



Estimating the production losses due to cystic echinococcosis in water buffaloes (*Bubalus bubalis*) in Turkey

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Abstract

The current study aimed at estimating the direct (condemned offal) and indirect (meat, milk, and fecundity losses) production losses due to cystic echinococcosis (CE) in water buffaloes in Turkey. A spreadsheet loss model was constructed, and the mean prevalence ratio of CE was accepted as 3.8% in male and 21.7% in female buffaloes. The annual financial losses were estimated with official and previously published data under expected (mean value), optimistic (lowered by 10%), and pessimistic (increased by 10%) scenarios with the prices current in 2021. The production losses in an infected male and female water buffalo were estimated at \$54.5 (\$49.1–59.9) and \$89.9 (\$80.9–98.9), respectively. Due to CE, the nationwide annual total production losses were estimated at \$1.5 million (\$1.3–1.6) for water buffaloes in Turkey. In conclusion, farmers, policymakers, and the public need to be informed about CE's risks and financial impact. Control/eradication programs should be included in government policies at the national level after a cost/benefit analysis.

Keywords Cystic echinococcosis · Production losses · Turkey · Water buffalo

Introduction

Cystic echinococcosis (CE), is a neglected zoonotic parasitic disease among livestock diseases. The disease is caused by the larval stages of the tapeworm *Echinococcus granulosus* sensu lato having dogs and wild carnivores as definitive hosts and ruminants (cattle, buffalo, sheep, goats, camels, bovine etc.) as intermediate hosts (Kassai 1999). As in other ruminants, CE causes low productivity (meat, milk, fecundity) and profitability in water buffalo farms and a severe public health problem worldwide (Budke et al. 2006; Harandi et al. 2012; Singh et al. 2014).

Production losses due to CE in water buffaloes could be as follows: i) condemned edible offal (liver, lung, spleen, heart), ii) losses of productivity (decreased carcass weight and milk production), and iii) a decrease in fecundity (calf birth rate). Furthermore, amongst the aforementioned losses,

first one could be categorized under direct losses, whereas another two under indirect losses (Singh et al. 2014).

The disease is spread worldwide, especially in underdeveloped and developing countries (Asia, Mediterranean, and Middle East countries) such as Turkey (Beyhan and Umur 2011; Dadkhah et al. 2011; Islam et al. 2003; Singh et al. 2020). Annual costs associated with CE are estimated to be US\$ 3 billion for treating cases and losses to the livestock industry. Additionally, the human deaths related to CE are estimated as 19,300 and 871,000 disability-adjusted life years (DALY's), globally each year (WHO 2021).

There are many studies in different countries such as Argentina (Bingham et al. 2016), India (Vaidya et al. 2018), Italy (Cringoli et al. 2021), Jordan (Torgerson et al. 2001), Kenya (Kere et al. 2019), Pakistan (Khan et al. 2020), Spain (Jimenez et al. 2002), Turkey (Sariozkan and Yalçın 2009) and Uruguay (Torgerson et al. 2000) about CE-related losses in cattle, sheep, and goats. However, studies on CE-induced losses in water buffaloes are rare (Harandi et al. 2012; Singh et al. 2014). On the other hand, as mentioned by Sarıözkan and Yalçın (2009), some previous studies based on economic losses of CE considered only the direct losses (Ghodake et al. 2014; Khaniki et al. 2013). Therefore, the losses estimated due to CE in the past studies are actually

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under-valued. This causes decision/policy makers to delay the measures to be taken for the disease.

To the best of the authors' knowledge, no study had been carried out in the past in Turkey, involving the assessment of economic losses associated with CE in water buffaloes. The present study aimed to estimate the production losses (reduced in carcass weight, milk production, fecundity, and edible offal) due to CE in water buffaloes at the national level under mean-expected, optimistic, and pessimistic scenarios.

