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Taenia saginata cysticercus: Its socioeconomic and psychosocial effects on cattle farmers in Botswana

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Despite claims that *Taenia saginata* taeniosis/cysticercosis cause adverse financial and socioeconomic effects on cattle farmers, there is no recent empirical evidence to justify this assertion in Botswana. This paper provides empirical analysis of bovine taeniosis and cysticercosis effects on farmers' wellbeing in Botswana. Interviews and observations using non-participatory structured questionnaire were used to collect primary data from industry stakeholders (n=149). Socio-economic effects were determined by analyzing fourteen (14) objectively verifiable socioeconomic indicators (OVIs) using binomial regression, while financial losses were estimated using means. Results indicate that farmers' emotional wellbeing and ability to save money were significantly affected ($p<0.05$) and ability to provide food for family was significantly affected ($p<0.10$). Affected farmers were 30.30 times (SE=0.87), 11.02 times (SE=0.89) and 8.29 times more likely to experience emotional disturbance, unable to save money and unable to provide food for family, respectively, compared to unaffected farmers. Economic losses arise from condemnation and devaluation of carcasses. Farmers' response to bovine cysticercosis effect included, diversifying, downsizing or abandoning cattle farming. Currently, Botswana government does not compensate for condemned carcasses but this study recommends compensation and provision of re-stocking seed calves as most efficient government intervention measure. Also, cattle insurance is recommended to reduce loss and disease cost.

Key words: *Taenia saginata* cysticercosis, cattle farming, financial loses, socio-economic effects.

INTRODUCTION

Botswana's *Taenia saginata* cysticercus prevalence has increased over the years; rising from 12% in 1974 (Mosienyane, 1986) to 20% in 2014 (Farmers' Magazine, 2016). Higher prevalence has been recorded in villages with high human population density and poor hygiene status (Tshiamo, 2015; Farmers' Magazine, 2016). Similarly, high bovine cysticercosis prevalence has been recorded in some other African nations. In Ethiopia,

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prevalence of taeniasis and cysticercosis vary across localities. Taeniansis prevalence ranges from 10 to 70%, while cysticercosis prevalence vary from 3 to 27%. Ethiopia recorded prevalence as high as 30% from several rural abattoirs in the late 70s (Hailemariam, 1980). However, in subsequent years, cysticercosis prevalence has dropped to about 3.1% in Central Ethiopia, in 2000 (Tembo, 2001) and 7.5% in 2003 in Addis Ababa (Nigatu, 2004). High prevalence of 17.5% was recorded in East Shoa in 2004 (Hailu, 2005); 21% at Nekemt in 1990 (Ahmed, 1990) and 26.25% at Awassa in 2006 (Abunna et al., 2007; Tolosa, 2010). Bovine cysticercosis prevalence in Nigeria is unsteady; about 2.6% in Kano State, North West Nigeria in 2009, 1.9 and 2.1% in 2009 and 2010, respectively in Bauchi Zone, North-Eastern Nigeria (Rabi'u and Jegede, 2010). In 2007 in Jos, Nigeria, bovine cysticercosis prevalence was 13% (Qadeer, 2008). Bovine cysticercosis is generally asymptomatic in cattle, with zero mortality rate, but causes great economic losses for the beef sector. Economic losses arise due to carcass condemnation or devaluation following treatment upon detection of cysticerci during meat inspection (Muela et al., 2010), as well as related insurance costs (Jansen et al., 2018).

In Botswana, bovine carcasses that harbour more than ten (10) cysts are confiscated without compensations paid to farmers. Also, carcasses harbouring less than 10 cysts do not qualify for the EU export which is Botswana's most lucrative market. They are detained and cold treated before being sold locally at reduced price (Livestock and Meat Industries Act, 2007). Either way, local famers lose money.

Macroeconomically, bovine cysticercosis infection resulted in annual national loss of export earnings of about one million pula (P1M: P1.00 = 0.5 USD) (International Monetary Fund [IMF], n.d.), in 1978 (Grindle, 1978); P5M (P1.00 = 0.68 USD) in detained and/or condemned carcasses in 1985 (Mosienyane, 1986) and about P35 million in 2008 (Aganga, 2009). In 2009, 2010, and 2012, beef exports worth P99 million (P10.56 = 1USD), P100M (P6.33 = 1USD), and P83M (P7.78 = 1USD), respectively, could not be sold to the EU markets (Tshiamo, 2015). Ethiopia like most other African countries lacks record of annual losses due to devaluation or treatment of infested carcasses. However, assessment of the economic effects of Taeniansis using inventory of Pharmaceutical shops (Pharmacies and rural drug vendors) showed that in between 2009 and 2011 a total of 29,952 adult doses worth 40,201.8 ETB (2,407.2 ETB = 1USD) was spent for treatment of human Taeniasis per annum (Dawit et al., 2012). However, Ahmed (1990) claimed that the average annual expense (loss) due to taenicidal drugs used for treatment in Ethiopia was estimated to be 4,937,583.21 ETB (approx. M2.0 USD).

To cushion these economic losses, Botswana government on different occasions provided bailout funds to the BMC. Equally the government provided intervention measures to some affected local farmers; these included, soft loans, seed calves and rarely as amenities in farms (Oladele and Lesotho, 2010). For example, in 2012, the government of Botswana provided an undisclosed amount of bailout funds to BMC Maun (Online Editor, 2012).

Apart from few subjective and variegated assertions regarding financial loses of bovine cysticercosis and perceived attendant socioeconomic effects to cattle farmers in Botswana (Mulale, 2001), there is no known study that determined socioeconomic effects of bovine cysticercosis to the individual cattle farmer in Botswana. It is imperative to assess the financial and socioeconomic effects of bovine cysticercosis on affected farmers. Understanding the recovery pattern of affected farmers will help to query the efficiency of the existing government intervention measures. In this study, fourteen (14) objectively verifiable indicators (OVIs) of farmers' socio-economic characteristics were subjected to binomial logistic regression in order to determine the effect of occurrence or non-occurrence of bovine cysticercosis on farmers' socioeconomic characteristics. Financial losses were determined using means.

