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Risk factors and economic losses associated with cystic echinococcosis among livestock in selected pastoral and agro-pastoral areas of Uganda

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Abstract

Background Cystic echinococcosis is a parasitic cyclo-zoonotic disease caused by the taeniid Echinococcus and causes significant economic losses in livestock production, yet its impact is often overlooked and under estimated.

Methods This study investigated the risk factors and economic impact of cystic echinococcosis in livestock, in Uganda's pastoral and agro-pastoral communities. In the study, 14,937 livestock were examined at selected slaughterhouses in Moroto, Kumi, Luwero and Nakasongola districts from March 2019 to February 2020. The visceral organs were examined for hydatid cysts during slaughter and the prevalence correlated with the risk factors got from livestock traders and livestock owners through questionnaire survey. Production losses and economic losses due to organ condemnations were also estimated.

Results This is the first study to provide insights into the financial impacts and risk factors towards Cystic Echinococcosis (CE) in livestock in Uganda. The key significant risk factors for the persistence of CE in goats were place of origin from Lira ($P \leq 0.000$), Nakasongola ($P \leq 0.002$), Luwero and Bukedea ($P \leq 0.002$), and tethering ($P \leq 0.001$); in cattle was communal grazing ($P \leq 0.0000$); and in sheep was being kept in large flocks ($P \leq 0.004$). The total annual economic losses due to CE on livestock inspected in abattoirs in the study districts was USD 21,352.7 (1 USD = 3,809.3 UGX) of which 11.7% was due to organ condemnation and 88.3% due to livestock production losses. More significant mean annual economic losses per livestock species examined occurred in Moroto district among Zebu cattle USD 8.4, goats USD 1.4 and sheep USD 1.4 than other districts.

Conclusion Results show that CE is a disease of significant economic and public health importance in PAP areas in Uganda with urgent need to create awareness and institute community-based control measures involving multistakeholder particiapation.to break livestock-dog cycle.

Keywords Cystic echinococcus, Livestock, Risk factors, Economic losses, Pastoral, Agro-pastoral areas Uganda

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Introduction

Cystic Echinococcosis (CE) is considered one of the most important and yet neglected parasitic disease of economic and public health importance [1–4]. CE is caused by *Echinococcus granulosus sensu lato* [5–7].

Humans, domestic and wildlife herbivores get infected by consuming tapeworm eggs of this worm in vegetables, pastures, water and soil contaminated by infected dog faecal matter [8]. CE occurrence is cosmopolitan [9]. In Africa, extensive studies have revealed varied distribution of CE in livestock and humans. In East Africa studies have been done in Kenya [10–13]; in Tanzania [14–17] and in Ethiopia [2, 18–23]; in North Africa: in Morocco [24, 25], in Egypt [26–30] and in Sudan [31, 32]. In Southern Africa: in Zambia [33, 34], Mozambique [35] and in South Africa [36–40]. Elsewhere in Africa studies done on CE has extensively been reviewed [41].

Economic losses in livestock occur as a result of rejections of affected body organs during postmortem inspections and reduced productivity of affected livestock. Globally CE is an economic and public health burden [42, 43]. For example: direct economic losses estimates in beef cattle reported between 2014 and 2016 in Australia varied between AU$163,006 to AU$38,683 respectively [44]; in Ethiopia, estimates were 19,190 ETB in sheep and goats [18]; 105,769.657 ETB in cattle at Dalomana municipal abattoir South-eastern, Ethiopia [45]. , 410,755.90 ETB in cattle at Wolayita Sodo municipal abattoir, Southern Ethiopia [46] and 127,456.3 ETB (7,497.43 US) at Mizan Teferi and Teppi municipal abattoirs in cattle [47]. In Turkey, nationwide CE production of losses of 89.2 M USD was reported [3]. In South Darfur State, Sudan, combined annual losses due organ condemnations and control costs was USD 38,682,492.3; 6,713,390.5; 7,213,173.9; and 175,180.9 USD per annum for cattle, sheep, goats and camel respectively [48]. Direct losses of USD 29,686 in Wau, South Sudan have also been reported [49]. Elsewhere in: Rio Negro Province, Argentina, annual losses ranged between USD 4,234,000 to 5,897,000 have been reported [50]. In Ahwaz, Iran losses of up to 459,659.6 USD in all ruminants have been reported [51]. Also in India losses up USD 212.35 million from cattle and buffalo have been reported [52]. In Peru, in South America, financial losses due to CE of USD 3,846,754 have been reported [53]. There are also varied significant losses which have been reported in the Mediterranean countries [24].

