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REGULAR ARTICLES

Investigation of *Cysticercosis bovis* prevalence using passive abattoir post-mortem inspection and active administration of structured non-participatory questionnaire to farmers in Botswana

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Abstract

Most government published statistics of C. bovis prevalence in Botswana emanate mainly from records available at the Botswana Meat Commission (BMC), the country's national export abattoir. Although BMC slaughters 44% of Botswana's annual cattle slaughter, prevalence data arising from BMC does not reflect prevalence from lower throughput abattoirs and potential hotspots. Thus, reporting national prevalence rate using solely BMC statistics may not be very informative and reflective of the bigger picture. It therefore became imperative to probe prevalence of bovine cysticercosis using a cross-sectional study through passive abattoir inspection, covering a wider scope (more regions) and some lower throughput abattoirs previously not accounted for. Furthermore, non-participatory interview using structured questionnaires was employed to actively elicit prevalence information directly from meat industry stake holders. Prevalence arising from survey was used to compare and query results from statutory (traditional) passive abattoir method. Abattoir prevalence was 17.17% (SE = 1.70027), and survey prevalence was 42.35%; both of which were higher than published prevalence of 13.5% and BMC prevalence of 10% (SE = 0.006576). Survey method was more holistic than passive abattoir method, by covering more frontiers thus yielding higher prevalence. At p = 025, abattoir and survey prevalence were significantly different from each other. In addition to delimitating novel hotspots in Botswana, this study showed significant difference, p = 0.002 in prevalence within districts and regions. Kalagadi district's prevalence differed significantly from other districts: differed from North East at p = 0.042, Central district at p = 0.002 and Ghanzi at p = 0.004. The results which arise from this methodological approach have been able to provide a more all-inclusive and reliable prevalence rate.

Keywords Botswana · *Cysticercus bovis* · Prevalence · Passive abattoir inspection · Active survey

Background of the study

Botswana's prevalence of bovine cysticercosis has been increasing consistently, rising from 12 in 1974 (Mosienyane 1986) to 20% in 2014 (Modisa 2014), before dropping to 13.5% in 2015 (Tshiamo 2015). Most published prevalence figures emanate from data available at BMC and high-throughput government abattoirs. BMC, the country's national export abattoir, anticipated the possibility of losing the patronage of the EU beef market because of these increasing rates. Consequently, BMC streamlined sourcing of cattle by avoiding designated hotspots, while providing containment measures for hotspots, sponsoring professionally managed paddocks/kraals/pens and maintaining strict inspection policies. At BMC, as in most other high-throughput (government) abattoirs, cattle carcass identified as harbouring *Cysticercus bovis* cysts was either rejected, devalued or destroyed depending on severity of cysticercosis infestation. This was done in compliance with the provisions of the Livestock and Meat Industries Act (2007). Heavily infested carcasses with ten or more cysts were confiscated and destroyed without compensations to farmers in accordance with the provisions of the Livestock and Meat Industries Act of 2007. These efforts helped to downregulate prevalence rates emanating from the BMC. As a result, farmers who suspect that their cattle may harbour the *Taenia saginata* cysts avoided the BMC, preferring the low-throughput abattoirs (Aganga, personal communication, March 8, 2017). Unlike the BMC, which maintains strict

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inspection policies, most low-throughput abattoirs do not, because they lack enough and/or competent meat inspectors. As a result, cases from low-throughput abattoirs are not reflected in the documented national prevalence rates for *C. bovis.* Similarly, cases of bovine cysticercosis from other regions of the country and other slaughter houses and backyard slaughter were either not captured or not reported, a common occurrence in most developing countries (FAO 2013). Consequently, deriving the national prevalence rate relying solely on the BMC data, which was the status quo (Modisa 2014), may not be very informative. It became imperative to conduct a more holistic study, which in addition to collating prevalence records available at BMC would elicit prevalence/incidence from low-throughput abattoir, as well as cover more regions of Botswana. Prevalence results from the survey method were compared with the results of the conventional passive abattoir inspection.