MATERIALS AND METHODS

Study area

This study was carried out in Central and North-East Districts of Central region and Kalagadi and Ghanzi districts of Western region in Botswana.

Data source

Primary data were sourced through direct observation and face-to-face interview using structured questionnaires. Information sourced included farmers' biodata, effects of bovine cysticercosis on farmers' finance and socioeconomic effects of bovine cysticercosis on farmers.

Secondary data were sourced from relevant published and un-published documents available at the Libraries of the Botswana University of Agriculture and Natural Resources (BUAN).

Calculation of sample size

Formula for sample size calculation (Ama et al., 2008):

$$n = \frac{N}{N-1}\left\{\frac{Z^2 p(1-p)}{e^2}\right\} + \left\{\frac{Z^2 p(1-p)}{e^2}\right\}$$

Where N = population size, Z = critical value of the normal distribution at the required confidence level, p = sample proportion, and e = margin of error.

N = Population size = 100,000 (since population size is large and not known and sample size does not change much for population larger than 100,000)

Z = Critical value = 1.96 (at 95% confidence level, the critical value

is 1.96)

p = Sample proportion = 0.10

e = Margin of error = 5% = 0.05

$$n = 100{,}000 \text{ x } \frac{1.96^2 \text{x } 0.1 \text{ x } (1-0.1)}{0.05^2} \Big/ 100{,}000 - 1 + \frac{1.96^2 \text{x } 0.1 \text{ x } (1-0.1)}{0.05^2} = 144.$$

Sample size of 144 was approximated to 150 respondents making allowance for non-responses.

Sampling techniques

The multistage sampling technique was used to identify animal holdings from the population which is stratified into regions and districts (Statistics Botswana, 2016).

The purposive sampling technique was used to select two agricultural regions, one with the highest cattle ownership population, which was the Central region and the other with the lowest cattle ownership population, which was the Western region (Statistics Botswana, 2015). From Central region, Central district with the highest cattle ownership population and North-East district with the lowest cattle ownership population were selected. From the Western region, Ghanzi district with the highest cattle ownership population and Kalagadi district with the lowest cattle ownership population (Statistics Botswana, 2015) were selected. The combined selection of the areas with highest and lowest cattle ownership populations was to facilitate comparison of characteristics ownership in these areas and variation in effect of *Taenia saginata* cysticercosis on cattle population and cattle farmers in these two areas. Snow ball sampling technique was used to identify individual respondents because there are no sampling frames available for this population (cattle owners) and the areas are vast (Naderifar et al., 2017). Contacted stakeholders provided references to other potential participants (Noy, 2008; Rizzo et al., 2015). Only one respondent was sampled from a household. Questionnaire was administered to one hundred and forty-nine (149) respondent households (Table 1).

Demographic profile of cattle ownership and cattle farming in Botswana demonstrate a higher population of cattle owners in the Central (urban) region but higher population of actual cattle and farms in the Western (rural) region. Thus, in this study more farmers were sampled in their farms in the Western region than in the Central region even though more farmers live in the Central Region.

Data analysis

Descriptive analysis and cross-referencing method

Descriptive statistics (means, percentages, correlation) and inferential statistics (Chi-square, t-tests) were used to analyze the data. The cross-referencing method, a comparative approach, was used to assess effect of bovine cysticercosis on socio-economic characteristics of farmers. This was achieved by comparing fourteen socioeconomic indicators of farmers during and after the experience of bovine cysticercosis and again between affected and non-affected farmers across these same periods of time.

Binomial logistic regression

The binomial logistic regression was used to further analyze effects of the occurrence of bovine cysticercosis on socio-economic factors of the farmers. The estimated effects of bovine cysticercosis (the independent variable) on the socio-economic characteristics of affected farmers (dependent variables) were calculated using this model. For example:

let Y be a binary response variable; let $Y_{\_i} = 1$, if the trait is present in observation; and $Y_{\_i} = 1$, if the trait is not present in observation.

$X = (X_1, X_2, ..., X_k)$ be a set of explanatory variables (independent variables) which can be discrete, continuous or a combination. X_i is the observed value of the explanatory variables for the observation i.

The model is given as:

$$\pi = \Pr\{Y_i = 1 - X_i = x_i\} = \frac{\exp(\beta_0 - \beta_1 x_i)}{\exp(\beta_0 + \beta_1 x_i)} \quad (1)$$

To achieve a linear relationship between the dependent and the independent variables, the log of the proportions were used. So, the equation became:

$$Log\left\{\frac{\pi}{1-\pi}\right\} = \beta_0 + \beta_1 x_1 \quad (2)$$

where π is the probability of not having the socioeconomic effect of bovine cysticercosis (a success) and 1-π, is the probability of having the socioeconomic effect of bovine cysticercosis on affected farmers. The ratio $\pi/(1-\pi)$ defines the odds in favour of not having the socioeconomic effect of bovine cysticercosis on affected farmers. This equation can be reduced to

$$y = \beta_0 + \beta_1 x_1 \quad (3)$$

where y is the dependent variables which has fifteen categories of the socio-economic effects of bovine cysticercosis on affected farmers, β_0 is the constant (intercept), which implies that if there is no independent variable, the odd of the socio-economies would be the value of the constant, β_1 is the parameter which is the amount of change in the log odds for a unit change in the independent variable, and X_1 is the independent variable, which is the occurrence of bovine cysticercosis.

Studied socioeconomic indicators (dependent variables)

Retrospective (secondary) data informed framework for primary data collected; particularly, the dependent variables. The categories of dependent variable were: S1=Ability to provide food for family; S2=Ability or difficulty accessing Healthcare; S3=Ability to provide education for wards; S4=Inability to afford house rent; S5=Inability of difficulty to save money; S6=Borrowed money for family upkeep; S7=Borrowed money for business; S8=Lay off workers; S9=Unable to employ new workers; S10=Unable to meet social responsibility; S11=Unable to meet religious responsibilities; S12=Suffered emotionally because of negative effect of bovine cysticercosis on farming business; S13=Diversify business because of uncertainty of cattle business; S14=Abandon cattle farming because of bovine cysticercosis.

All analysis was carried out using, Microsoft Excel and Statistical Package for Social Science (SPSS) version 24.