CE has been reported to occur in communities characterized by poverty and poor hygienic conditions coupled with living with undewormed wild and domestic canids sharing water resources thereby contaminating food and pastures [14, 54].

In Uganda, with the exception of the studies of CE in dogs [55], in humans [56, 57] and in livestock [58–60]. No studies have been done to determine the risk factors and financial losses due to CE in livestock. It's upon this background, that this study was designed and conducted to assess the economic cost caused by CE in livestock coupled with the establishment of the risk factors that were responsible for its endemicity among pastoral and agro-pastoral communities in Uganda.

Materials and methods

Study area

This was a cross-sectional study conducted between March 2019 to February 2020 at selected designated abattoirs in the districts of Moroto in Karamoja region, Kumi in Teso region, Luwero and Nakasongola in Buganda region, Uganda (Fig. 1). Moroto district in Karamoja region was representing pastoral areas keeping livestock, while Kumi district in Teso region, Luwero and Nakasongola districts in central Uganda were representing agro-pastoral areas keeping of both livestock and growing crops. A total of 25,689 livestock (8,044 zebu, 6,575 Ankole cattle, 8,515 goats and 2,555 sheep) were slaughtered during the study period, of which 14,937 were examined.

A simple random sampling procedure was used during this study. In each study site, only four animals or less depending on the numbers of slaughters were selected, where the number of animals exceed, only four animals were randomly chosen and if they were less all were selected and examined for cysts. This selection process was used for all species of livestock slaughtered.

A post-mortem inspection (PMI) was conducted on all slaughtered cattle, sheep, and goats but further examination for the hydatid cysts were done on the previously randomly identified and selected animals. The livestock brought for slaughter consisted mostly of local indigenous breeds, which were purchased from nearby local livestock markets. Before entering the slaughter facility, animals selected for PMI were chosen at random and marked with paint for easy traceability. Information on species, breed, origin/market of purchase, date, and age was documented for each selected animal. During the postmortem inspection, every organ was visually assessed, palpated, and incised to examine and detect embedded cysts, following the guidelines outlined by (61). Information on the risk factors was also obtained from the farmer's farming and slaughter practices.

Estimation of economic loss

During the inspection, the condemned organ tissues with CE lesions were trimmed, weighed, and recorded in specialized sheets. A portion of the affected organs was also estimated.

Economic losses due to CE was taken as sum of direct losses due to (a) offal organ condemnation (losses of offal