Materials and methods

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

Data sources and data collection

Primary data was collected through passive abattoir post-mortem meat inspection at export and local abattoirs, slaughter slabs and butcheries and through the use of questionnaire administered directly to farmers and beef industry stake holders. Information collected at the abattoirs were numbers of animals slaughtered, numbers of slaughtered animals harbouring *Cysticercus bovis* and original source (region and district) of slaughtered cattle. Information collected using questionnaire included biodata of farmers and farms, farmers' knowledge of *C. bovis* and farmers' record of *C. bovis* in farm. Secondary data was obtained from government record and published materials. Information collected were prevalence across years and list of designated hotspots of *C. bovis.*

Sampling procedures and population

Abattoir sampling

Abattoir sampling involved the multistage, purposive sampling and convenience techniques. The multistage sampling technique was used because the population is stratified into regions, districts and animal holdings (Statistics Botswana 2015). Purposive sampling technique was used to select 2 agricultural regions, one with highest abattoirs recording, which is the Central region, and the second region with the lowest cattle slaughtered, which is the Western region. From the Central region, the districts with the highest slaughter were selected, which is the Central district, and the district with the lowest slaughter population was selected, which is the North East district. From the Western region, the district with the highest slaughter was selected, which is Ghanzi district, and the district with the lowest slaughter population was selected, which is the Kalagadi district (Statistics Botswana 2013). Convenience sampling technique was applied to select a total of fifteen meat premises that were assessable (Table 1). These premises were representative of the population because they arise from a combination of designated hotspots and free zones.

Questionnaire sampling

The multistage and the purposive sampling techniques as described in abattoir sampling were used to select the regions and districts for administration of questionnaire. Convenience sampling technique was used to enumerate individual respondents based on availability. Convenience sampling was imperative since human and animal populations are sparse (Statistics Botswana 2015). One hundred and forty-nine respondents were sampled (Table 2.) The questionnaires were administered directly with the help of a local interpreter for non-English speaking respondents.

Data analysis

Descriptive statistics was used to lay out and describe the data. Data from passive abattoir post-mortem examination was subjected to the *t* test in order to check for significant difference in means of prevalence among the abattoirs. Results of means of prevalence within and between districts using questionnaire were compared for any significant difference and relevance using analysis of variance (One-Way ANOVA) tests.

Results

Botswana Meat Commission (BMC), Botswana's main export abattoir, reported lowest prevalence of 10% (SE = 0.006576). Tithe Meat Complex, a low-throughput abattoir located at Ghanzi district in Western region, reported prevalence of 10% (SE = 0.108062). Multi specie abattoir Botswana (MSAB) located in Central district reported prevalence of 12.5% (SE = 0.096654) (Tables 3 and 8). Highest prevalence of 33.3% (SE = 0.098647) was recorded at Cecil Waters Meat Place, in Kalagadi district in Western region. The next highest prevalence of 27.3% (SE = 0.103034) was recorded at Lesongwane Meat Market in North East district of Central region (Tables 3 and 8).

Using a one sample *t*-statistics to compare abattoir and published prevalence, *t* value of 10.1 and *p* value of 0.000 (SE = 1.70027) are both significant. Confidence interval with

Table 1 Sampled abattoirs and meat premises according to regions and districts

Regions	Central regions		Western region	
Districts	Central and Kweneng districts	North East district	Ghanzi district	Kalagadi district
Meat premises	BMC Lobatse Multi-Species Abattoir Botswana Tsholeta slaughter slab Kubu Slaughter Slab Maruping Slaughter Slab	Selibe-Phikwe Town Council Abattoir Mmadinare Abattoir Sandy's Meat Botshabelo Meat Shop Lesongwane Meat Market	Thothonu Meat Place Rhodes (Meg Farm) Tithe Complex	Cecil Waters Kang Meat Market

For the purposes of this study, the meat premises sampled in Molepolole, Mahalapye, multispecies abattoir (MSAB) and BMC Lobatse were grouped and designated 'central + Kweneng' district. BMC was sampled and held as a standard, being that its prevalence is considered the (standard) national prevalence (Modisa 2014)

lower value of 13.5266 and an upper value of 20.8200 are both higher than those of BMC and published prevalence, and they also exclude zero (Table 4).