Table 1. Sample size by district of respondents.

District	Sample size
North Central	30
Central + Kweneng	31
Kalagadi district	36
Ghanzi	52
Total	149

RESULTS

About 19.5% of farmers could not provide food for their family because of occurrence of bovine cysticercosis in their farms (Table 2). Of these farmers, 41.4% owned between 50 and 99 cattle, 20.7% owned between 10 and 49 cattle, 17.2% owned between 100 and 499 cattle, and 13.8% owned more than 500 cattle (Table 3). About 23.00% of men and 13.00% of women could not provide food for their family (Table 4). Farmers of age range of >75 years were least affected across board with a score of 0.0%, except for 25.00% of them that were unable to provide education and save money, respectively. Age range of 16 to 25 years had the next lowest scores across board. Forty percent of farmers within age range 65 to 75 years were unable to provide food for the family; these were the most affected age range; followed by age range 26 to 35 years with a score of 29.20% (Table 4).

Males were more affected than females in all socioeconomic characteristics except in these five indicators; 'experiencing emotional disturbances', 'meeting social obligations', 'ability to pay rent', 'diversifying business' and 'ability to provide family upkeep', where females farmers were more affected (Table 4).

Similarly, 15.4% of the farmers reported that they could not afford healthcare for family (Table 2). Of these farmers, the most affected were farmers who owned between 50 and 99 cattle accounting for 39.10% of farmers' population, followed by farmers who owned between 10 and 49 cattle accounting for 21.7% of farmers' population. Farmers who owned between 5 and 9 cattle were the least affected group whereas farmers who owned less than 5 cattle claimed that their ability to provide health for family were not affected by occurrence of bovine cysticercosis in their farms (Table 3). About 18.20% of males more than 10.90% of females had difficulty providing/accessing healthcare for the family (Table 4). Of the farmers who could not provide healthcare for family, 60.0, 33.0, 25.0 and 20.0% of them were of ages range of 16-25, 56-65, 26-35 and 66-75 years, respectively. Farmers who were above 75 years claimed they did not have difficulty providing healthcare for family (Table 4).

About 10.4% of the farmers claimed that they could not provide education for their children/wards (Table 2). Of these affected farmers, 36.6% owned between 50 and 99 cattle, while 22.7, 13.6 and 13.6% of them owned between 10-49, 5-9 and 100-449 cattle, respectively (Table 3). Gender dynamics showed that about 17.3% of male and 13.0% of female could not provide education for their children (Table 4). About 40 and 27.8% of farmers of ages between 16-25 and 56-65 years, respectively claimed that they were not able to provide education for their children. Similarly, 25% each of farmers of age ranges of 26 to 35, 66 to 75, and above 75 years, respectively could not provide education for their children (Table 4).

About 12.1% of the farmers claimed they could not afford house rent because of negative effect of bovine cyticercosis on farmers' finance (Table 2). More female farmers about 15.2% than male farmers (11.20%) could not pay house rent. About 50.0% of farmers who could not afford house rent owned between 50 and 99 cattle; these were the most affected farmers. Also 22.2 and 16.7% of affected farmers owned between 10 and 49 cattle and above 500 cattle, respectively (Table 3). Age dynamics showed that 25 and 22.2% of farmers of age ranges 26-35 and 56-65 years could not afford house rent, respectively. Similarly, 20 and 25% of farmers of ages between 16-25 and 66-75 years, respectively could not pay house rent. No farmers above 75 years failed to afford house rent (Table 4).

Approximately 45.60% of farmers could not save money because of effect of bovine cysticercosis on their income (Table 2). Of these affected farmers, 32.4% owned between 50 and 99 cattle. The next most affected categories owned between 100-499 and more than 500 cattle, each making up 23.50% of farmers (Table 3). More male farmers (48.0%) than female farmers (43.5%) could not save money due to effect of bovine cysticercosis on their finance. With 66.7% score, farmers aged between 56 and 65 years were the most affected followed by farmers of ages between 16 and 25 years with 60.0%. About 44, 43.9 and 37.5% of farmers of ages between 26-35, 36-45 and 46-55 years, respectively could not save money (Table 4).

About 18.10% of the farmers claimed they borrowed money for family upkeep; 44% of which owned between 50 and 99 cattle. Of the farmers who borrowed money for family upkeep 18.5, 14.8 and 14.8% of them owned more than 500 cattle, between 100 and 499 cattle and between

Table 2. Percentage distribution of negative effect of bovine cysticercosis on the social-economy of farmers.

Response	Percentage negative effects of bovine cysticercosis on farmers' responsibilities N (%) [sample size =149]													
	Food	HC	EDU	HR	SV	BMF	BMB	LW	ENW	SR	RR	ED	DVB	ABD
Affected	(29) 19.5	(23) 15.4	(15) 10.4	(18) 12.1	(68) 45.6	(27) 18.1	(21) 14.1	(30) 20.1	(44) 29.5	(39) 26.2	(21) 14.1	(61) 40.9	(45) 30.2	(4) 2.7
Not Affected	(116) 77.9	(122) 81.9	(133) 89.2	(126) 84.6	(78) 52.3	(116) 78.5	(187) 83.2	(115) 77.2	(103) 68.5	(106) 71.1	(125) 83.9	(85) 57.0	(100) 67.1	(140) 94.0
Not Indicated	(4) 2.6	(4) 2.7	(1) 0.4	(5) 3.3	(3) 2.1	(5) 3.4	(4) 2.7	(4) 2.7	(3) 2.00	(4) 2.7	(3) 2.0	(3) 2.0	(4) 2.7	(5) 3.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Food: Ability to provide food for family; HC: ability or difficulty accessing healthcare; EDU: ability to provide education for wards; HR: ability to afford house rent; SV: ability to save money; BMF: borrowed money for family upkeep; BMB: borrowed money to revive business; LW: laid off workers; ENW: unable to employ new workers; SR: unable to meet social responsibility; RR: unable to meet religious responsibilities; ED: experienced emotional disturbance because of negative effect of bovine cysticercosis on farming business; DVB diversified business because of uncertainty of cattle business; ABD: abandoned cattle farming because of bovine cysticercosis.