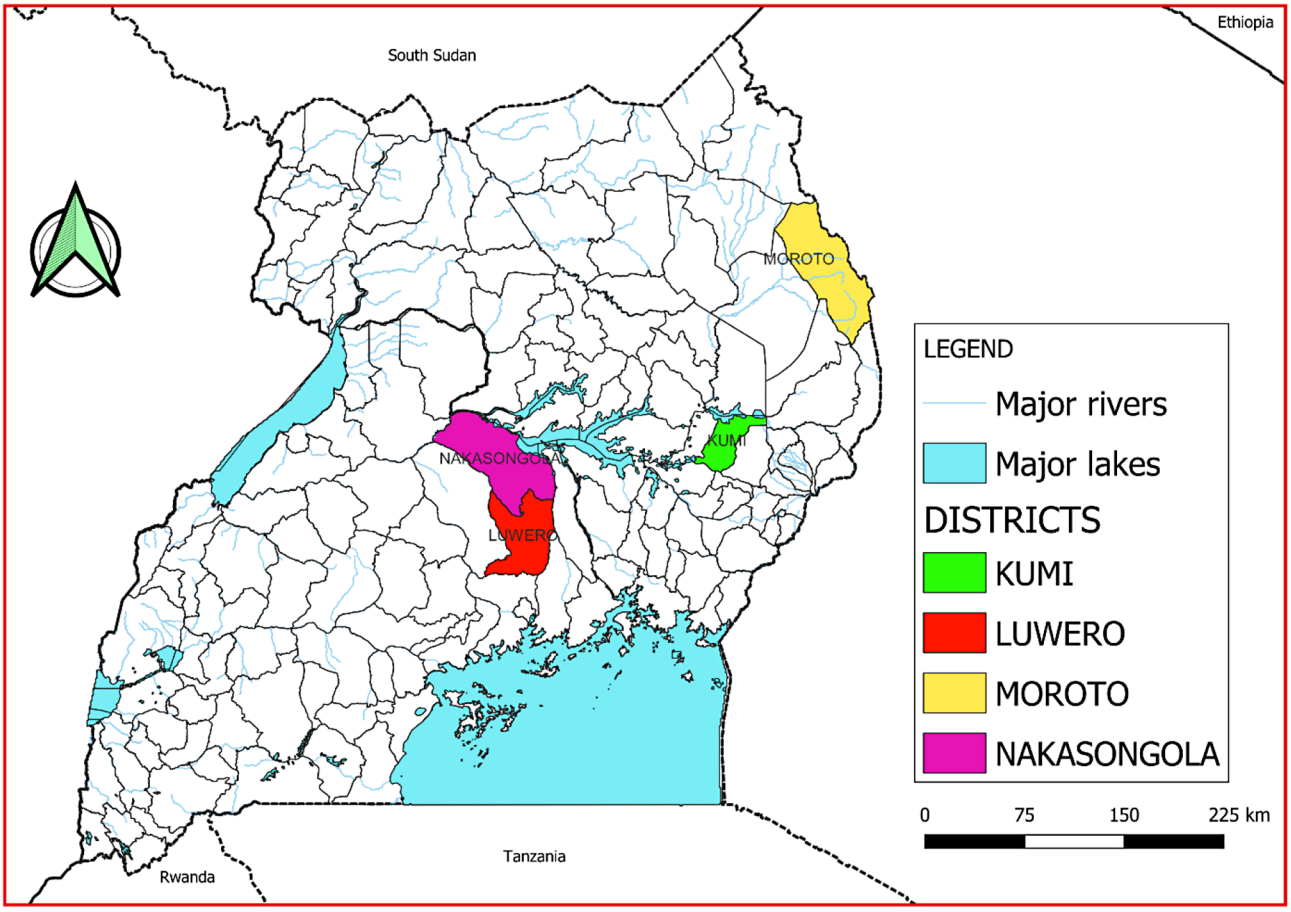

Fig. 1 Map of Uganda showing study areas

[L_{offal}]) and (b) carcass weight loss (meat production losses) due to CE disease (L_{meat}).

(a) Direct losses (losses of offal (L_{offal}) = NAS * P_{CE} * Cp * Pi.

where: -.

NAS - Number of animals slaughtered during 12-month study period.

P_{CE} - Prevalence of CE in cattle, goats and sheep.

Pi - Percent involvement of lung.

Cp - Average price of organ (lung/liver) at study abattoir.

(b) Carcass weight production losses (L_{meat}) = (number of slaughtered animals x CE prevalence) x (percentage reduction in the mean carcass weight) x (producer price of meat) adopted from (3). Mean reduction of carcass weight due CE was taken to be 3.75% for all species (46, 62). While the dressed average carcass weight was taken to be 126 Kg for adult zebu, 159 Kg for adult Ankole cattle (63), 20.5 Kg adult goat and 22.29 Kg for adult sheep (16).

Mean prices of meat per Kg was taken to be UGX 16,250 for goat, 14, 500 for sheep and UGX 13,500 cattle.

The cost of CE losses in livestock examined were extrapolated to represent total annual losses for all livestock slaughtered in the district abattoirs computed as summation of (CE losses per each livestock species (goats, sheep, cattle) examined / total number of each livestock species examined) * total number of each livestock species slaughtered during the study period.

