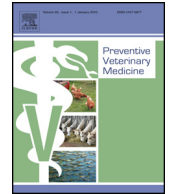




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Sarcocystis spp. in llamas (*Lama glama*) in Southern Bolivia: A cross sectional study of the prevalence, risk factors and loss in income caused by carcass downgrades

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ABSTRACT

Llamas (*Lama glama*) are intermediate hosts of the protozoan parasite *Sarcocystis* spp. This parasite is described as causing economic losses in the production of llama meat in South America. The aim of this study was to estimate prevalence, identify risk factors and explore spatial patterns of *Sarcocystis* in llamas in an area of the Bolivian High Plateau including estimating financial losses due to carcass downgrades as a result of the presence of *Sarcocystis* cysts.

Information was collected from a local abattoir between 2006 and 2011 on 1196 llamas. *Sarcocystis* status was determined at meat inspection where any carcasses with one or more visible cysts were deemed *Sarcocystis* positive. A high prevalence was found, estimated to vary between 23.4% (95% CI 16.6–30.1) in 2007 and 50.3% (95% CI 44.4–56.3) in 2011. Period prevalence between 2006 and 2011 was estimated at 34.1% (95% CI 31.4–36.8). Age, sex and type (analogous to breed) were identified as risk factors for *Sarcocystis* using a mixed-effects logistic regression model adjusting for clustering by community and owner. Llamas over 4.5 years of age had an increased odds of being *Sarcocystis* positive (OR 19.31, 95% CI 9.10–40.98) as well as females (OR 1.75, 95% CI 1.13–2.68) and long haired type llamas (OR 1.90, 95% CI 1.26–2.87). An interaction between age and sex was detected indicating that the increased odds of disease from the youngest age group to the 2.5–4.5 years group was much more pronounced in females than in males. Spatial patterns of *Sarcocystis* were explored at district level by means of Standardised Morbidity Ratios and some spatial heterogeneity was revealed. Estimates of financial loss due to the disease were calculated using the difference in price paid for *Sarcocystis* positive and negative meat. Loss due to *Sarcocystis* varied per year but could be up to 20% of the annual income generated through the abattoir by sale of meat.

Overall this study shows a high prevalence of *Sarcocystis* in the study area with some heterogeneity between districts. It also identifies some previously unknown risk factors for *Sarcocystis* and gives financial estimates of the cost of the disease as a result of carcass downgrades. We hoped these findings will add to the understanding of *Sarcocystis* in llamas in Southern Bolivia and will be useful when considering if controls are necessary, worthwhile and practical.

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1. Introduction

Bolivia is one of the poorest countries in Latin-America with the third lowest human development index in the

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region (Klugman, 2010). In the high plateau area (Altiplano), livelihoods are highly dependent on livestock and in particular sheep and llama (Camprero, 2004). Llamas are an important source of income by provision of protein, hide, fibre and transport (Leguia, 1991) but llama meat is often regarded as a low value product compared to other protein sources such as beef or mutton, mainly due to the presence of sarcocystiosis (Viscarra et al., 2002). This disease is caused by the protozoan parasite *Sarcocystis* of which two species are identified in llamas, *Sarcocystis aucheniae* and *Sarcocystis lamacensis* (Taylor et al., 2007). *Sarcocystis* is a member of the *Sarcocystidae* family of protozoan parasites, which involve an intermediate and final host in their life cycle. The intermediate host for *Sarcocystis* spp. is typically an herbivore or omnivore such as a cow, sheep or pig and the final host is usually a predator species such as the dog or cat. Sporocysts, infective to the intermediate host, are passed through the faeces of the final host and picked up by the intermediate host by ingestion. The parasite encysts in muscle cells in the intermediate host and this is the infective stage for the carnivorous final host (Urquhart et al., 1996). It is thought that most *Sarcocystis* species are species-specific for intermediate hosts and family-specific for final hosts (Tenter, 1995). Of the *Sarcocystis* species found in llamas, it has been identified that *S. aucheniae* uses the dog as a final host; however, the final host for *S. lamacensis* is not known (Taylor et al., 2007). Some other *Sarcocystis* species such as *Sarcocystis hominis* and *Sarcocystis suihominis* are known to include man as a final host (Fayer, 2004) with the route of infection commonly being the ingestion of raw or undercooked meat products containing mature sarcocysts. There is some suggestion of zoonotic potential of *Sarcocystis* spp. in llamas (Leguia, 1991) but evidence is limited. Therefore, it is not widely known if the *Sarcocystis* species harboured in llamas is transmissible to humans (Fayer, 2004). Clinical signs of *Sarcocystis* infection in the intermediate host are rare and sarcocysts are mainly a secondary *post mortem* finding (Fowler, 2010). Despite the lack of evidence of the parasite as zoonotic or as a cause of clinical disease in llamas, *Sarcocystis* infection can cause important financial losses due to downgrading of meat (Leguia, 1991; Tenter, 1995; More et al., 2008; Fowler, 2010). Meat with visible cysts attributable to *Sarcocystis* is deemed unfit for human consumption at meat inspection, unless it is processed into a dehydrated form of meat termed 'charque'. This is mainly due to aesthetic reasons as cysts are visible in affected musculature as macroscopic oval white structures approximately 0.5–5 mm in size (Urquhart et al., 1996; Leguia, 1991), see Fig. 1. Drying meat is an effective way of destroying sarcocysts (Leguia, 1991) and ensures affected meat can still be sold for human consumption; however, this meat has a lower value compared to fresh meat.

