Hydatidosis of camel (*Camelus dromedarius*) at Jijiga municipal abattoir, Eastern Ethiopia: prevalence, associated risk factors and financial implication

Etana Debela · Buckhary Abdulahi · Bekele Megersa ·
Bersissa Kumsa · Fufa Abunna · Desie Sheferaw ·
Alemayehu Regassa

Received: 7 May 2013 / Accepted: 16 January 2014 / Published online: 8 February 2014
© Indian Society for Parasitology 2014

Abstract A cross-sectional study was conducted from November 2010 to May 2011 to estimate the prevalence of camel hydatidosis, associated risk factors and financial loss in Jijiga municipal abattoir, Somali Regional State, Eastern Ethiopia. Accordingly, of the total 400 inspected camel, 92 (23 %) camels and 109 organs were positive for hydatid cyst with the highest proportion recorded in lung (56 %) followed by liver (33.9 %), spleen (7.3 %) and kidneys (2.8 %). The prevalence of hydatidosis significantly varied among age categories ($P < 0.05$), sex ($P < 0.05$) and body condition score ($P < 0.05$) of camels. Hence, there is higher likelihood for occurrence of camel hydatidosis among the older age groups (OR 1.8, 95 % CI 1.2, 3.3), in female camels (OR 2.8, 95 % CI 1.7, 4.7) and in poor body conditioned camels (OR 4.1, 95 % CI 2.2, 7.9) than younger camels, males and camels with good body condition score, respectively. Of the total 288 examined cysts for fertility and viability, 59.7 % (172/288) were fertile while the rest 24.0 % (69/288) cysts were sterile. Of the 172 fertile cysts 69.8 % ($n = 120$) were viable and 30.2 % ($n = 52$) were non-viable. The rest 16.3 % (47/288) cysts were found dead.

It was also observed that the pulmonary and hepatic cysts had fertility rate of 63.7 % (116/182) and 57.4 % (54/94), respectively. The total annual direct financial loss recorded in this study as result of organs condemnation due to hydatid cyst, was 12,147.75 Ethiopian birrs (\$714.57 or \$7.77/camel). If this value could be extrapolated to the infected camel population of the region, financial loss due to hydatidosis could be enormous. In conclusion, this study showed the importance of hydatidosis and the associated direct financial loss due to the condemnation of organs affected by hydatid cyst in the study area.

Keywords *Camelus dromedarius* · Hydatidosis · Prevalence · Cyst viability · Financial loss

Introduction

One humped camel (*Camelus dromedaries*) is the most important animal that adapted in marginal areas, and also able to survive and produce under harsh environmental conditions (Knoess 1977; Abbas and Tilley 1990; Schwartz 1992). In Ethiopia, as in most dry lands of Africa and Asia, camels are the principal sources of income, food, providing draught power and determining the wealth and social status of millions of pastoralists (Getahun and Belay 2002).

Despite the fact that Ethiopia possesses 2.3 million heads (MOI (Ministry of Information) 2005) of camels, little is known about camel husbandry practices or the productive and reproductive performance (Getahun and Belay 2002). Their natural desert habitat subjects them to severe stress conditions which makes them susceptible to many diseases and ailments (Abbas et al. 1993; Agab 1993). Parasitic diseases either lower their working efficiency or even may result in death in camels. Hydatidosis

E. Debela (✉) · B. Abdulahi · B. Megersa · D. Sheferaw ·
A. Regassa
School of Veterinary Medicine, Hawassa University,
P.O. Box 05, Hawassa, Ethiopia
e-mail: etana_debela@yahoo.com

B. Kumsa
Department of Parasitology, College of Veterinary Medicine and
Agriculture, Addis Ababa University, P.O. Box 34, Bishoftu,
Ethiopia

F. Abunna
Department of Clinical Studies, College of Veterinary Medicine
and Agriculture, Addis Ababa University, P.O. Box 34, Bishoftu,
Ethiopia

is a disease that is not readily apparent to the farmers but of considerable economic and public health importance occurring in many countries (Ansari-Lari 2005; Taylor et al. 2007) and appearing to be endemic in camels in the whole of eastern Africa (Schwartz and Dioli 1992).

There are very few information (Woldemeskel et al. 2001; Samuel 2007; Salih et al. 2011; Gizachew et al. 2013) available on the prevalence and financial importance of camel hydatidosis in Ethiopia. Therefore, this study was designed to estimate the prevalence of hydatidosis, to assess the associated risk factors and to see the implication of financial loss due to the condemnation of affected organs at Jijiga municipal abattoir, Eastern Ethiopia.