Data analysis

The data set for individual variables was coded, entered into Excel 16.0, and imported into R statistical software version 3.1.2 with Rcmdr package used for analysis (64). The significant differences between proportions were assessed using chi-squared tests and Fisher's exact tests to determine the odds ratios (ORs) at 95% confidence interval (CI). Variations in CE frequency were examined based on livestock species, age, districts and affected organs. Univariate and multivariate logistic regression were employed to pinpoint the risk factors linked to the

Table 1 Number of organs with CE infection (percentage) among goats, sheep and cattle examined across the districts

Species	Organ inspected	Location of the abattoir									
		Moroto	95% CI	Kumi	95% CI	Luwero	95% CI	Nakasongola	95% CI	total	95% CI
Goats	Lung	280(27.7)	22.5–32.9	8(0.6)	0–6.0	12(0.5)	0-4.5	2(0.2)	0-6.4	302(5.1)	2.6–7.6
	Liver	36(3.6)	2.5–9.7	1(0.1)	0-6.3	5(25.2)	0-63.3	0	0	42(0.7)	0-3.2
sheep	Lung	252(24)	18.7–29.3	2(2.1)	0-12.7	0	0	0	0	259(18.8)	14.0-23.6
	Liver	56(5.3)	0-12.2	0	0	0	0	0	0	56(4.1)	0-9.3
Zebu	Lung	345(20.8)	16.5–25.1	15(0.9)	0-5-5.7	4(0.9)	0-10.2	0	0	364(9.8)	6.7–12.9
	Liver	218(12.8)	8.4–17.2	19(1.2)	0-6.1	4(0.9)	0-10.2	0	0	241(6.8)	3.6–10.0
Ankole	Lung	0	0	0	0	23(0.8)	0-4.4	18(1.6)	0-7.4	50(1.3)	0-4.4
	Liver	0	0	0	0	1(0.004)	0-1.2	18(1.6)	0-7.4	41(1.0)	0–4.0

Table 2 Prevalence of CE among species in the study districts

Species	Moroto	CI	Kumi	CI	Luwero	CI	Nakasongola	CI	Overall	CI
Goat	294(29.1)	23.9–34.3	9(0.6)	0–5.6	16(0.6)	0–4.4	2(0.2)	0–6.4	521(5.5)	0- 16.7
Sheep	294(28)	22.9–33.1	7(2.1)	0–12.7	0	0	0	0	301(21.9)	24.0–34.2
Zebu cattle	531(31.3)	27.4–35.2	29(1.8)	0–6.6	7(1.6)	0–10.9	0	0	567(15.2)	12.2–18.2
Ankole cattle	0	0	0	0	51(1.8)	0–5.4	31(2.8)	0–8.6	82(2.1)	0–5.2

occurrence of CE in slaughtered livestock. Univariate logistic regression was first used identify significant risk factors which were responsible for occurrence. Thereafter factors with $P<0.05$ significance relationship were farther subjected to multivariate logistic regression to develop a model to predict occurrence of CE.

Results

A total of 25,689 livestock were slaughtered, out of which 14,937 were examined during the study period. These included 5,873 goats, 1377 sheep, 3726 small East African zebu cattle (SEAZ), 3,954 Ankole cattle, and 7 exotic Friesian cattle.

Notably, there were no sheep slaughtered in Luwero and Nakasongola districts, and no Ankole cattle slaughtered in Moroto and Kumi districts. The number and percentage of organs infested with CE per district are presented in Table 1. The lung was the most affected and involved organ, overall lung: liver ratio was found to be 7.2 for goats, 4.6 for sheep, 1.5 for Zebu cattle and 1.2 for Ankole cattle. Moroto had the highest prevalence of CE in zebu cattle, goats and sheep while Luwero and Nakasongola had high prevalence of CE in Ankole cattle as outlined in Table 2.

The Univariate logistic analysis identified the origin of the livestock, method of grazing, ownership, herd and flock size as significant risk factors. Details were as shown in Table 3.

While multivariate logistic regression showed that communal grazing in cattle, origin and tethering in goats and owning large flocks of sheep were key risk factors to CE infection in these animals in the study areas.