At p value = 5.13E-08 (SE = 0.006576), BMC prevalence of 10% is significantly lower than published national prevalence of 13.5%. Prevalence rates of other abattoirs were not significantly different from published prevalence. For example, MSAB at p value = 0.325149 (SE = 0.022058) and SPTC at p value = 0.709282 (SE = 0.023581) were not statistically different from published prevalence (Table 8).

District abattoir prevalence of *C. bovis* was derived by calculating mean value of prevalence obtained from sampled abattoirs and meat premises within district. District survey prevalence of *C. bovis* was worked out by calculating percentage of respondents within district who answered "yes" to the question, "Have you recorded beef measles in your carcass in the last one year (2016-2017)?" (Table 5). In all four districts, survey prevalence was higher than abattoir prevalence (Table 6).

Whereas abattoir prevalence was 17.17% (SE = 1.70027) (Table 4), survey prevalence was 42.31% (Table 5). Both prevalence results are higher than both BMC and published prevalence of 10% and 13.5%, respectively (Table 4). At p = 0.376, Levene's statistic of abattoir and questionnaire prevalence is not significant (Table 9). This shows that the variances of abattoir and questionnaire samples are not the same (equal), because both samples were drawn from the same population. Data was therefore eligible for ANOVA test. Using a paired sample t test, questionnaire and abattoir prevalence results were compared to show which was more suited in measuring prevalence. This analysis was done to challenge the statutory use of passive abattoir post-mortem examination as only means of measuring prevalence. At p = 0.025, analysis shows that there is significant difference between abattoir and questionnaire prevalence (Table 9).

Levene's statistic of abattoir prevalence arising from the four districts was carried out to assess its suitability for ANOVA. At p value = 0.241, Levene's statistics is not significant (Table 10). This shows that samples are independent even though they are from the same population. ANOVA shows there is significant difference p value = 0.002 between abattoirs, but there was no significant difference within districts (Table 10).

Survey prevalence of districts were Central = 20.00%, North East = 38.71%, Ghanzi = 57.70% and Kalagadi = 30.56%. Abattoir prevalence of districts were Central = 13.24%, North East = 18.96%, Ghanzi = 12.77% and Kalagadi = 29.15% (Table 6). Multiple comparisons of abattoir prevalence of *C. bovis* across districts show a significant difference p value = 0.042 (SE = 3.2759) between North East and Kalagadi. Mean prevalence of Kalagadi differs significantly from mean prevalence of Central and Ghanzi districts at p value = 0.002 (SE = 3.2759) and p value = 0.004 (SE = 3.5743), respectively (Table 11). Prevalence data across years show that high prevalence were recorded in 2014 at 20% and in 2012 at 18%. Lowest prevalence was noticed in 2002 at 10% (Table 7). Published prevalence in 2015 was 13.5% (Tshiamo 2015), while current prevalence determined by this study in 2017 was 17.13% (Table 7). This is 26.9% prevalence increase. About 94.6% of respondents had knowledge of existence *C. bovis*. About 28% and 14.7% respondents had their carcasses detained and condemned, respectively (Table 5).