Materials and methods

According to the previous studies conducted in different regions of Turkey (Black Sea, Thrace, and East Anatolia), the prevalence values of CE varied between 10.2–22.3% in water buffaloes and the mean prevalence was accepted as 16.4% for nationwide (Beyhan and Umur 2011; Türkmen 1992; Umur and Aslantaş 1993). Additionally, as considered in this study the disease prevalence was reported as 3.8% in male and 21.7% in female buffaloes by Beyhan and Umur (2011). Similar to Sariozkan and Yalçın (2009) the CE-related production losses nationwide and per infected buffalo were estimated with the deterministic-static model under three scenarios; expected (mean value), optimistic (mean value lowered by 10%), and pessimistic (mean value increased by 10%) scenarios for evaluating the range (better and worse) of different situations. Reduction in carcass weight (3.75%) and milk production (6.25%) was calculated based on previous studies (Majorowski et al. 2005; Sariozkan and Yalçın, 2009). The official data buffalo populations were obtained from the Turkish Statistical Institute and Ministry of Agriculture and Forestry (TUIK 2020; MAF 2020). Also, according to slaughterhouse records 42% of the slaughtered buffaloes were male (< 3 years old), 23% of the slaughtered buffaloes were male (> 3 years old), 9% of the slaughtered buffaloes were female (< 3 years old), and 26% female (> 3 years old). So, weighted mean prevalence of slaughtered buffaloes is calculated as 20.0% [(3.22% × 790) + (7.69% × 432) + (6.81% × 169) + (62.50% × 489)] based

on Beyhan and Umur (2011). Market prices of meat, milk, offal, and calf were taken into account in the calculations. The estimation was conducted per infected animal (male, female) and nationwide annually (current prices in 2021). The liver, heart, and lungs were taken into account as edible offal (except the spleen). According to this information, total production losses (TPL) were estimated in four categories (losses of meat, milk, fecundity, and condemned edible offal) by using the constructed spreadsheet model adapted from Sariozkan and Yalçın (2009) given in Table 1.

The technical and financial parameters used for the estimation of losses in Turkey are presented in Table 2.

Results

The estimated production losses per infected male and female water buffalo due to CE in Turkey under three different scenarios are given in Table 3.

The mean production losses in an infected male water buffalo were estimated at \$54.5 (optimistic 49.1 and pessimistic 59.9) and in female water buffalo \$89.9 (80.9–98.9) in Turkey with current 2021 prices (Table 3).

Nationwide production losses from CE in water buffaloes in Turkey under different scenarios are given in Table 4.

The nationwide annual financial losses due to CE in water buffaloes were estimated at \$1.5 million (1.3–1.6) for the year 2021. Milk production and fecundity losses were ranked as the highest loss at 69.0% and 29.7% in total production losses (TPL), respectively. The amount associated with meat and edible offal losses was low. Almost entire TPL consisted of indirect losses. The share of direct losses was low due to the amount of slaughtering (Table 4).

Discussion

A significant increase in the world's population has led to higher demands for livestock products. Water buffaloes are a potentially good source of meat and milk-producing animals. However, livestock diseases such as CE are limited to this

Table 1 Spreadsheet loss model for estimation of CE induced losses in water buffalo

Loss components	Calculation methods
1. Meat production losses (L_{meat})	[(Mean no. of slaughtered buffaloes × CE prevalence) × (reduction in the carcass weight, kg) × (meat price)]
2. Milk production losses (L_{milk})	[(Mean no. of milked buffaloes × CE prevalence) × (reduction in the milk production, kg) × (milk price)]
3. Losses of fecundity ($L_{fecundity}$)	[(Mean no. of breeding buffaloes × CE prevalence) × (mean no. of newborn calves, year/head × reduction in fecundity, %) × (calf price)]
4. Losses of offal* (L_{offal})	[(Mean no. of slaughtered buffaloes × CE prevalence) × (weight of offal, kg × prices of condemned offal)]
Total production losses (TPL)	$TPL = [(L_{meat}) + (L_{milk}) + (L_{fecundity}) + (L_{offal})]$