The likelihood of CE infection in cattle practicing communal grazing was 404 times more in Moroto districts than other districts while livestock from Nakasongola and Luwero were 271 and 71 times respectively riskier of getting CE compared to Kumi and Moroto. Tethering of goats on the hand was 60 times more at risk of exposure to CE infection and, owning large sheep flock size 4 times at risk of infection than cattle and goats as seen in Table 4.

In all districts, the lungs recorded more direct economic losses due to offal organ condemnation than the liver in goats and sheep and the reverse was true for Zebu and Ankole cattle during public health meat inspection protocols as illustrated in Table 5. Moroto district reported highest total economic losses as a result of the direct and indirect losses attributed to CE in livestock species inspected at slaughter across all districts (Table 6). Meanwhile, Table 7 displays the extrapolated annual direct, indirect, and total losses due to CE for all livestock species processed in district abattoirs. The estimated total annual economic losses among goats, sheep and cattle slaughtered in all district study abattoirs were as shown in Table 8.

The yearly economic cost per animal slaughtered was standardized since the annual livestock slaughters were not the same. The mean economic cost (USD) due CE per livestock examined after slaughter per district were as shown in Table 9.

Discussion

The communities in the study areas were predominantly pastoralists in Moroto district in Karamoja region; agro-pastoralists in Kumi district in Teso region and Luwero and Nakasongola districts in Buganda region. The lung was the most affected and involved organ in all animals and districts, overall lung: liver ratio was found to be 7.2 for goats, 4.6 for sheep, 1.5 for Zebu cattle and 1.2 for Ankole cattle. CE prevalence was very high in goats,

Table 3 Univariate logistic analysis of risk factors of occurrence of cystic echinococcosis in cattle, goats and sheep

Risk factor	Variable		Freq.=yes	Fishers exact test (95% C. I)	OR	*P*-value
Animal origin	Moroto		90(28.8%)	19.4–38.2	1.7	0.000***
	Kumi		109(34.8%)	25.8–43.8		
	Luwero		37(11.8%)	11.4–22.2		
	Nakasongola		77(24.6%)	15.0–34.2		
Grazing method:	Cattle	Communal	179(57.2%)	50.0–64.4	1.3	0.000***
		Tethering	63(21.1%)	11.0–31.2		
		Zero grazing	13(4.2%)	0–15.1		
		Paddocked	6(1.9%)	0.9–12.8		
	Goats	Communal	144(46%)	37.9–54.1	0.5	0.000***
		Tethering	102(32.6%)	23.5–41.7		
		Zero grazing	3(1%)	0–3.7		
		Paddocked	1(0.3%)	0–11		
	Sheep	Communal	110(35.1%)	26.2–44.0	102	0.000***
		Tethering	42(13.4%)	0–23.7		
		Zero grazing	0(0%)	0		
		Paddocked	11(0.35)	0–3.8		
Deworming	Not dewormed		272(86.9%)	82.9–90.9	1.56	0.418
Herd sizes	Small		299(95.5)	93.3–97.8	1.42	0.335
	Large		10(3.2%)	0–14.1		
	Very large		4(1.3%)	0–12.4		
Sharing of water	With dogs and livestock		112(35.8%)	34.4–51.2	1.25	0.442
Dog keeping	Confinement		28(8.9%)	4.1–13.7		0.068
	Roaming		134(42.8%)	34.4–51.2		
	Roam with livestock		29(9.3%)	0 -19.3		
Dog faecal disposal	Deep burial		16(5.1%)	0–15.9	1.22	0.101
	Left to dry in the open		168(53.7%)	46.2–61.2		
	discarded to the bush		7(2.2%)	0–13.1		
Ownership	Own livestock		313(100%)	100	1	0.000***
Sex of owners	Male		260(83.1%)	78.5–87.7	0.43	0.001
	Female		53(16.9%)	6.7–29.9		
Occupation	Farmer		235(75.1%)	63.5–86.7	0.8	0.7972
	Formal job		25(8%)	0–18.6		
	Businessman		49(15.7%)	6.4–26.0		
	Others		4(1.3%)	0–12.8		