Materials and methods

Study area and animals

The study was conducted at abattoir located in Jijiga town which is situated between 8°44'N and 11°00'N longitude and between 40°22'E and 44°00'E latitude, at an altitude ranging between 1,760 and 2,300 meter above sea level. The study animals were one humped camels (*C. dromedaries*). The sources of the animals were Jigjiga, Babilie, Kabriyah and Awbarre districts of Jigjiga zone, Somali region. Most part of these districts is characterized by pastoralism and agro-pastoralism, and with high camel breeding potential. The people in the districts used camels for packing, transportation, ploughing and traction purposes. Camels also used as source of cash income, milk and meat (Mehari et al. 2007).

Sample size determination and sampling procedure

It was mentioned that it is reasonable to assume that a systematic sample is as representative as a simple random sample. Hence, the sample size was calculated using the formula given for simple random sampling (Thrusfield 2005) with 50 % expected prevalence, 95 % confidence interval and 5 % desired absolute precision. Accordingly, the sample size was determined to be 384. However, 400 animals were included in this study with the intention of maximizing the sample size to increase precision. The sampling procedure was carried out using systematic random sampling (Pfeiffer 2002; Thrusfield 2005) in such a way that sampling units were selected at equal intervals with the first animal being selected randomly. The estimate of the total number of animals slaughtered during the preceding year (year 2009) was 1,800, which were obtained from the record. The number of slaughtered animal during the 5 months of the year 2010 was calculated to be 750 as our current study period was also 5 months. Subsequently,

the sampling interval was computed as the total number of animals slaughtered during the study period divided by the required sample size. Therefore, the sampling interval was 2 (750/400). Then the first animal was chosen randomly from the first two animals after which every two camel was included in the sample during the slaughter operation.

Study type and methodology

During the cross-sectional active abattoir survey, both ante mortem and post mortem inspections were carried out in accordance with the procedures of Ethiopian Ministry of Agriculture Meat Inspection Regulation 1972. In the ante mortem inspection, pre-slaughter examinations of camels were conducted and information concerning age, body condition score and sex of each study animals were properly recorded. The age grouping was done based on dentition as described by Schwartz and Dioli (1992) and Khan et al. (2003). The age of the animals was recorded on the basis of the dentition and was conventionally grouped into three age groups as young 3 to 5, 6 to 8 and >9 years.

The body condition scoring was carried out based on the guideline given by Faye et al. (2001) for *C. dromedarius*. This was by looking at the back (ischial tuberosity, sacrotuberal ligament, anogenital region, spinous apophyses) and flank (coxal tuberosity, hollow of the flank, transverse apophyses, ribs and hump). In line with this, the scores were classified into six starting from 0 (very thin) to 5 (very conditioned). For convenience, these categories were summarized into three classes as poor (0 and 1), medium (2 and 3) and good (4 and 5). Since this work was carried in the abattoir, less number of animals was found lean whereas others were with medium and good body condition score.

Additionally, general behaviour of the animals, nutritional status, cleanliness and sign of diseases and any pathology were registered according to the standard ante mortem inspection procedures (Gracey et al. 1999) and animals that were fit for human consumption were allowed for slaughter. All the 400 camels that were examined by ante mortem inspection were also thoroughly examined during post mortem inspection. Thorough post mortem examination was done by inspection, palpation and incision of visceral organs: liver, lung, heart, kidney and spleen (FAO 1994; Gracey et al. 1999). Cysts encountered at post mortem examination were grossly examined for calcification, and non calcified cysts were randomly selected and taken to the laboratory for fertility test.

Examination of cysts fertility and viability of protoscolices

After collection of samples from each cysts positive organ, the cyst wall was penetrated with needle and opened with scalpel blade and the contents were transferred into test tube. Based on

the presence and the absence of brood capsule containing protoscolices in hydatid fluid, cysts were identified and classified as fertile and infertile. The infertile cysts were also further classified as sterile (fluid filled cysts without any protoscolices) and calcified as per the procedure given by (McPherson 1985). To determine viability of protoscolices a drop of the sediment consisting of the protoscolices was placed on a microscopic glass slide and 22 × 22 mm cover slip was applied and observed for amoeboid peristaltic movement (flame cell activity) with the objective of ×40 (Smyth and Barrett 1980). When it is doubtful or confusing to observe such movements, a drop of 0.1 % aqueous eosin solution was added to equal volume of protoscolices to completely or partially exclude the dye while the dead one take it up (Smyth and Barrett 1980; McPherson 1985).