Table 3. Number and percentage of negative effect of bovine cysticercosis across farm capacities N (%).

Farm capacities	Percentage negatives effects of bovine cysticercosis on farmers' responsibilities N (%)													
(No. of cattle)	Food	HC	EDU	HR	SV	BMF	BMB	LW	ENW	SR	RR	ED	DVB	ABD
>500	4 (13.80)	4 (17.40)	2 (9.10)	3 (16.70)	16 (23.50	5 (18.50)	5 (23.80)	7 (23.30)	6 (13.60)	7 (17.90)	3 (14.30)	16 (26.20	11 (24.40)	0 (0.00)
100-499	5 (17.20)	3 (13.00)	3 (13.60)	1 (5.60)	16 (23.50	4 (14.80)	6 (28.60)	7 (23.30)	9 (20.50)	10 (25.60	5 (23.80)	13 (21.30	11 (24.40)	1 (25.00)
50-99	12 (41.40)	9 (39.10)	8 (36.60)	9 (50.00)	22 (32.40	12 (44.40	7 (33.30)	8 (26.70)	13 (29.50	11 (28.20	9 (42.80)	17 (27.90	11 (24.40)	1 (25.00)
10-49	6 (20.70)	5 (21.70)	5 (22.70)	4 (22.20)	12 (17.60	4 (14.80)	1 (4.70)	6 (20.00)	9 (20.50)	9 (23.10)	2 (9.50)	13 (21.30	7 (15.90)	1 (25.00)
5-9	2 (6.90)	2 (8.60)	3 (13.60)	1 (5.60)	2 (2.90)	2 (7.40)	2 (0.90)	2 (6.70)	2 (4.50)	2 (5.10)	2 (9.50)	2 (3.30)	3 (6.70)	1 (25.00)
<5	0 (0.00)	0 (0.00)	1 (4.50)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (6.80)	0 (0.00)	0 (0.00)	0 (0.00)	2 (4.40)	0 (0.00)
Total cases	29 (100)	23 (100)	22 (100)	18 (100)	68 (100)	27 (100)	21 (100)	30 (100)	44 (100)	39 (100)	21 (100)	61 (100)	45 (100)	4 (100)

Food: Ability to provide food for family; HC: ability or difficulty accessing healthcare; EDU: ability to provide education for wards; HR: ability to afford house rent; SV: difficulty to save money; BMF: borrowed money for family upkeep; BMB: borrowed money for business; LW: laid off workers; ENW: unable to employ new workers; SR: unable to meet social responsibility; RR: unable to meet religious responsibilities; EE: suffered emotionally because of negative effect of bovine cysticercosis on farming business; ABD: abandoned cattle farming because of bovine cysticercosis; DVB: diversified business because of uncertainty of cattle business; N: number.

Table 4. Socio-economic effects of bovine cysticercosis across gender and ages of farmers (%).

Socio-economic effects	Category	Gender (%)		Age of farmer (in years)						
		Male	Female	16-25	26-35	36-45	46-55	56-65	66-75	>75
Ability to provide food for family	Affected	23.20	13.00	80.00	29.20	12.20	12.50	27.80	40.00	0.00
	Not affected	76.80	87.00	20.00	70.80	87.80	87.50	72.20	60.00	100.00
Ability to provide healthcare for family	Affected	18.20	10.90	60.00	25.00	9.80	6.30	33.30	20.00	0.00
	Not affected	81.80	89.10	40.00	75.00	90.20	93.80	66.70	80.00	100.00

Table 4. Cont'd.

Ability to provide education	Affected	17.30	13.00	40.00	25.00	7.30	10.40	27.80	25.00	25.00
	Not affected	82.70	87.00	60.00	75.00	92.70	89.60	72.20	75.00	75.00
Ability to afford house rent	Affected	11.20	15.20	20.00	25.00	9.80	4.20	22.20	25.00	0.00
	Not affected	88.80	84.80	80.00	75.00	90.20	95.80	77.80	75.00	100.00
Ability to save money	Affected	48.00	43.50	60.00	44.00	43.90	37.50	66.70	0.00	25.00
	Not affected	52.00	56.50	40.00	56.00	56.10	62.50	33.30	100.00	75.00
Did you borrow money for family upkeep	Affected	23.00	9.10	40.00	20.00	15.00	14.90	27.80	40.00	0.00
	Not affected	77.00	90.90	60.00	80.00	85.00	85.10	72.20	60.00	100.00
Did you borrow money for business upkeep	Affected	16.00	11.10	20.00	16.00	10.00	16.70	16.70	20.00	0.00
	Not affected	84.00	88.90	80.00	84.00	90.00	83.30	83.30	80.00	100.00
Did you lay off workers	Affected	23.00	15.60	40.00	28.00	12.50	18.80	22.20	40.00	0.00
	Not affected	77.00	84.40	60.00	72.00	87.50	81.30	77.80	60.00	100.00
Unable to employ new workers	Affected	31.00	28.30	40.00	24.00	19.50	31.30	50.00	20.00	0.00
	Not affected	69.00	71.70	60.00	76.00	80.50	68.80	50.00	80.00	100.00
Difficulty to meet social responsibility	Affected	25.30	30.40	60.00	37.50	22.00	20.80	27.80	40.00	0.00
	Not affected	74.70	69.60	40.00	62.50	78.00	79.20	72.20	60.00	100.00
Difficulty to meet religious responsibility	Affected	18.00	6.50	60.00	20.00	9.80	6.30	22.20	40.00	0.00
	Not affected	82.00	93.50	40.00	80.00	90.20	93.80	77.80	60.00	100.00
Experienced emotional disturbance	Affected	60.00	54.30	60.00	36.00	34.10	37.50	66.70	40.00	50.00
	Not affected	40.00	45.70	40.00	64.00	65.90	62.50	33.30	60.00	50.00
Diversified business because of bovine cysticercosis	Affected	27.30	39.10	20.00	36.00	31.70	21.30	50.00	40.00	0.00
	Not affected	72.70	60.90	80.00	64.00	68.30	78.70	50.00	60.00	100.00
Abandoned business because of bovine cysticercosis	Affected	3.10	2.20	0.00	4.20	2.50	4.20	0.00	0.00	0.00
	Not affected	96.90	97.80	100.00	95.80	97.50	95.80	100.00	100.00	100.00

10 and 49 cattle, respectively (Table 3). About 23.0% of male more than female with about 9% borrowed money for family upkeep. Farmers of ages between 16-25 and 66-75 years were affected severely, with 40.0% of each category needing extra support to meet family needs. About 27.8, 20.0 and 15.0% of farmers of ages between 56-65, 26-35 and 36-45 years, respectively borrowed money for family upkeep. No farmer above 75 years experienced difficulty in keeping up with family needs (Table 4).