Table 2 Questionnaire sample size according to districts of respondents

Districts	Sample size
North Central	30 + (1 invalid)
Central + Kweneng	31
Kalagadi district	36
Ghanzi	52
Total	149 + (1 invalid)

Discussion

The Botswana Meat Commission (BMC), the government-owned export abattoir and MSAB, a high-throughput abattoir,

Table 3 Prevalence results of passive abattoir post-mortem examination

Region	Meat premises	Capacity/week	Frequency	Prevalence
Central	BMC (Standard)	2700	270	10.00
	MSAB (Kweneng)	240.0	30	12.5
	Molepolole I (Kweneng)	200–230	30	14.0
	Molepolole II (Kweneng)	250–260	35	13.7
	Mahalapye I (Central)	150	24	16.0
North East	SPTC Abattoir	210	31	14.8
	Madinare Abattoir	40	8	20.0
	Sandy's Meat	12.0	2	16.7
	Botshabelo Meat Shop	10–15	2	16.0
	Lesongwane Meat Market	10–12	3	27.3
Ghanzi	Thothonu Meat Place	15	2	13.3
	Rhodes (Meg Farm)	20	3	15.0
	Tithe Complex	10.0	1	10.0
Kalagadi district	Cecil Waters	12	4	33.3
	Kang Meat Market	20	5	25.0

operate at slaughter scales higher than privately owned, low-throughput abattoirs and slaughter slabs (Table 3). BMC and MSAB observe higher compliance with provisions of Livestock and Meat Industries Act (2007), which specifies procedures and actions to be taken regarding *Cysticercus bovis*. Beef identified to be infested with *C. bovis* cysts cannot be exported to the European Union, Botswana's main and most profitable beef export market. Infested carcass is either condemned if containing more than 10 cysts, or detained and treated and if containing less than 10 cysts (Livestock and Meat Industries Act 2007). Farmers whose carcasses are condemned receive no compensation, whereas farmers whose carcasses are detained and treated receive 75% of the original value of carcass (Aganga 2009). BMC and MSAB abattoirs are expected to record prevalence rates higher than lower throughput abattoirs and slaughter slabs, going by their higher capacity and mandatory compliance with standards of meat inspection. On the contrary, BMC and MSAB recorded lowest prevalence rates. This paradox can be explained by the reasons that farmers who suspect that their cattle may harbour *C. bovis* cysts prefer to sell their cattle to low-throughput abattoirs and (unlicensed) slaughter slabs instead of major abattoirs, because the former fails to conduct thorough investigations (Aganga 2009; Uchendu 2020). Secondly, BMC's low prevalence figures arise because in the recent years, BMC boycotted cattle supplied from known *C. bovis* hotspots. BMC's prevalence data, usually considered as national standard, has been the main source of published national prevalence (Modisa 2014). Cases not presented to BMC are either misdiagnosed or unreported (Table 8).

These undetectable cases were detected in this study using questionnaires. Unlike the abattoir inspection method, which was passive and investigated only major and government abattoirs, survey method was proactive and investigated private, low-throughput abattoirs, slaughter houses, meat inspectors and individual farmers. These explain why survey prevalence is much higher than abattoir prevalence. It is imperative to highlight that both the abattoir and questionnaire samples were subjected to the Levene's test of significance to give $p = 0.376$, which was not statistically significant. This means that the variances of the two samples are the same (equal) and that both samples originate from the same population (Tables 9 and 10). Conclusively the questionnaire (survey) method can be described to be more holistic and thorough than the passive abattoir method.

C. bovis hotspots exist homogenously within district and region. Both high and low prevalence scores were detected within districts and regions using abattoirs and survey method.

Table 4 One sample statistics comparing abattoir prevalence and published prevalence

N	Mean	Std. deviation	Std. error mean	T	Df	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference	
								Lower	Upper
15	17.1733	6.58510	1.70027	10.100	14	0.000	17.17333	13.5266	20.8200

The lower value of 13.5266 and an upper value of 20.8200 are both higher than both the BMC (10) and published (13.5) prevalence rates and excludes zero

Table 5 Farmers' knowledge of *C. bovis* and some effects of *C. bovis* on farming

	Knowledge	Record	Detained	Condemned	EFC
(%) Yes	94.6	42.3	28.0	14.7	18.1
(%) No	5.4	57.7	72.0	85.3	81.9
Total	100.0	100.0	100.0	100.0	100.0

Knowledge, respondents who had knowledge of *C. bovis*; Record, respondents who recorded *C. bovis* in their carcass; Detained, respondents whose carcasses were detained; Condemned, respondents whose carcasses were condemned; EFC, respondents whose farm capacity was affected by *C. bovis*