Estimation of direct financial loss

An attempt was made to assess the direct financial loss due to hydatidosis by considering the average number of hydatid positive camels slaughtered per annum at Jigjiga municipal abattoir and the degree of organ condemnation using the following formula:

$$\text{Annual loss} = (N_{ps} \times I_{lu} \times C_{lu}) + (N_{ps} \times I_{li} \times C_{li}) + (N_{ps} \times I_{ki} \times C_{ki}) + (N_{ps} \times I_{sp} \times C_{sp})$$

where, N_{ps} is the total number of positive animal slaughtered per annum, I_{lu} is the prevalence of the lung hydatidosis, I_{li} is the prevalence of liver hydatidosis, I_{ki} is the prevalence of kidney hydatidosis, I_{sp} is the prevalence of spleen hydatidosis, C_{lu} is the cost of lung, C_{li} is the cost of liver, C_{ki} is the cost of kidney and C_{sp} is the cost spleen.

Data analysis

Data were entered into the excel sheet and descriptive analysis was performed to calculate different proportions.

Logistic regression analysis was employed to analyze the existence of association between the different risk factors and hydatidosis. Odds ratio was also used to see the direction and degree of association. All the analyses were carried out using STATA version 11 software.

Results

Prevalence and analysis of the risk factors

Of the total 400 camels examined during slaughter 92 (23 %) were found to be positive for hydatid cysts. The occurrence of hydatidosis significantly varied among age ($P < 0.05$) group, sex ($P < 0.05$) and body condition score ($P < 0.05$) of camels. Hence, there is higher likelihood of occurrence of camel hydatidosis among the older age groups (OR 1.8, 95 % CI 1.2, 3.3), in female camels (OR 2.8, 95 % CI 1.7, 4.7) and in poor body conditioned camels (OR 4.1, 95 % CI 2.2, 7.9) than younger camels, males and camels with good body condition score, respectively (Table 1).

Organ level distribution of the cyst

Of the examined organs, 109 were found positive for hydatid cyst with the highest relative percentage recorded in lung (56 %) followed by liver (33.9 %), spleen (7.3 %) and kidneys (2.8 %). Out of the total 288 hydatid cyst encountered in the inspected organs, the relative percentage of cysts in the lung, liver, spleen and kidney accounted for 63.19 % (182/288), 32.64 % (94/288), 3.13 % (9/288), and 1.04 % (3/288), respectively (Table 2).

Cyst fertility and viability

Of the total 288 observed and examined cysts for fertility and viability, 59.7 % (172/288) were fertile while the rest

Table 1 Logistic regression analysis of various risk factors association with the occurrence of camel hydatidosis in Jijiga Municipal Abattoir

Risk factors	No examined	No (%) affected	Crude OR (95% CI)	Adjusted OR (95% CI)	P value
Sex					
Male	262	43 (16.4)	1	1	
Female	138	49 (35.5)	2.8 (1.7–4.5)	2.8 (1.68–4.69)	0.000
Age					
3–5	107	28 (26.2)	1	1	
6–8	67	22 (32.8)	1.38 (0.7–2.7)	1.13 (0.5–42.38)	0.748
>9	226	42 (18.6)	1.55 (1.1–2.7)	1.83 (1.2–3.3)	0.047
BCS					
Good	141	21 (14.9)	1	1	
Medium	160	30 (18.8)	1.32 (1.1–2.4)	1.23 (0.7–2.3)	0.526
Poor	99	4 (4.0)	4.04 (2.2–7.5)	4.13 (2.2–7.9)	0.000

Table 2 Number of organs affected by hydatid cyst and the relative percentage of the cyst in each organs

Organ	No of organs affected	Relative Percentage (%)	No of cysts in each organ	Relative percentage (%)
Lung	61	56.0	182	63.2
Liver	37	33.9	94	32.6
Spleen	8	7.3	9	3.1
Kidney	3	2.8	3	1.0
Total	109		288	

24.0 % (69/288) cysts were sterile. Of the 172 fertile cysts 69.8 % ($n = 120$) were viable and 30.2 % ($n = 52$) were non-viable. The rest 16.3 % (47/288) cysts were found dead. It was also observed that the pulmonary and hepatic cysts had fertility rate of 63.7 % (116/182) and 57.4 % (54/94), respectively. That is, the organ level difference in terms of fertility and sterility status of the cyst revealed that 116 (63.7 %), 51 (28.0 %) and 15 (8.2 %) cyst represented fertile, sterile and calcified in lung whereas the liver had 54 (57.5 %) fertile 14 (14.9 %) sterile and 26 (27.7 %) calcified cysts, respectively (Table 3).