About 14.10% of the farmers borrowed money to revive their businesses (Table 2). Of the affected farmers about 18.5% owned between 50 and 99 cattle, while farmers who owned between 10 and 49 cattle and between 100 and 449 cattle each contributed 14.8% of farmers who borrowed money to revive business. Farmers who owned between 5 and 9 cattle and less than 5 cattle did not borrow money to revive their business (Table 3). 16.0% of the male farmers and 11.3% of the female farmers borrowed money to revive their farming business. 20.0% each of farmers between 16-25 and 66-75 years were affected farmers. With a score of 10.0% farmers of age bracket 36 to 45 were the least affected (Table 4).

About 20.1% of respondents laid off workers; of which 26.7% owned between 50 and 99 cattle. Farmers who owned between 100 and 499 cattle and more than 500 cattle each contributed 23.30% of the total unemployment. Whereas 23.00% of male farmers laid off workers, only 15.60% of female farmers laid off workers. The most hit age bracket each at 40% were farmers between 16-25 and 66-75 years. Farmers above 75% claimed they did not lay off workers (Table 4).

In addition to laying off workers, about 29.50% of the farmers were unable to employ new workers (Table 2); 29.5% of which owned between 50 and 99 cattle. Farmers who owned between 100 and 449 and above 500 cattle each contributed 23.3% of farmers who could not employ new workers (Table 3). 50% of farmers aged between 56 and 65 years, 40.0 and 19.0% of farmers aged between 16-25 and 36-45 years, respectively could not employ new workers. 31.3% of male farmers and 28.3% of female farmers could not employ new workers (Table 4).

Ability to meet social responsibilities became difficult to impossible task for 26.20% of farmers (Table 2); 28.6% of whom owned between 50 and 99 cattle (Table 3). About 25.0, 23.1 and 17.9% of affected farmers owned between 100-949 cattle, between 10-49 cattle and above 500 cattle, respectively (Table 3). More female (30.4%) and less male (25.3%) farmers could not meet social responsibilities; with most and least affected farmers being of age brackets 16-25 years (at 60%) and 46-55 years (at 22%), respectively (Table 4).

About 14.10% of the farmers had difficulty meeting religious responsibilities (Table 2). Of this category, 23.80 and 42.80% were farmers who owned between 50 and 99 cattle and between 100 and 499 cattle, respectively (Table 3). Most affected age range was between 16 and 25 years with 60%, followed by age range 66 to 75 years with 40% affected. Farmers of ages above 75 years did not encounter difficulty meeting social responsibilities (Table 4).

Farmers (40.9%) were disturbed emotionally (Table 2); 60% of male and 54% of female were disturbed emotionally (Table 3). No farmer having less than 5 cattle was emotionally disturbed by effect of bovine cysticercosis on their farms. Highest affected farmers were of ages between 56 and 65 years at 66.7%, followed by farmers of ages between 16 and 25 years at 60% (Table 4).

About 30.20% of the farmers diversified their business into crop farming, artisans, petty trading, etc., while 40% of the farmers abandoned cattle farming entirely (Table 2). 25% each of farmers who abandoned cattle farming owned between 100 and 449 cattle, 50 and 99 cattle, 10 and 49 cattle and 5 and 9 cattle, respectively. About 24% of farmers who owned more than 500 cattle, 24% who owned between 100 and 499 cattle and 24% who owned between 50 and 99 cattle diversified their business. 15.9 and 6.7% of farmers who owned 10-49 cattle and 5-9 cattle, respectively diversified their business (Table 3). 27.3% of male farmers and 39.1% of female diversified their business while 3.1% of male and 2.2% female farmers abandoned farming business. At 50%, the age range between 56 and 65 had the highest score of farmers who diversified their business, while the lowest age range of farmers who diversified was 16 to 25 years at 20%. 4.2% of farmers between ages 26 and 35 abandoned cattle farming, while no farmers of age between 16 and 25 and above 56 years abandoned cattle farming (Table 4).

Farmers' emotional wellbeing and ability to save money were both significantly affected ($p < 0.05$) by occurrence of bovine cysticercosis in their farms. Farmers' ability to provide food for family was also significantly affected ($p < 0.10$) (Table 5). The effect of bovine cysticercosis on farmers' ability to provide healthcare, education, payment of rental for family, farmers' ability to meet social and religious obligation were not statistically significant ($p < 0.05$). Other socio-economic characteristics that were not significantly affected by bovine cysticercosis ($p > 0.05$) were 'ability to employ new workers', 'diversification or abandonment of farming business', and borrowing money to keep up with family needs and revive business' (Table 5). Farmers who experienced bovine cysticercosis in their farms were 30.30 times more likely to experience emotional disturbance than those who experienced bovine cysticercosis. Farmers who did not experience bovine cysticercosis in their farms were times 11.2 and 8.29 times more likely to save money and provide food for family, respectively than those who experienced bovine cysticercosis (Table 5).

About 44 respondents spent P181, 511.50 in cold treatment of infected carcasses in 2017 (1USD = P10.7)

Table 5. Binomial logistic regression of effect of bovine cysticercosis on the socio-economy of cattle farmers.