However, an identified pattern was that the prevalence rates were generally higher in the rural and poorer communities than in the urban and elite communities even within the same district. For example, both Celcil Waters, a village slaughter, with highest prevalence of 33.3% and Tithe Meat Place, in the city, with low prevalence of 10% are located within the Western region. Similarly, within the North East district, prevalence rate of Selibe-Phikwe Town Council (SPTC) Abattoir, an urban government-operated abattoir, was 14.8%, while prevalence rate of Lesongwane Meat Market, a rural abattoir, was 27.3% (Table 3). These findings agree with those of Farmers' Magazine, Botswana (2016) and Hendrickx et al. (2019) which both claim that prevalence and spread of bovine cysticercosis are closely linked to poverty and poor hygiene. Major and important risk factors (determinants) of *C. bovis* are favoured by poverty and poor hygiene (Uchendu 2020).

Although abattoir(s) in a district record high prevalence, categorising a district as a hotspot based solely on prevalence data obtained at abattoir may be erroneous. Cattle slaughtered in an abattoir may be reared and purchased from another district or region; hence, *C bovis* could be imported. Thus, for proper assessment of *C. bovis* hotspots, efficient trace back mechanism is vital. Carcass should be tagged with its original source of the cattle. For instance, although Ghanzi district of Western region is the highest producer of beef cattle, most of these cattle are sold to and slaughtered at BMC in Lobatse, in the Southern region. As such, although the positive cases are detected at Southern region, these cases must be traced back to Ghanzi district in Western region. This finding agrees with NRC (2009) and USDA [n.d.], both of which have described disease traceability, beyond clinical diagnosis, as vital component for rapid response and disease surveillance.

Table 6 Comparison of abattoir and questionnaire prevalence across districts

Districts of respondents	Questionnaire (%)		Abattoir (%)
	District prevalence	DCP	
Central + Kweneng	20.00	6.71	13.24
North East	38.71	8.05	18.96
Kalagadi	30.56	7.38	29.15
Ghanzi	57.72	20.13	12.77
Mean Prevalence		42.3	17.17

DCP districts contribution to overall prevalence

Table 7 Prevalence across years

Year	Prevalence
1974	12.0
1983	15.0
2002	10.0
2006	12.0
2012	18.0
2014	20.0
2015	13.5
2017	17.1

Ref: (Mosienyane 1986; Modisa 2014; Tshiamo 2015)

Abattoir prevalence of 17.37% (Table 4) was higher than both 2015 published prevalence of 13.5% (Tshiamo 2015) and BMC prevalence of 10% (Table 3). This indicates about 26.9% rise in *C. bovis* prevalence from 2015 to 2017 (Table 7). This could be a genuine increase in *C. bovis* prevalence in Botswana, thus validating the claims of Modisa (2014) and Tshiamo (2015) that Botswana's *C. bovis* prevalence was increasing persistently.

In addition, increase in prevalence observed may have arisen from better detection methods and wider area coverage employed by this study. This validates authors' argument that determining prevalence using a combination of BMC data and data from middle-/low-throughput abattoirs is more representative than using BMC data alone. Adopting this more holistic detection method was imperative to address concerns of FAO (2013), which claim that reliable estimates of *C. bovis* are lacking due to the low pathogenicity and under-reporting of this infection.

Although some abattoirs showed higher *C. bovis* prevalence than both the BMC and national prevalence, only the BMC prevalence was significantly different from the published prevalence (Table 8). The reason is that most meat premises having high prevalence possesses small sample size. Cecil Waters with prevalence of 33.3% (SE = 0.098647) and Lesongwane with prevalence of 27.3 (SE = 0.103034) have slaughter capacities of 12 and 11 cattle per week, respectively (Table 8).