Financial loss

The direct financial loss has been calculated on the basis of wholesome and intact visceral organs i.e. lung, liver, spleen and kidney. Based on the previous formula (Given above under materials and methods), annual financial loss was calculated as:

$$\begin{aligned} \text{Loss} &= (92 \times 0.58 \times 5) + (92 \times 0.30 \times 110) \\ &\quad + (92 \times 0.033 \times 20) \\ &\quad + (92 \times 0.087 \times 2) = \$714.57 \end{aligned}$$

where 92, 5, 110, 20 and 2, were number of positive study camels slaughtered, price of lung, liver, kidney and spleen during the study period, respectively. Then the annual loss can be calculated as, Annual Loss = $(336 \times 0.58 \times 5) + (336 \times 0.30 \times 110) + (336 \times 0.033 \times 20) + (336 \times 0.087 \times 2) = 12, 147.75$ Ethiopian birr (714.57 USD),

where, 336 is number of positive camels slaughtered in study year. If this value could be extrapolated to the infected camel population of the region, financial loss due to hydatidosis could be enormous.

Discussion

In the present study, the prevalence of the hydatid disease in the study area was 23 %, which is in a general agreement with reports of Woldemeskel et al. (2001) and Salih et al. (2011). Such similarities in the prevalence of hydatidosis in the different locations of the country might be related to similarities in livestock health practices and associated risk factors among the communities of the study areas. Relatively higher prevalence of camel hydatidosis were reported from Ethiopia (Gizachew et al. 2013), and elsewhere in the world (Abdul-Salam and Farah 1988; Ibrahim and Craig 1998; Ahmadi 2005; Mohamed 2010).

The present study showed that lung was more frequently infected (57.6 %) than the liver (30.4 %). This finding is in agreement with the reports from Ethiopia (Woldemeskel et al. 2001; Salih et al. 2011; Gizachew et al. 2013) and other parts of the world (Anwar and Khan 1998; Ibrahim and Craig 1998; Sharif et al. 1998; Ahmadi 2005). The higher frequency of infection in lung and liver might be due to the fact that lungs and livers possess the first great capillaries site encountered by the migrating echinococcus oncosphere, hexacanth embryo, which adopt the portal vein route and primarily hepatic and pulmonary filtering system sequentially before any other organ involved. Furthermore, the lungs might be predominantly infected with hydatid cyst than any other organ probably due to the presence of large capillary beds in the lung than any other organs.

In this study, an attempt was made to assess the relationship between body condition score and cyst infection. The result indicated that there was a significant difference ($P < 0.05$) in rate of infection among different the body condition scores. Animals having poor body condition were found to have high cyst infection. According to Polydorou (1981) in moderate to severe infections, the

Table 3 Distribution of fertile (viable, nonviable), sterile and calcified hydatid cysts in different organs of camels slaughtered at Jijiga abattoir

Organs inspected	No (%) positive organs	No (%) of cyst	Non-calcified cysts			Calcified cyst
			Fertile cyst		Sterile cyst	
			Viable	Non-viable		
Liver	61	182 (63.2)	82 (45.1)	34 (18.7)	51 (28.0)	15 (8.2)
Lung	37	94 (32.6)	37 (39.4)	17 (18.1)	14 (14.9)	26 (27.7)
Spleen	8	9 (3.1)	1 (11.1)	1 (11.1)	3 (33.3)	4 (44.4)
Kidney	3	3 (1.0)	0 (0.0)	0 (0.0)	1 (33.3)	2 (66.7)
Total	109	288 (100)	120 (41.7)	52 (18.1)	69 (24.0)	47 (16.3)

parasite may cause retarded performance and growth, reduced quality and yield of meat and milk. Hence this could partially explain why animals with poor body condition in the current study were associated with the higher prevalence of the infection.