Dependent variable	B	S.E.	Wald	df	Sig.	Exp.(B)
Ability to provide food for family	2.12	1.28	2.75	1	0.09b	8.29
Ability to provide healthcare for family	23.10	7903.89	0.00	1	0.99	1.08E+10
Ability to provide education	-2.98	1.91	2.45	1	0.12	0.05
Ability to afford house rent	-1.96	1.61	1.48	1	0.22	0.14
Ability to save money	2.40	0.89	7.28	1	0.01a	11.02
Borrowed money for family upkeep	0.17	1.30	0.02	1	0.90	1.19
Borrowed money for business upkeep	-0.33	1.12	0.09	1	0.79	0.73
Laid off workers	1.50	1.12	1.79	1	0.18	4.47
Ability to employ new workers	-1.22	1.12	1.18	1	0.28	0.30
Difficulty to meet social responsibility	-1.00	0.92	1.18	1	0.28	0.37
Difficulty to meet religious responsibility	-0.14	1.73	0.01	1	0.94	0.87
Experienced emotional disturbance	3.41	0.87	15.52	1	0.00a	30.30
Diversified business	0.05	1.08	0.00	1	0.96	1.05
Abandoned business	0.26	1.50	0.03	1	0.86	1.30

a = Significance at 5%; b = Significance at 10%; Actual exp. = (SPSS) exp – 1. E.g.: 30.29 -1 = 29.29.

(International Monetary Fund [IMF], n.d.). This makes average expenditure for cold treatment of infested carcass in 2017 equal to P4,125.26 per farmer with a range of P1,000-P11,000 (Table 6). Total amount of money lost by 110 respondents due to devaluation of carcasses infested with cysticercosis in 2017 was P522,635.00, at an average loss of P4,751.27 per farmer and a range of P1,000-P75,000 (Table 6). Similarly, 62 respondents lost P2,124,240.00 due to condemnation of carcasses in 2017. This brings it to an average of P34, 261.93 lost per farmer due to condemnation of carcasses in 2017, with a range of P1,000-P10,000 (Table 6).

Farmers (47.70%) had their carcasses retained and devalued while 38.90% of farmers had their carcasses condemned due to bovine cysticercosis infection. About 44.70% of farmers spent money treating their retained carcass (Table 7). 10% of the rural farmers in North East district delayed cattle farm expansion, whereas 30% resorted to other business alongside diversifying into goat, sheep and crop farming (Table 7).

Although 42.3% of farmers experienced bovine cysticercosis in their farms only 17.4% of farmers claimed that bovine cysticercosis caused drop in farm capacity.

DISCUSSION

Bovine cysticercosis had the most socioeconomic effect on farmers' emotional wellness followed by farmers' ability to save money (Table 4), both of which were significant at $p < 0.05$ (Table 5). Cattle farmers have shown emotional attachment to their animals (Gender Researcher 2012 in Andrea, 2016) as such, death of cattle, condemnation or devaluation of carcass due to bovine cysticercosis can disturb farmers' emotionally. Ironically, some farmers who did not experience bovine cysticercosis in their farms were emotionally disturbed in anticipation of possible future occurrence of bovine cysticercosis. This accounts for observed higher percentage of farmers who suffered emotional disturbances than prevalence of bovine cysticercosis (Tables 2 and 7).

At all levels of farm size and in all age brackets, both male and female farmers were unable to save money either because their carcasses were condemned and destroyed or because their carcasses were retained and devalued (Tables 2, 3 and 4). Farmers whose carcasses were condemned did not receive compensation, while farmers whose carcasses were detained and chilled were paid a percentage of original beast price. These results are in line with Jansen et al. (2018) and Maria et al. (2018) both of whom studied economic impact of *T. saginata* taeniasis/cysticercosis in Belgium and Brazil, respectively. Whereas Maria et al. (2018) demonstrated negative financial effects of bovine cysticercosis on cattle farming, Jansen et al. (2018) highlighted that *T. Saginata* caused more economic loss in the animal/meat sector than in the human health sector.

At the BMC, carcasses identified at meat inspection to harbour more than 10 cysts are condemned and destroyed while carcasses that harbour less than 10 cysts are retained in compliance with provisions of the Livestock and Meat Industries Act (2007). Farmers whose carcasses are destroyed receive P60 (P11.49 =1USD) (International Monetary Fund [IMF], n.d.), or equivalent of transport cost for conveying animals to abattoir. This amount is arbitrarily paid to all farmers irrespective of the pre-slaughter value of cattle. Unlike in Belgium where approximately 30% of all bovines are insured prior to slaughter (Jansen et al., 2018), there is

Table 6. Financial effects of bovine cysticercosis on farmers in 2017 (1 USD = 11.6 pula).

Amount (pula)	Midpoint Amount (pula)	Cold treatment of carcass		Devaluation of carcass		Condemnation of carcass	
		Frequency	Amount spent (P)	Frequency	Amount lost (P)	Frequency	Amount lost (P)
1,000-3,000	2,000	21	42,000	38	76,000	0	0.0
3,001-5,000	4,000.5	12	48,006	25	100,012.5	0	0.0
5,001-7,000	6,500.5	4	26,002	23	149,511.5	18	117,009
7,001-9,000	8,500.5	4	34,002	11	76,504.5	11	93,505.5
9,001-11,000	10,500.5	3	31,501.5	9	94,504.5	7	73,503.5
60,000-70,000	65,000.5	0	0.0	3	19,501.5	9	585,004.5
70,001-80,000	75,000.5	0	0.0	1	75,000.5	5	375,002.5
80,001-90,000	85,000.5	0	0.0	0	0.0	7	595,003.5
90,001-100,000	95,000.5	0	0.0	0	0.0	3	285,001.5
100,001-110,000	105,000.5	0	0.0	0	0.0	2	210.001
Total	-	44	181,511.50	110	522,635.00	62	2,124,240.00

no known cattle insurance policy in Botswana.

Retained carcasses are cold treated by chilling at temperature below 4°C for about 10 days before passing for public consumption (Livestock and Meat Industries Act, 2007). Treated carcasses do not qualify for export to the EU, Botswana's most priced beef market; they are sold locally at reduced price. The BMC pays farmers 75% of the actual value of the retained carcass; that is 25% loss, whereas Senn Foods, another high throughput abattoir pays farmers 85% of the original value of the carcass; that is, 15% loss (Uchendu, 2020). In Belgium, Geerts (1990) recorded 30 to 45% value loss per carcass in 1990, whereas Jansen et al. (2018) recorded 40 to 70% value loss per carcass in 2018, following cold treatment.