Although time series analysis of *C. bovis* prevalence does not show a consistent pattern (Table 5), it does appear that there is a correlation between annual atmospheric temperature and *C. bovis* annual prevalence. The probable explanation for the spike in prevalence from 12 in 2006 to 18% in 2012 and 20% in 2014 (Table 5) is that Botswana experienced drought

Table 8 Comparison of individual abattoir prevalence with published prevalence (standard) of 13.5% (Tshiamo 2015)

Premises	Capacity/week	Frequency	Prevalence	Expected frequency		SE	*P* value
Botswana Meat Commission	2700	270	10	364.5	0.006576	0.005774	5.13E-08
MSAB (Kweneng)	240	30	12.5	32.4	0.022058	0.021348	0.325149
Molepolole I (Kweneng)	215	30	14	29.025	0.023305	0.023664	0.584938
Molepolole II (Kweneng)	255	35	13.7	34.425	0.0214	0.021533	0.537231
Mahalapye I (Central)	150	24	16	20.25	0.027902	0.029933	0.814875
SPTC Abattoir	210	31	14.8	28.35	0.023581	0.024504	0.709282
Mmadinare	40	8	20	5.4	0.054031	0.063246	0.885513
Sandy's Meat	12	2	16.7	1.62	0.098647	0.107669	0.627178
Botshabelo Meat Shop	12.5	2	16	1.6875	0.096654	0.103692	0.602049
Lesongwane Meat Market	11	3	27.3	1.485	0.103034	0.134324	0.909775
Thothonu Meat Place	15	2	13.3	2.025	0.088233	0.087678	0.490958
Rhodes (Meg Farm)	20	3	15	2.7	0.076412	0.079844	0.577814
Tithe Complex	10	1	10	1.35	0.108062	0.094868	0.373012
Cecil Waters	12	4	33.3	1.62	0.098647	0.136049	0.977633
Kang Meat Market	20	5	25	2.7	0.076412	0.096825	0.933839

Ho is that Po = 0.135, where Ho is null hypothesis; Po = prevalence of individual meat premises; EF is expected frequency = Observed X 0.135; SE = SQ Root of Po (1-Po/N); ESE = P (1-P)/N where N is national prevalence; *P* Value = probability of rejecting null hypothesis when true

between 2010 and 2012 (Juana 2014). Drought causes scarcity of pasture and animal feed, which lead to hunger and starvation. Malnourished animals are prone to immunosuppression and germ recrudescence (Drovers 2011), both of which allows worn burden to establish easily. Scavenging arising from scarcity of pasture increases contact exposure of cattle to pasture and debris contaminated with human faeces which may contain eggs of *Taenia saginata*. This agrees with findings of Vicente and Vercauteren (2019) that scavenged material can potentially favour transmission and spread of infectious disease or contaminants to wild animals, farm animals and humans.

There was significant difference in *C. bovis* prevalence (means) among sampled abattoirs (Table 4). This indicates that the proportion of cattle with *C. bovis* in Botswana is significant. At 95% confidence interval, the wide difference between the upper and lower confidence interval, both of which are higher than the BMC and published prevalence (Table 4), shows that there is wide range (disparity) among abattoirs prevalence of *C. bovis* (Ama et al. 2008). It also shows that there is significant difference between and among BMC and published prevalence and prevalence obtained through this study. This disparity holds and equally calls for a holistic prevalence study since it is apparent that relying on BMC results alone is not representative of cysticercosis prevalence in Botswana.

Kalagadi district recorded abattoir prevalence (Table 6), which was higher than and significantly different from the other three districts (Table 11). However, there was no significant difference in *C. bovis* prevalence between and/or among Ghanzi, North East and Central (Tables 10 and 11). Whereas the other three districts are largely urban settlements, the

Table 9 Levene's test for equality of variances and *t* test for equality of means of independent samples test of abattoir and questionnaire prevalence

		Levene's test for equality of variances		*t* test for equality of means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
Prevalence	Equal variances assumed	0.914	0.376	− 2.971	6	0.025	− 20.99750	7.06654	− 38.28871	− 3.70629
	Equal variances not assumed			− 2.971	4.816	0.033	− 20.99750	7.06654	− 39.37387	− 2.62113