Table 4 Multivariate logistic regression analysis to determine risk factors towards CE in cattle, goats and sheep species

Livestock	Variable	Risk factor	Odds Ratio	*P* value
Cattle	Management	Communal grazing	404	0.000***
Goats	Origin	Bukedea	52.7	0.002**
		Malera	73.7	0.012*
		Luwero (within)	71.1	0.002**
		Nakasongola (within)	271	0.000***
		Lira	17.4	0.000***
	Management	Tethering	59.7	0.000***
Sheep	Ownership	Large herds	3.86	0.004**

sheep and zebu cattle in Moroto district than in other studied districts (Table 4). These findings of CE organ prevalence were lower than what was reported among cattle slaughtered in abattoirs in Ethiopia in Debre Markos Municipality abattoirs (84.3% lungs, 16.7% livers) [61]; in Wolayita Sodo Municipal abattoir (57.8% lungs, 35.5% livers) (48); in Hawassa Municipal abattoir (52.9% lungs, 34.2% livers) [62], in Southern Wollo abattoir (50.5% lungs and 40.6%) by [25] and in Bahir Dar Abattoir 57.9% lungs, 36.6% livers) in [63]. Similar CE organ prevalence has also been reported elsewhere in abattoirs in Ethiopia in Masha Municipal Abattoir (93% lungs, 3.14% liver) by [64]; and in Ambo Municipal Abattoir (12.1% lungs, 7.5% livers) [10]. From above findings it was shown that a lung was the most affected organ in East Africa among livestock. However, these findings on CE organ prevalence were contradictory only in one study done in Ethiopia where the livers of goats and sheep were more involved (50.7%) than the lungs (37.5%) [23].

The high CE prevalence of CE in cattle, goats and sheep in Moroto could be attributed to differences in lifestyles affecting the level of dog–livestock interactions and sources and level of water availability. The Karamojong in Moroto, practice transhumance pastoralism where they

Table 5 Direct economic losses in (USD) among goats, sheep and cattle across study districts due to offal organ condemnation due to CE during meat inspection

Livestock species	Attribute	Lung	Liver	Total
Goat	Moroto	85.7	27.8	113.5
	Kumi	53.1	24.9	78.1
	Luwero	0.1	0.1	0.2
	Nakasongola	0	0	0
	Subtotal	138.9	52.9	191.8
	% Contribution	72.4	27.6	100
Sheep	Moroto	74.0	40.9	114.9
	Kumi	0.2	0	0.2
	Luwero	0	0	0
	Nakasongola	0	0	0
	Subtotal	74.2	40.9	115.0
	% Contribution	64.5	35.5	100
Zebu cattle	Moroto	720.9	892.9	1,613.8
	Kumi	1.4	6.1	7.6
	Luwero	0.4	0.9	1.4
	Nakasongola	0	0	0
	Subtotal	722.7	900.0	1,622.7
	% Contribution	44.5	55.5	100
Ankole cattle	Moroto	0	0	0
	Kumi	0	0	0
	Luwero	0.1	6.1	6.2
	Nakasongola	3.5	7.3	10.8
	Subtotal	3.7	13.4	17.0
	% Contribution	21.5	78.5	100

Table 6 Direct, indirect and total losses (USD) due to CE for livestock species examined on slaughter in all districts

Livestock	Moroto	Kumi	Luwero	Nakasongola	Total
Direct losses					
Goats	113.5	78.1	0.2	0	191.8
Sheep	114.9	0.2	0	0	115.0
Zebu cattle	1,613.8	7.6	1.4	0	1,622.7
Ankole cattle	0	0	6.1	7.3	17.0
Sub total	1,842.2	85.8	7.6	7.3	1,946.6
Indirect losses					
Goats	965.8	27.7	15.9	17.4	1,026.7
Sheep	960.1	22.5	0	0	982.6
Zebu cattle	8,899.6	479.2	0.9	0	9,379.8
Ankole cattle	0	0	420.3	1,685.7	2,105.9
Sub total	10,825.5	529.4	437.1	1,703.0	13,495.0
Total	12,667.7	615.2	444.7	1,710.3	15,441.6

