clinically sick camels	Camels with clinical signs are treated	565
Biannual treatment of seropositive camels	Camels that are seropositive are treated in two consecutive wet seasons	816

(88 %) of respondents recognised the importance and impact of surra on camel production, particularly household income and the consequent social impact. Most respondents (80 %) reported that surra could impact the fertility of their herds. Most respondents (94 %) also attributed biting flies to be responsible for causing surra. In addition, herders recognised the different risks between different ecological zones with a substantial increase in the risk of infection when biting flies were present in these areas. All the interviewed camel herders could identify biting flies responsible for surra and understood the role the vector played in the transmission of *T. evansi*. The economic losses from trypanosomosis in this study included a reduction in body condition by 39.5 % for camels in the study area. However, the economic study indicated that the greatest losses were associated with decreased milk yield and carcass weight. A reduction in milk yield of 27 % and reduced export market value of 26 % was reported in this study.

Economic loss assessment

Estimating the economic loss resulting from surra is not easy due to limited information on the impact of the disease on the population. The impact of surra has previously been restricted to losses from mortality and the costs in controlling the disease (Reid 2002). In the present study, estimating economic values of milk yield and export market for males were based on the mean values recorded. The annual expected return when no treatment was administered was evaluated in the surra endemic area. In Table 4, the benefits of the no treatment strategies are reported. Overall, the annual benefits of the no treatment and curative treatment strategy were US$1,808,225.00 and US$2,212,855.00, respectively. The no treatment strategy gives an indication of the amount of revenue herders obtain if nothing is done to control the disease. The financial loss was calculated by subtracting the total value of sick camels if no treatment was administered by the total value of camels when treatment was administered. The expected amount of revenue the herders could lose per year in the studied area was estimated at US$404,630 (Table 5). The results show that the largest loss was associated with decreased milk yield (US$314,630). The revenue obtained from the market value of exported animals was also reduced by US$90,000 if no treatment was administered (Table 5).

Table 4 Comparing the benefits of no treatment and treatment strategies in camel production

Category	Population size	Camels affected	Revenue with surra (US$)	Revenue without surra (US$)
Female	1609	431	1,447,225.00	1,761,855.00
Male	550	144	361,000.00	451,000.00
Total	2159	575	1,808,255.00	2,212,855.00

Table 5 Economic effects of surra in camel production and benefits of treatment

Category	Value of reduced production (US$)	Average loss per head (US$)	Benefit of treatment (US$)	Average benefit per head (US$)
Female	314,630.00	195.54	310,320.00	720
Male	90,000.00	163.64	88,560.00	615
Total	404,630.00	359.18	398,880.00	1335

The benefits of treatment were calculated by subtracting the total cost of treatment administered to the herds from the increase in production obtained due to disease control (Table 5). Overall, the benefit in treating camels in the study area was US$398,880 ($n$=2159). Most of this (US$310,320) was due to improved milk production in treated animals (average of $720 per head). The remaining $88,560 was obtained from the increased value of exported camels (US$615—Table 5). The average loss per animal estimated for reduced production and body condition loss in the study area of Somaliland was US$195.54 and US$163.64. Extrapolating the current findings to the total camel population with approximately two million of camels is at risk of acquiring surra in the endemic region of Somaliland. The study has indicated a loss in the magnitude of US$223,164,000 with milk production of US$164,253,600 and US$58,910,400 for body condition loss.

Benefit-cost ratios of treatment strategies

The results of calculating benefit-cost ratios for different treatment strategies are presented in Table 6. The B/C ratios of the three-treatment strategies are all greater than one, indicating there is a financial benefit in adopting any of the three control strategies in Somaliland. The most economical viable treatment of *T. evansi* in Somaliland was the adoption of biannual treatment of seropositive camels (Table 6).

Table 6 Benefit-cost ratios of different treatment strategies for *T. evansi* in camels

Treatment options for surra	Number treated	Treatment cost (US$)	Benefit-cost ratio
Biannual treatment of all camels	4275	76,656.10	5
Monthly treatment of all clinically sick camels	6784	93,800.70	4.08
Biannual treatment of all seropositive camels	1633	39,844.91	9.61

Discussion

The results of this study provide valuable information on the economic impact of trypanosomosis in camels raised under an extensive pastoral system in Somaliland. A simple spreadsheet was used to estimate the economic losses from reduced milk yield and meat production resulting from infection of camels with *T. evansi* and to compare the economic viability of different disease control strategies. This study highlighted the impact surra had on milk yield and meat production if no treatment was undertaken. Furthermore, most respondents (80 %) reported that surra affected the fertility of their female camels resulting in increased calf mortality. Another study undertaken in the central regions of Somalia also reported the detrimental effects of trypanosomosis on the fertility of camels and high mortalities in calves during their first year of life (Baumann and Zessin 1992). In addition, an extended inter-calving interval of 34 months was reported (Baumann and Zessin 1992). Others have reported an inter-calving interval of 24 months in camels raised under a pastoral production system (Farah 2004). A major constraint to production of camels is the high mortality of calves in the first 3 months of age (Farah 2004). However, it is uncertain if this is due to trypanosomosis, a reflection of the poor management system adopted or the presence of other infectious diseases. Nevertheless, it is important to assess the economic impact of reduced production and disease in camels raised under pastoralist management systems. In this study, 39.5 % of carcasses were of poor quality. This could be the result of the chronic form of infection with *T. evansi*. Loss of body condition, progressive emaciation and reduced drought power are characteristic findings of camels affected with surra (Njiru et al. 2004; Swai et al. 2011). These presentations would also likely be associated with reduced milk and growth rate and poor carcass quality.