Table 10 Multiple comparisons of abattoir prevalence of *C. bovis* across districts

Test of homogeneity of variances				ANOVA					
Percentages of *C. bovis*				Percentages of *C. bovis*					
Levene's statistic	df1	df2	Sig.		Sum of Squares	Df	Mean Square	F	Sig.
1.619	3	11	0.241	Between groups	438.454	3	146.151	9.533	.002
				Within groups	168.636	11	15.331		
				Total	607.089	14			

These Levene's statistic of abattoir samples at 0.241 ($P < 0.05$) is not significant, showing that samples are independent. The ANOVA shows that there is significant difference 0.002 ($P < 0.05$) between abattoirs (Table 10)

Kalagadi district is predominantly a rural area and home for the Basarwa tribes (Bush men) (Logan and Silberbauer 2019). The Basarwa tribe, until present, are nomadic cattle herders who are unreceptive to technology and use of basic amenities, like toilets. Both the perpetual gazing of animals and refusal to adopt hygienic disposal of human faeces has made eradication of *C. bovis* in the Kalagadi district difficult, if not impossible. There was significant difference in *C. bovis* prevalence between districts but not within districts (Table 10). These differences informed the need to study the lifestyles of indigenes at district level as risk factors of *C. bovis*. Uchendu (unpublished 2020) has shown a correlation between lifestyle of humans as risk factor and *C. bovis* prevalence rates.

Conclusions and recommendations

This study focused on BMC, some middle- and low-throughput abattoirs, butcheries, slaughter houses and household slaughters. Results of this study are more representative than the officially quoted prevalence obtained from BMC data alone. Using questionnaire to directly investigate farmers and beef industry stakeholders allowed for an active and more holistic study and thus challenged the status quo of calculating prevalence based only on passive abattoir post-mortem inspection. *C. bovis* prevalence in Botswana is increasing over years. Authors recommend that officially designated meat inspection officers should conduct thorough investigation at the major and high-throughput abattoir as well as at private and low-throughput abattoir. This will ensure that farmers who deliberately avoid the major abattoirs will still be picked up at the low-throughput abattoirs. Equally recommended is the combined use of statutory passive abattoir inspection and survey method as the latter has shown to be more sensitive in detecting prevalence of cysticercosis. The differences in means of prevalence across and within districts inform the need to

Table 11 Multiple comparisons of abattoir prevalence of *C. bovis* across districts

(I) District of meat premises	(j) District of meat premises	Mean difference (i-j)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
North East	Central + Kweneng	5.7200	2.4763	.155	− 1.733	13.173
	Kalagadi	− 10.1900**	3.2759	.042	− 20.049	− .331
	Ghanzi	6.1933	2.8594	.193	− 2.412	14.799
Central + Kweneng	North East	− 5.7200	2.4763	.155	− 13.173	1.733
	Kalagadi	− 15.9100**	3.2759	.002	− 25.769	− 6.051
	Ghanzi	.4733	2.8594	.998	− 8.132	9.079
Kalagadi	North East	10.1900**	3.2759	.042	− .331	20.049
	Central + Kweneng	15.9100**	3.2759	.002	6.051	25.769
	Ghanzi	16.3833**	3.5743	.004	5.626	27.140
Ghanzi	North East	− 6.1933	2.8594	.193	− 14.799	2.412
	Central + Kweneng	− .4733	2.8594	.998	− 9.079	8.132
	Kalagadi	− 16.3833**	3.5743	.004	− 27.140	− 5.626

Using the Tukey HSD test to compare one district against another

**The mean difference is significant at the 0.05 level

study the differences in lifestyles of locals as well as the correlation between the lifestyle of locals and observed prevalence at the district level.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent All authors have given their consent that this work is valid and represent their views of the study, and all authors have given their consent for this work to be published.

Statement of animal rights This work did not involve the use of animal for laboratory studies. There is no violation of animal right.

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