The prevalence of hydatidosis was found to be significantly higher in female camel than the male (OR 2.8, $P < 0.05$). This finding is in line with the reports of Salih et al. (2011) and Gizachew et al. (2013) from Ethiopia, and Abdul-Salam and Farah (1988) from Kuwait. This might be related to the practices keeping female camel around the homesteads at the backyard for milk production purpose. Hence, they were exposed to the contaminated environment with shedding of gravid segment of *Echinococcus granulosus* by infected dogs (Parija 2004). Moreover, female camels remain longer than males for reproductive purposes in the area and this justifies the probability of having higher prevalence and mean intensity in females than in males.

Age of the camels also significantly (OR 1.83, $P < 0.05$) influence the prevalence of hydatidosis. According to Ibrahim et al. (2011) hydatidosis infection rates increased with age of the animals. This variation accounted to the high probability of the exposure of older animals to the infection during their long existence in life. Camel are slaughtered at their medium or older age, and growth of the hydatid is slow and maturity being reached in 6–12 month (Urquhart et al. 1996). It is also possible to relate to the general fact that most of the camel are slaughtered in their older age when they become exhausted in milk and/or in calf production or when they are in reduced capacity of work and due to lowering of immune response to infection. Likewise, body condition score also significantly (OR 4.13, $P < 0.05$) influenced prevalence of camel hydatidosis being higher in animals with poor body condition than those with medium and good conditions which might be associated to decreased immune response of the animal to the infection of *E. granulosus*.

The estimated annual financial loss of 11,963.22 ETB (equivalents to 703.72 USD) due to camel hydatidosis was comparable to the report of Gizachew et al. (2013). But it appeared to be lower on cattle from the various parts of the country (Jobire et al. 1996; Getaw et al. 2010). The difference in financial loss estimates in various abattoirs or regions may be associated to the variations in the prevalence of the disease, species difference, risk factors influencing the occurrences of the infection and in the retail market price of the organs. The indirect body weight loss due to diseases, which is in real term difficult to calculate, the treatment loss and loss due to impact posed to the public health were not also calculated in the current study.

In conclusion, hydatidosis was found to be one of the most important parasitic diseases with economic implications in

camels in Jijiga and its surrounding, warrant serious attention for its prevention and control. Sex, age and condition of camels had association with the occurrence of hydatidosis.

References

- Abbas B, Tilley P (1990) Pastoral management for protecting ecological balance in Halaib District, Red Sea Province, Sudan. *Nomadic peoples* 29:77–86
- Abbas B, Saint-Martin G, Planchenaut D (1993) Constraint to camel production in Eastern Sudan: a survey of pastoralist conception. *Sud J Vet Anim Husb* 32(1):31–41
- Abdul-Salam JM, Farah MA (1988) Hydatidosis in camels in Kuwait. *Parasitol Res* 74:267–270
- Agab H (1993) Epidemiology of camel diseases in Eastern Sudan with emphasis on Brucellosis. MSc thesis, University of Khartoum. pp 172
- Ahmadi NA (2005) Hydatidosis in camel (*C. dromedaries*) and their potential Role in the Epidemiology of *Echinococcus granulosus*. *Iran J Helminthol*. 79:119–125
- Ansari-Lari M (2005) A retrospective survey of hydatidosis in livestock in Shiraz, Iran, based on abattoir data during 1999–2004. *Vet Parasitol* 133:119–123
- Anwar AH, Khan MN (1998) Parasitic fauna of camel in Pakistan. In: The proceedings of the third annual meeting for animal production under arid conditions, United Arab Emirates University. pp 69–76
- FAO (1994) Manual on meat inspection for developing countries, FAO animal production and health paper 119, FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy
- Faye B, Bengoumi M, Cleradin A, Tabarani A, Chilliard Y (2001) Body condition score in dromedary camel: a tool for management of reproduction. *Emir J Agric Sci* 13:01–06
- Getahun T, Belay K (2002) Camel husbandry practices In Eastern Ethiopia; The case of Jijiga and Shinile zone. *Nomadic People* 6:72–78
- Getaw A, Beyene D, Ayana D, Megersa B, Abuna F (2010) Hydatidosis prevalence and its economic importance in ruminants slaughtered at Adama Municipal abattoir, Central Oromia, Ethiopia. *Acta Trop* 113:221–225
- Gizachew B, Kibru F, Asrade B (2013) Camel hydatidosis: prevalence and economic significance in pastoral regions of Ethiopia. *J Parasitol Vector Biol* 5(6):90–95
- Gracey JF, Collins DS, Huey RJ (1999) Meat Hygiene, 10th edn. Bailliere Tindall, London
- Ibrahim MM, Craig PS (1998) Prevalence of cystic echinococcus in camels (*Camelus dromedaries*) in Libya. *J Helminthol* 72:27–31
- Ibrahim K, Thomas R, Peter K, Omer RA (2011) A molecular survey on cystic echinococcosis in Sinnar area, Blue Nile state (Sudan). *Chin Med J* 124(18):2829–2833
- Jobire Y, Lobagho F, Tiruneh R, Abebe G, Dorchie P (1996) Hydatidosis in three selected regions in Ethiopia: an assessment trial on its prevalence, economic and public health importance. *Revue Med Vet* 147(11):797–804
- Khan BB, Iqbal A, Riaz M (2003) Production and management of camels. University of Agriculture, Faisalabad, pp 152–156
- Knoess KH (1977) The camel as a meat and milk animal. *World Anim Rev* 22(1):39–44
- McPherson CN (1985) Epidemiology of hydatid disease in Kenya: a study of the domestic intermediate hosts in Masailand. *Trans R Soc Trop Med Hyg* 79(2):209–217