*Liver, heart and lung included

Table 2 Technical and financial parameters used in the analysis

Parameters	Values	References
a. Technical parameters		
Mean prevalence of infection (%)	16.4 (14.8–18.0) ^d	Beyhan and Umur (2011); Türkmen (1992); Umur and Aslantaş (1993)
Mean prevalence in male buffaloes (%)	3.8 (3.4–4.1) ^d	Beyhan and Umur (2011)
a) Prevalence in male buffaloes (< 3 years/head)	3.22	Beyhan and Umur (2011)
b) Prevalence in male buffaloes (> 3 years/head)	7.69	Beyhan and Umur (2011)
Mean prevalence in female buffaloes (%)	21.7 (19.5–23.9) ^d	Beyhan and Umur (2011)
a) Prevalence in female buffaloes (< 3 years/head)	6.81	Beyhan and Umur (2011)
b) Prevalence in female buffaloes (> 3 years/head)	62.5	Beyhan and Umur (2011)
Total population of buffaloes (head)	180,826	TUIK (2020)
Population of male buffaloes (head)	53,162	TUIK (2020)
Population of female buffaloes (head)	127,664	TUIK (2020)
No. of slaughtered buffaloes (head/year)	1,880	TUIK (2020)
a) No. of slaughtered male buffaloes (< 3 years/head)	790	MAF (2020)
b) No. of slaughtered male buffaloes (> 3 years/head)	432	MAF (2020)
c) No. of slaughtered female buffaloes (< 3 years/head)	169	MAF (2020)
d) No. of slaughtered female buffaloes (> 3 years/head)	489	MAF (2020)
Mean carcass weight (kg/head)	213.8	Calculated from TUIK (2020)
Reduction in carcass weight (kg/head) ^a	8.0 (7.2–8.8) ^{a,d}	Majorowski et al. (2005) and Sariözkan and Yalçın (2009)
Mean no. of milked buffaloes (head)	75,879	TUIK (2020)
No. of breeding buffaloes (head)	92,580	MAF (2020)
Mean milk production (l/head/lactation)	998	TUIK (2020)
Reduction in milk production (l/head)	62.4 (56.2–68.6) ^{b,d}	Majorowski et al. (2005) and Sariözkan and Yalçın (2009)
Mean no. of newborn calf per year (head)	0.8 ^c	Çolakoğlu and Özbeyaz (1999)
Reduction in no. of newborn calf (%)	11.0 (9.9–12.1) ^{c,d}	Budke et al. (2005); Majorowski et al. (2005)
Mean liver weight (kg/head)	5.0	Adapted from Vaidya et al. (2014)
Mean heart weight (kg/head)	3.0	
Mean lung weight (kg/head)	6.0	
b. Financial parameters		
Producer price of meat (US\$/kg)	4.5	DMYMB (2021)
Producer price of milk (US\$/l)	1.0	DMYMB (2021)
Prices of calf (US\$/head)	250.0	DMYMB (2021)
Price of liver (US\$/kg)	2.5	DMYMB (2021)
Price of heart (US\$/kg)	1.0	DMYMB (2021)
Price of lung (US\$/kg)	0.4	DMYMB (2021)

^aReduction in carcass weight calculated as 3.75% of mean carcass weight. ^bReduction in milk production calculated as 6.25% of mean milk production. ^cData of cattle were used due to lack of reduction in newborn calf’s data related to CE infection in water buffaloes. ^dOptimistic and pessimistic values represented in parenthesis

Table 3 Production losses per infected water buffalo due to CE under different scenarios

Loss item	Expected (mean) estimation		Optimistic estimation		Pessimistic estimation	
	Male	Female	Male	Female	Male	Female
L _{meat}	36.0	-	32.4	-	39.6	-
L _{milk}	-	62.4	-	56.2	-	68.6
L _{fecundity}	-	27.5	-	24.7	-	30.3
L _{offal}	18.5	-	16.7	-	20.3	-
Total losses	54.5	89.9	49.1	80.9	59.9	98.9