Table 9 The mean annual economic cost (USD) due to CE per livestock examined after slaughter per district

Livestock	Moroto	Kumi	Luwero	Nakasongola	Overall
Goats	1.4	0.1	0.0	0.0	0.2
Sheep	1.4	0.1	0.0	0.0	0.8
Zebu cattle	8.4	0.3	0.8	0.0	3.0
Ankole cattle	0.0	0.0	0.4	0.6	0.5

Table 7 Extrapolated annual direct, indirect and total losses in USD due CE for all livestock species slaughtered in district abattoirs

Livestock	Moroto	Kumi	Luwero	Nakasongola	Total
Direct losses					
Goats	223.2	101.3	0.9	0	325.4
Sheep	159.9	0.5	0.0	0	160.4
Zebu	1995.9	12.2	#2.2	0	2010.3
Ankole	0	0	0.5	0.3	0.8
Sub total	2378.9	114.1	3.6	0.3	2496.9
Indirect losses					
Goats	1899.1	35.9	64.6	9.6	2009.2
Sheep	1336.3	75.2	0	0	1411.5
Zebu	11006.6	774.3	770.1	0	12551.1
Ankole	0	0	1804.8	1079.8	2884.6
Sub total	14242.0	885.4	2639.5	1089.4	18856.3
Total USD	16,620.9	999.5	2,643.2	1,089.6	21,353.2
% Contribution	77.8	4.7	12.4	5.1	100

Table 8 Total annual economic losses (USD) among goats, sheep and cattle slaughtered in all district abattoirs

Livestock	Direct losses	Indirect	Total	% Contribution
Goats	325.4	2,009.2	2,334.6	10.9
Sheep	160.4	1,411.5	1,571.9	7.4
Zebu	2,010.3	12,551.1	14,561.4	68.2
Ankole	0.8	2,884.6	2,885.4	13.5
Total	2,496.9	18,856.3	21,353.2	100
Total USD	2,496.9	18,856.3	21,353.2	
% Contribution	11.7	88.3	100	

move with their livestock and dogs to areas with water and pasture during dry periods leading to high densities of livestock-dog interactions increasing the likelihood of CE transmission to livestock. In such scenarios, dogs' faecal matter with *E. granulosus* eggs easily finds its way to contaminate water sources, soil and pastures [56]. However, in agro-pastoral areas in Teso, Luwero and Nakasongola, livestock farmers live a sedentary lifestyle and have better access to clean safe water from boreholes, protected dams and spring wells with restricted dog access. Dogs were mainly kept for hunting and security reasons [52, 57].

The risk factor for CE occurrence in cattle was communal grazing (Tables 5 and 6). This was a common practice in managing cattle herds in pastoral and agropastoral areas in the study area. In all districts, goats with CE had a very highly strong association with the place of origin being from Lira and within Luwero for goats slaughtered in Luwero district abattoir, and Bukedea and Malera for goats slaughtered in Kumi district abattoir. Lira, Bukedea and Malera were places close to Karamoja and were usually invaded during the dry season by pastoralists from Moroto who came in search of pasture and water accompanied by their un-dewormed dogs. While in Luwero, the dogs usually kept for hunting were not dewormed

and their movements were not restricted. Again, in agropastoral areas, goat tethering was a major CE risk factor (Tables 5 and 6). Most goats in agropastoral districts were grazed through rope tethering around homesteads where the pasture was heavily contaminated with dog faeces. Among sheep, owning of large herds of sheep (Table 5) was the key risk factor for CE infection. This was true for Moroto, where sheep were grazed separately in large herds in communal grazing areas. These increase their chance of getting CE infected especially in the dry season while grazing as has been already described for cattle.