- Mehari Y, Mekuriaw Z, Gebru G (2007) Potential of camel production in Babilie and Kabrebiyah woreds of Jijiga zone, Somali Region, Ethiopia. *Livestock Research for Rural Development*, 19 Article #58. Retrieved October 23, 2013, from <http://www.irrd.org/irrd19/4/meha19058.htm>
- Mohamed MI (2010) Study of cystic echinococcosis in slaughtered animals in Al Baha Region, Saudi Arabia: interaction between some Biotic Factors. *Acta Trop* 113(1):26–33
- MOI (Ministry of Information) (2005) Expert products of Ethiopian press release of ministry of information. Department of press and audiovisual, Addis Ababa
- Parija SC (2004) Medical Parasitology, Protozoology and Helminthology text and Atlas, 2nd edn. Medical Books Publisher, Chennai, pp 221–229
- Pfeiffer DU (2002) Veterinary Epidemiology: An Introduction, Royal Veterinary College, Hawkshead Lane, North Mymms, Hertfordshire AL9 7TA, United Kingdom. pp 28–36
- Polydorou K (1981) Animal health and economics, Case study: echinococcosis with reference to Cyprus. *Bulletin, Office International des Epizooties* 93:981–992
- Salih M, Degefu H, Yohannes M (2011) Infection rates, cyst fertility and larval viability of hydatid disease in camels (*Camelus dromedarius*) from Borana, Kereyu and Harar Areas of Ethiopia. *Glob Vet* 7(6):518–522
- Samuel BT (2007) Gross and microscopic pulmonary lesions of camels from Eastern Ethiopia. *Trop Anim Health Prod* 40:25–28
- Schwartz HJ (1992) Productive performance and productivity of *dromedarius* (*Camelus dromedarius*). *Animal Res Dev* 35:86–98
- Schwartz HJ, Dioli M (1992) The one humped camel in the eastern Africa. Verlag Joseph Morgraph, Germany. 282
- Sharraf L, AL-Rawashdeh OM, Al-Qudah KM, Al-Ani FK (1998) Prevalence of gastrointestinal helminthes, hydatid cysts and nasal myiasis in camel in Jordan. In the proceeding of the third annual meeting for animal production under arid conditions. United Arab Emirates. pp 108–114
- Smyth JD, Barrett NJ (1980) Procedure for testing the viability of human hydatid cyst following surgical removal, especially after chemotherapy. *Trans R Soc Trop Med Hyg* 74:649–652
- Taylor MA, Coop RL, Wall RL (2007) Veterinary Parasitology, 3rd edn. Blackwell Publishing, Oxford
- Thrusfield M (2005) Veterinary Epidemiology, 3rd edn. Blackwell science Ltd, London, pp 182–198
- Urquhart GM, Armour J, Duncan JL, Dunn AM, Jennings FW (1996) Veterinary Parasitology, 2nd edn. Blackwell Science Ltd., London, pp 120–129
- Woldemeskel M, Issa A, Mersie A, Potgieter LND (2001) Investigation of parasitic disease of one-humped camel (*camelus dromedarius*) in eastern Ethiopia. *J Camel Pract Res*. 8:77–81