Production losses were given in US\$ (1 US\$ = 8.5 TL)

Table 4 Annual total production losses (TPL) from CE in buffaloes in Turkey under different scenarios

Loss item	Expected (mean) estimation	Optimistic estimation	Pessimistic estimation
L _{meat}	13,536.0	12,182.4	14,889.6
L _{milk}	1,027,462.4	924,716.2	1,130,208.6
L _{fecundity}	441,976.9	397,779.2	486,174.6
L _{offal}	6,730.4	6,057.4	7,403.4
TPL	1,489,705.7	1,340,735.2	1,638,676.2

Production losses were given in US\$ (1 US\$ = 8.5 TL)

potential production. Current prevalence values and previous studies indicated that CE is an endemic disease in Turkey (Altıntaş and Yazar 2004; Beyhan and Umur 2011; Umur 2003), similar to neighbouring countries such as Greece, Iraq, and Iran (Al-Nassir 2012; Chaligiannis et al. 2015; Dadkhah et al. 2011; Hammad et al. 2018; Khanmohammadi et al. 2008; Samavatian et al. 2009).

The prevalence of CE recorded in water buffaloes in Turkey (10–22%) was higher than in some countries such as Iraq (2.3%), Egypt (4.2%), Italy (5.6%) and Nepal (6.7%) (Abbas 2016; Cringoli et al. 2021; Hammad et al. 2018; Manandhar et al. 2006). However, CE is more prevalent in Iran (31.8%), Pakistan (33.1%), Bangladesh (36.1%), Greece (42.0%) and India (50.9%) (Chaligiannis et al. 2015; Islam et al. 2003; Khan et al. 2013; Samavatian et al. 2009).

The high number of wild dogs, infected pastures, unofficial slaughtering of domestic animals, traditional slaughtering in Islamic observances, insufficient abattoir facilities and easy access of wild dogs to infected organs may be considered the main reasons for the high prevalence of the disease (Eslami and Hosseini 1998; Sariözkan and Yalçın 2009; Umur 2003). Additionally, in rural areas, the proximity of domestic animals and wild dogs increases the infection risk, and the high incidence rate of *E. granulosus* sensu lato in dogs' intestines leads to severe environmental contamination and a potential risk for domestic animals and public health (Khan et al. 1990).

On the other hand, the buffaloes are generally of higher age when slaughtered due to use in breeding, and age is reported as an essential factor of high prevalence ratios in buffaloes (Aarif et al. 2015; Beyhan and Umur, 2011). The high prevalence ratio of CE in female water buffaloes in Turkey is related to their long-term use as breeding animals (15–20 years). Male water buffaloes (except breeding ones) were generally slaughtered at 2–4 years old, and so prevalence in males was lower than females.

Cystic echinococcosis is also more prevalent in sheep (40–50%) in Turkey (Altıntaş and Yazar 2004; Sariözkan and Yalçın 2009). Accordingly, it is known that sheep and dogs have an essential responsibility for spreading the

disease. Similar to Egypt (Abbas 2016) the extensive use of dogs with sheep flocks for protection in rural areas may increase the prevalence of CE in Turkey. For this reason, potentially infected dogs around the buffalo farms might increase the prevalence ratios of buffaloes. A buffer zone (of at least 5 km) near buffalo farms is suggested to new farms for preventing the spread of the infections (Cringoli et al. 2007).

There are limited studies based on loss estimation of CE in water buffaloes, and some of them ignored indirect losses and only considered direct losses i.e. condemned organs (Borji et al. 2012; Ghodake et al. 2014; Khaniki et al. 2013). At the same time, the amount of indirect losses is relatively high. Similar to the present study detailed and systematic attempts are rare in the literature (Harandi et al. 2012; Singh et al. 2014).