Retaining the carcass leads to direct and indirect financial and non-financial losses. For instance, carcass was retained in refrigerator, in addition to incurring chilling cost, lose meat water, and carcass weight. Muela et al. (2010) noted that chilling of carcass leads to weight loss after 90 h of chilling. Carcass not sold in time lose quality, as a result, meat sellers use enhancer to recover meat quality. This leads to extra costs, notwithstanding the possible health implication of quality enhancers on meat. Customers' confidence and trust on meat operators either reduce or lost entirely and some carcasses are turned into by-products, which are sold at reduced price. Harrison et al. (1986) reported that loss of meat quality due to chilling lead to major economic loss in beef. Farmers whose carcasses were retained and monies paid late could not save money because their business investment and market projected plans were distorted. Sometimes extra meat is mixed with the cold-treated meat to make customers purchase them.

Incessant destruction or retention of carcass and delayed payment for purchased cattle experienced at BMC has caused farmers to lose confidence in BMC (Uchendu, 2020). Furthermore, due to high detection rates and low compensation, farmers avoid selling their animals to the BMC rather they sell to low throughput abattoirs. Low throughput abattoirs either lack enough or have no meat inspectors thus, these bovine cysticercosis cases pass undetected (Uchendu, 2020). Currently, the BMC, Senn Foods and other high throughput beef buyers have partly or completely blacklisted some Agricultural Extension Areas designated as bovine cysticercosis hotspots. Cattle farmers from those Extension Areas are forced to sell at lower prices to local buyers or divert their cattle to farms located in non-hotspots Extension Areas before they can be sold. All of these developments make accurate measurement of bovine cysticercosis prevalence in Botswana difficult if not impossible.

Ordinarily, bovine cysticercosis prevalence rate should be higher than or equal to percentage devaluation, since all bovine cysticercosis cases must have been either condemned (if cysts exceed 10) or treated (if cysts is less than 10). However, this study showed prevalence rate lower than percentage devaluation. This is so because, whereas the prevalence estimated for one year (2016-2017), the percentage devaluation calculated for five years (2012-2017) (Table 7). Similarly, percentage devaluation should be equal to percentage of farmers who paid to treat their carcass but the latter is lower (Table 7). Reason being that in some cases, the cost of treating retained carcasses within government facilities was borne by the local government council, not farmers; as such treatment costs were not counted to farmers. It appears that in Ethiopia, farmers bear the full cost of treating their infected carcass (Alemneh and Adem, 2017).

Farmers within the age ranges of 16-25 and 66-75 years laid off the highest number of workers. Whereas the former age group are majorly beginners in cattle farming, the latter are mainly retirees from civil service

Table 7. Percentage of farmers according to types of effect of bovine cysticercosis on farming and socio-economy of farmers.

Financial effect	Affected	Not affected	No answer
Farmers who recorded bovine cysticercosis in their farms	42.30	57.70	0.00
Farmers who experienced negative effect on the farm capacity	17.40	79.30	3.90
Farmers in North East whose capacity were affected	10.00	85.00	5.00
Farmers who experienced negative financial effect due to bovine cysticercosis	50.00	45.60	4.30
Farmers whose animals were retained and devalued (2012-2017)	47.70	51.00	1.30
Farmers whose animals were condemned	38.90	59.70	1.30
Farmers who spent money treating carcass	44.70	54.00	1.30

Bovine cysticercosis caused carcass retention and devaluation to 47.70% of farmers and carcass condemnation to 38.90% of farmers. About 44.70% of farmers spent money treating their retained carcass. Bovine cysticercosis caused drop in farm capacity of 17.40% of the farmers. 42.30% of farmers recorded bovine cysticercosis in their farms.

age groups are majorly part-time and small-scale farmers. With their liquidity level low their staffing capability following occurrence of bovine cyticercosis in their farms was limited. This phenomenon typifies economics of scale in farming (Stigler, 1958) and explains why both age groups laid off highest number of workers. Although percentage of farmers who laid off workers was not statistically significant ($p < 0.05$), affected farmers were 4 times more likely to attribute their laying off of workers to bovine cysticercosis than unaffected farmers (Table 5).

Farmers' 'ability to provide food for family' was significantly negatively affected ($p < 0.10$) (Table 5). Affected farmers were 8.29 times more likely to attribute their inability to provide food for their family to bovine cysticercosis than unaffected farmers (Table 5). Just as in laying off of workers, farmers of age brackets between 16-25 and 66-75 years recorded the highest inability to provide food for family (Table 4). The full-time farmers who had less than 10 cattle accounted for a substantial proportion of farmers who could not 'provide food for their family'. Rural small-scale farmers with less than 50 and between 50 and 99 cattle borrowed money for family upkeep (Table 4). This is understandable because the liquidity of small-scale farmers is meagre, thus, any financial shock would affect them. However, farmers having 100-499 cattle and above 500 cattle did not borrow money for family upkeep (Table 4).

Bovine cysticercosis does not cause cattle mortality (Murrell et al., 2005), thus lacks direct effect on farm capacity. However, economic losses arising from bovine cysticercosis caused farmers to deliberately reduce farm stocking capacity (Table 7). Rural farmers in North East district in particular, delayed farm restocking and expansion, while some diversified into artisan businesses and/or goat, sheep and crop farming. These typified the indirect negative effect of bovine cysticercosis on farm capacity and agree with findings of Uchendu et al. (2015) that financial losses arising from livestock diseases cause Nigerian cattle farmers to reduce production scale, diversify farming business or outrightly abandon farming business.

Despite bovine cysticercosis effect on finance of farmers, most affected farmers were able to access/provide healthcare services for their family (Tables 2 and 4). The Government of Botswana through the National Medical Aid provides nationwide free and accessible health-care (National Health Policy, 2012). Similarly, the percentage of children who quit school on account of parents' inability to pay school fees was negligible (Tables 2 and 4) because education in Botswana is free and almost compulsory. The nation's ruling party claims that the best economic policy is education thus, increasing education funding ranks third most important priority areas for the ruling party (BFTU, 2007).