Although sarcocystiosis is thought to be one of the most prevalent protozoan infections in several animal species around the world (More et al., 2008; Taylor et al., 2007) little work has been done to establish prevalence, risk factors for infection and financial consequences of the presence of *Sarcocystis* in llamas. A report investigating the validation of a serological test for *Sarcocystis* in llamas in Bolivia estimated prevalence on meat inspection to be

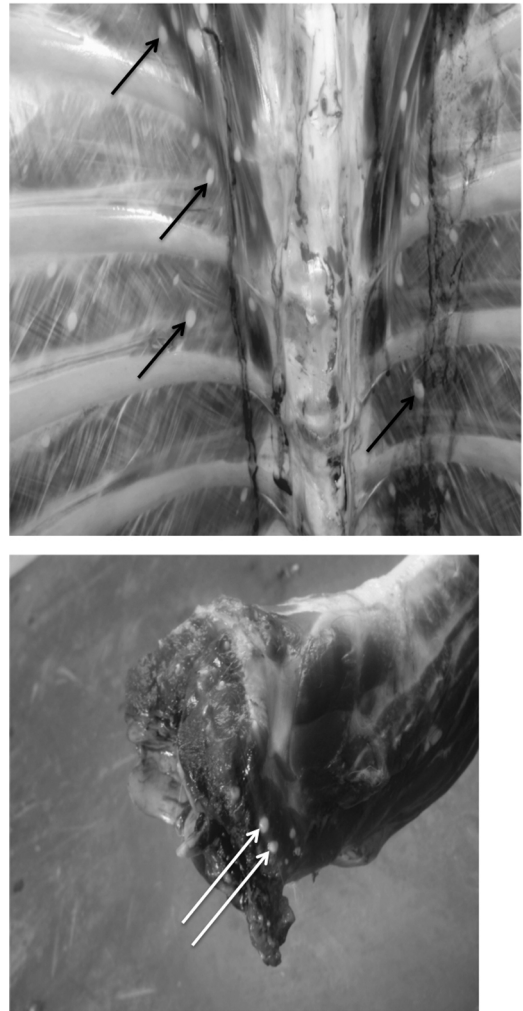


Fig. 1. *Sarcocystis* cysts in a llama carcass – intercostal muscles and neck muscles.

35% (Viscarra et al., 2002) but it varied highly depending on which slaughterhouse the data were gathered from. Other studies have estimated prevalence by measurement of antibodies in serum samples. The results from these studies have shown seroprevalence of 96% in llamas in Argentina (More et al., 2008) and 89.7% (95% CI 87.8, –91.6) in alpacas (*Lama pacos*) in Peru (Castro et al., 2004). Studies to establish risk factors for the disease are very limited in llamas. Age was identified as a risk factor for *Sarcocystis* in alpacas in Peru, where animals over 1 year old had a significantly higher probability of seropositive status compared to animals below 1 year of age (Castro et al., 2004). Documented economic assessments of the impact of *Sarcocystis* in llamas are also scarce. It has been estimated that sarcocystiosis makes up 11.4% of the total annual losses directly attributable to parasitic disease in alpacas in Peru (Leguia, 1991). In Bolivia, previous work showed that the main economic effect of *Sarcocystis* was from downgrading meat (Meijer et al., 2000).

The study presented here uses data gathered in a newly established llama abattoir located in an area of the

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