In Iran, total production losses (\$918,418) and losses for condemned offal (\$1.2–1.3) per infected buffalo were lower than in Turkey (Borji et al. 2012; Harandi et al. 2012; Khaniki et al. 2013). However, the direct losses (%14.3) in Iran was higher than Turkey. It's thought that the low number of slaughtered buffaloes and prevalence ratio particularly in male buffaloes are effective in the low direct losses in Turkey. In India, total production losses in buffaloes (\$85 million) were higher than in Turkey; however, losses per infected buffalo (\$18.5) were lower (Singh et al. 2014). Different values between the countries might be related to livestock population (total, male and female), the prevalence of infection, estimating methodologies (loss items included in analyses), year/period of the study, and prices of livestock products.

As mentioned in previous studies (Sariözkan and Yalçın 2009) and also in the current study, CE is responsible for considerable production losses in ruminants in Turkey. Approximately the estimated CE-related production losses in an infected male buffalo (\$54.5) in Turkey accounted for 5–6% of the market value of a male buffalo. Milk production losses due to CE per infected female buffalo (\$89.9) approximately equivalent to 90 L of milk and 9% of a buffalo's lactation milk production in Turkey.

Total production losses (TPL) from CE in ruminants in Turkey (expected estimation) are given in Table 5.

Except for buffaloes (\$1.5 million), TPL due to CE reported as \$32.4 million in cattle, \$54.1 million in sheep, and \$2.7 million in goats (Sariözkan and Yalçın 2009). So, estimated TPL in water buffaloes is only equal to approximately 1.6% of the whole losses of ruminants in Turkey (Table 5).

In Turkey, the dominant genotype of *E. granulosus* sensu lato is G1 and sheep have the mainly fertile cysts (Umur 2003) and biggest contribution (59.7%) in the TPL due to CE in ruminants. Buffaloes have the mainly sterile and/or calcified cysts (81%) in Turkey (Beyhan and

Table 5 Total production losses (TPL) from CE in ruminants in Turkey (expected estimation)

Loss item	Cattle*	Sheep*	Goats*	Buffaloes
L _{meat}	6,748,061	12,180,570	603,750	13,536.0
L _{milk}	19,563,605	11,321,985	808,830	1,027,462.4
L _{fleece}	0,0	1,401,274	32,425	0,0
L _{fecundity}	3,442,764	19,308,811	814,228	441,976.9
L _{offal}	2,596,656	9,902,333	458,271	6,730.4
TPL	32,351,086 (35.7%)	54,114,973 (59.7%)	2,717,503 (3.0%)	1,489,705.7 (1.6%)

*Sarıözkan and Yalçın 2009

Umur 2011). For reducing the cost of CE, a national control and eradication program is needed which includes; uncontrolled slaughtering particularly in Muslim Festival of Sacrifices should be prevent, the infected organs should be buried in furnace of slaughterhouses, consumption of infected organs by dogs should be prevent and treatment with anthelmintics should be encouraged.

In this study, a deterministic-static model was used for estimation of the CE-related losses, and it may be more beneficial to apply a dynamic-stochastic model in the future. The present study is the first attempt to estimate the production losses of CE in water buffaloes in Turkey. Therefore, the study may encourage other researchers in different countries to evaluate the real economic impact (direct and indirect losses) of CE in water buffaloes.

In conclusion, the results of this study may be used as decision support in the allocation of monetary funds in Turkey. In the short-term, eradication of CE may be complicated; however, farmers, policymakers, and the public needed to be informed about the risks and financial impact of CE. In the long-term, control and eradication programs should be included in policies of the government at the national level after a cost/benefit analysis.

Author contribution SS and MK conceived and designed the research together; MK collected the data and SS analyzed the data; The authors wrote the manuscript together and contributed equally in the preparation and revision of the manuscript. All authors read and approved the final manuscript.

Data availability Yes.

Code availability Not applicable.

Declarations

Conflict of interest The authors have declared that no competing interests exist.

Ethics approval Not applicable.

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