Farmers' ability to provide accommodation for themselves and their herd boys was drastically affected (Table 2). Majority of the unaffected farmers were locals who lived in their communities within the rural areas, proximal to their farms and cattle posts and did not pay house rent. However, migrant-farmers and farmers who lived in the cities far from their farms and cattle post forfeited their extra rented houses in the city to relocate to the villages and farm houses. Some others reduced frequency of farm visits.

Unlike in Belgium where financial losses caused by bovine cysticercosis were cushioned through cattle insurance programs (Jansen et al., 2018), Botswana lacks cattle insurance programs. Thus, most affected farmers borrowed money to revive their cattle business except few farmers who benefited from the Botswana government bovine cysticercosis intervention scheme. This intervention schemes included, re-stocking calves, provision of basic amenities like, boreholes, farm implements (Online Editor, 2012).

Financial losses affected farmers' ability to pay workers' salaries. Consequently, some farmers and beef industry operators laid off workers, while many others were unable to employ new workers. Majority of the farmers who could not employ new workers were low-scale operators, while farmers who experienced drastic drop in farm capacity laid off workers since they did not need extra labour in their business. Affected farmers,

most of whom were small scale farmers, reduced their expenditure due to shortage of funds. The large and medium scale farmers did not lay off workers. Most affected farmers diversified their businesses within and outside the farming industry as extra source of income.

Beyond diversification of business some farmers abandoned cattle farming. These groups consisted mainly of migrant farmers who could no longer sustain their livelihood through cattle farming. The least affected groups were part-time farmers who owned less than 10 cattle. Majority of such farmers were beginners or retiring farmers who do not depend fully on the cattle farming business as the major source of livelihood. A cross tabulation of scale of production and effects of bovine cysticercosis shows that the small-scale full-time farmers were more affected by the bovine cysticercosis than the large scale and or part-time farmers.

Not all farmers who experienced bovine cysticercosis on their farms suffered major financial loses that could alter their livelihood pattern. These were part-time farmers involved in other businesses, large-scale farmers, and farmers having other livestock. These had other sources of livelihood. Majority of the farmers whose livelihood patterns were affected were full time farmers who owned less than 100 cattle (50-99 and 10-49 cattle). Across all the indicators of socioeconomic effect, full-time farmers who owned less than ten (10) cattle were most negatively affected.

Cost of cold treatment of infected carcass, economic losses due to devaluation of treated carcasses and condemnation of heavily infected carcasses accounted for majority of financial losses caused by bovine cysticercosis. Estimated average amount of P4, 125.26 was spent per farmer in cold treatment of infected carcasses, while an average of P4, 751.27 was lost per farmer due to devaluation of infected carcasses and an average of P34, 261.93 was lost per farmer due to condemnation of carcasses in 2017 (1USD = P10.7) (International Monetary Fund [IMF], n.d.) (Table 6). In a related study in Awka Nigeria, Ikpeze et al. (2008) recorded estimated loss of revenue from meat condemnation due to cysticercosis as N186892.38 (1USD = N345) (International Monetary Fund [IMF], n.d.). Condemnation due to generalized cysticerci infection in affected organs amounted to N109467.50 (58.6%) of the loss, while condemnation of moderately and locally infected organs contributed N28435.08 (15.2%) and N48989.8 (26.2%) to the total loss, respectively. In Kenya, in 1996, bovine cysticercosis alone led to loses estimated at £7 million annually through a combination of poor productivity, death of stock, condemnation of infected organs and reduction in carcass quality (Harrison et al., 1986),

As intervention strategies the government of Botswana provided re-stocking seed calves to severely affected farmers, social amenities like pipe water to the farms proximal to the urban areas and bore holes to farms and cattle post removed from the urban areas. The government also organized regular campaign programs on prevention and control of bovine cysticercosis.

Authors recommend some important features for determining farmers' vulnerability (**V**) to bovine cysticercosis. These include the following: scale of production (**S**) = number/worth of animal in farm or cattle post; level of involvement of farmer (**L**) = part time or full time; magnitude of dependants on farmers vis-à-vis income level (**D**) =family size versus scale of production versus level of involvement; magnitude of effect of bovine cysticercosis on farming business (**E**) = amount lost by detention, devaluation and destruction of animals and the number of animals destroyed; type, usefulness and promptness of government intervention to farmers following devaluation or destruction of affected animals (**I)**.

An appropriate model of vulnerability (**V**) can be worked out and this can be used as farmers' vulnerability predictive model in policy advocacy for intervention measures.

CONCLUSIONS AND RECOMMENDATIONS

This study has shown that bovine cysticercosis had negative effects on cattle farmers' finances and socioeconomic characteristics in Botswana. Generally, devaluation and condemnation of carcasses arising from identification of cysts in carcasses and cost of treating the infected carcass had financial implications. Bovine cysticercosis had significant effects on farmers' emotional and psychological health, farmers' ability to save money and ability to provide food for family. Also not significantly affected were farmers' ability to provide healthcare, education, rental for family, farmers' and ability to employ new workers. Further effects included: farmers' inability to meet social, religious and family obligations, causing some to borrow money for upkeep of family and/or farming business. Severity of effects on farmers was dependent on the magnitude of the infection, farmers' scale of production, presence or absence of extra survival strategies and government intervention. On the average each farmer spent about P4, 125.26 in cold treatment of infested carcass in 2017 alone, while losing P4, 751.27 and P34, 261.93 due to devaluation and condemnation of carcasses respectively in 2017 alone. Farmers' response to the effects of bovine cysticercosis included outright closure of farms for severely affected farmers; reduction in farm capacity, particularly for farmers who own large number of cattle but were not severely affected and diversification of business for mostly low scale farmers. Of the existing government intervention measures, the most effective were provision of re-stocking seed calves, payment for treating (chilling) infested carcass, and installation of socio amenities, which also played vital role in cushioning the adverse

effects of bovine cysticercosis on the livelihood pattern of the farmers.

This study recommends that government intervention measures should equally emphasize farmers' emotional and psychological wellness, ability to save money and ability to provide food for the family as these were the most affected socioeconomic indicators. Furthermore, this study recommends viable cattle insurance policy for farmers and government payment of compensation for condemned animals both of which are currently not practiced in Botswana.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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