The findings reported in this study agree with the reports of others in highlighting that surra causes high mortality, low milk and meat production and reduced draught output and manure production (Desquesnes et al. 2013). Infection with *T. evansi* can result in reduced weight gain by as much as 7.6 kg over a 3-month period in fattening cattle and can result in reduced draught output by up to 30 % in buffalo (Reid 2002). In the present study, the results indicated that surra led to a 27 % reduction in milk yield and a reduction of 26 % in meat production. Infection of camels with *T. evansi* is usually chronic, and therefore the economic impact of the disease on production is more likely in the areas where the disease is endemic. Infection may last for 3 to 4 years and lead to reduced milk and meat yield of adults (Boid et al. 1985).

This study found that the financial loss attributable to surra in the endemic area, if no control programme was adopted, was US$404,630. As was expected, the largest single financial loss was associated with reduced milk yield in lactating camels followed by reduced income obtained from camels exported for meat. These findings agree with those reported by others on the impact of surra on camel production (Njiru et al. 2004; Zeleke and Bekele 2001). Several studies have highlighted the reduced meat production and milk yield of infected cattle in the Philippines (Reid 2002). In that study, cattle infected with *T. evansi* produced significantly less milk than did non-infected cattle and milk production increased after treatment with isometamidium (Pholpark et al. 1999).

This highlights the significant negative impacts when no disease control programmes are implemented. The annual risk of infection of camels with *T. evansi* has the potential to result in significant annual financial losses through morbidity and mortality. Dobson et al. (2009) reported that failure to adopt effective treatment strategies for surra in an endemic area by small-holder livestock owners in the Philippines could result in a loss of US$160,000 per year. This study only investigated benefits from controlling the disease on milk and meat production and did not study costs associated with mortality, reduced reproductive performance and lower draught potential or the costs of replacing camels. Consequently, it is likely that the losses associated with the disease are even higher than that reported here. The financial losses due to *T. evansi* infection in horses in the Brazilian Pantanal region has been estimated to cost ranchers US$2.4 million annually due to the mortality of over 6000 horses (Seidl et al. 1998). Similarly, in Indonesia, the annual loss from surra was estimated at US$28 million (Reid 2002). These losses can be greatly reduced if an effective control strategy is adopted (Seidl et al. 1998). In this study, adopting an annual treatment strategy resulted in a substantial benefit of US$2,212,855 to the surveyed herders. This highlights the benefit to the herders in controlling the disease.

Adopting this control strategy would result in an annual benefit of US$398,880 in terms of milk and camel export market for surveyed herders in the studied area of Somaliland. However, all the camels in Somaliland are at risk of acquiring surra infection, and therefore extrapolating the current findings to the total population could potentially lose US$223,164,000. This highlights the significance of surra on animal health and production in Somaliland. In the current study, all three-treatment options evaluated were economically beneficial strategies; however, the biannual treatment of seropositive camels in the herds was the best financial option. This regime relies on the treatment of seropositive animals twice a year allowing the camels to be treated in the two wet seasons. In the wet seasons, it is likely that the risk of infection increases as most infections have been reported during this time (Baumann and Zessin 1992).

Treatment recommendations and strategies for chemotherapeutic control depend on information about the risk of trypanosomosis and the disease's prevalence (Abdel-Rady 2008). However, mass treatment with chemotherapeutic drugs and overdosing have led to increasing resistance in Africa and

potential toxicity (Anene et al. 2001; Salifu et al. 2010). Control strategies are designed to reduce animal mortality. The highest cost of treatment in this study was the monthly-targeted treatment of all clinically sick camels. An important advantage of this treatment strategy is that all sick animals receive a treatment. However, in the current study, the biannual treatment of seropositive camels was more economically efficient.

The evaluation of economic losses of trypanosomosis in camels raised under extensive pastoral systems is difficult because of the absence of individual animal records and the challenges of collecting epidemiological data in the field. This is mainly due to the management practices of nomadic pastoralists and the remote areas camel herders operate in. However, improving animal health and productivity is becoming critically important in this livestock industry. Furthermore, considering strategic approaches to the control of surra can play a major role in achieving efficient and economically viable production. Losses from trypanosomosis can be reduced greatly if appropriate interventions are adopted in all camel rearing areas. A control strategy for *T. evansi* depends mainly on the use of curative and prophylactic drugs and consideration of other factors including animal movement and herd management.

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Conflict of interests The authors declare that they have no conflict of interests.

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