The total economic cost of CE in the study area was USD 21,353.2 among livestock slaughtered annually (Table 8) of which 88.3% were indirect economic losses associated with production losses caused by weight loss caused by CE. Only 11.7% were due losses due to condemnation of offal organs: lungs and liver. This showed that although CE was a disease of public health concern it was a significantly very important economic disease of cattle, goats and sheep causing production losses in these areas hence disrupting household incomes and food security. CE was causing high economic losses in Moroto district (Tables 8 and 9) amounting to USD 16,620.9. It caused a very highly significant loss among zebu cattle in Moroto district. Elsewhere in Ethiopian abattoirs, lower economic annual losses of USD 2,631 had been reported by [64]; of USD 1,820.8 by [12] and higher losses of USD 21,031.6 reported by [22]. Luwero district incurred substantial CE losses, it had 12.4% of the total CE economic loss which occurred in the study area involving Ankole cattle (Table 7). This area could become a hot spot for CE. Efforts should be made to deworm dogs and reduce the population of stray dogs.

CE was highly prevalent among small ruminants slaughtered in Moroto district abattoir (Table 4) and constituted 18.3% of the total annual CE economic cost among livestock slaughtered in the study area. In Moroto district abattoir CE caused an economic loss of USD 3,803.9 among small ruminants annually slaughtered (Table 9) of which goats constituted 58.7%. In sheep, CE was a problem only in Moroto district (Tables 4, 8 and 9). CE economic losses found in this study were lower than USD 43,333.5 [71] and USD 149,312USD [23] in Ethiopia; and USD 43,788 in goats in South Sudan [72]. The difference in economic losses could be due to variances in management practices, CE prevalence and the magnitude of livestock slaughtered at the abattoirs.

Direct losses due to organ condemnation constituted 10.4% of the total CE costs. Most CE organ condemnation losses occurred more in the lungs than the liver in goats and sheep (Table 6). In cattle (Zebu and Ankole cattle) more losses occurred in the liver than in the lungs. The findings of the economic cost of this study in the slaughter abattoirs, need to be extrapolated to the livestock population of each district and region based on slaughterable age to determine the real economic cost of CE in the district or region. These costs are quite high especially if done on annual basis among livestock especially in Moroto district.

Conclusion

CE is more prevalent in Moroto in cattle, goats and sheep. Luwero was becoming a hot spot for CE involving Ankole cattle. Communal grazing was risk factor for CE in cattle. The place of origin and tethering were the risk factors for CE in goats and owning large herds was a risk factor for CE in sheep. CE was public health disease causing high economic production losses in livestock. Most impact of CE economic losses occurred in Moroto involving goats, sheep and zebu. The lungs were more responsible for causing economic losses in sheep and goats while cattle, had more losses in the liver than the lungs.

Recommendations

There was a need to sensitise and educate the communities about risk factors and economic losses caused due to CE infection in livestock. There was an urgent need to control CE by breaking dog-livestock CE cycle by routine deworming of dogs. More studies should be expounded to other areas of Uganda to determine the level of economic injury of CE and associated risk factors and more importantly molecular characterisation of CE to determine the circulating serotypes as a way of mapping out corrective preventive means by all the respective stakeholders.

Abbreviations

CE	Cystic echinococcosis
SVAR	School of Veterinary Medicine and Animal Resources
Rec	Research Ethics Committee
UNCST	Uganda National Council for Science and Technology
IRB	Institutional Review Board
SEAZ	Small Esat African Zebu
PM	Post-mortem
UGX	Uganda Shilling
USD	United States Dollar
ETB	Ethiopian Birr
AU$	Australin Dollars
PMI	Postmortem inspection

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Author contributions

L. O., M. O. and F. E. conceived and designed the study; F.E supervised data collection, L.O, M.O. and F.E analysed data; L.O, M.O wrote, reviewed and edited the manuscript; K. I. and L. O. carried out the fieldwork; L. O, E.J, E.O. and K.I. performed laboratory analysis; L. O. performed statistical analyses and all the authors wrote and reviewed the article.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval
Approval for the study was obtained from the Institutional Review Board (IRB) of the School of Veterinary Medicine and Animal Resources (SVAR) research ethics committee (REC)-SVAR IACUC/ IRB-Ref SVAR_IACUC/40/2020, Makerere University and from Uganda National Council of Science and Technology (UNCST)-Ref A87ES. Approval for the study in each district was obtained from the respective District Veterinary Offices and written consent from livestock owners and butchers was obtained before enrolment into the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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