



Causes, dynamics and financial losses associated with red offal condemnation at a beef abattoir in Namibia

Erick Kandiwa¹, Pricilla Mbiri¹, Alaster Samkange¹, Oscar Madzingira^{1*}, Adrianatus Maseke², Jessey Alice Kamwi², Borden Mushonga¹

¹School of Veterinary Medicine, Faculty of Agriculture and Natural Resources, University of Namibia, Neudamm Campus, Namibia.

²Directorate of Veterinary Services, Ministry of Agriculture, Water and Forestry, Namibia.

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ABSTRACT

There are limited studies on red offal condemnations and their financial implications at high throughput abattoirs in Namibia. Causes of condemnation, temporal distributions and financial losses associated with red offal condemnations at a beef abattoir in Namibia from 2016 to 2018 were determined. A total of 39157 red offal valued at N\$6 422 586.00 (US\$364 805) were condemned following the slaughter of 251697 cattle. Condemnations were dependent on the year [$\chi^2(14) = 587.13, p < 0.001$], month [$\chi^2(77) = 1898.72, p < 0.001$] and season [$\chi^2(7) = 111.12, p < 0.001$] of study. Overall, 2016 had the most and 2018 the least condemnation of red offal (38.73% and 23.22%, respectively; $p < 0.05$). Most red offal condemnations (13.34%, $p < 0.001$) occurred in June, with livers and lungs as the most condemned organs (54.32% and 29.88%, respectively; $p < 0.001$). The highest condemnations were caused by miscellaneous causes (such as abscesses and hematomas) followed, in descending order, by inflammatory, parasitic and bacterial causes and contaminations (38.3%, 29.4%, 16.6% and 15.8%, respectively, $p < 0.05$). Liver condemnations varied with the year and season under study [$\chi^2(20) = 1834.02, p < 0.001$ and $\chi^2(9) = 1010.43, p < 0.001$; respectively], as were lung condemnations according to pathological condition [$\chi^2(12) = 492.43, p < 0.001$ and $\chi^2(6) = 45.84, p < 0.001$; respectively]. The occurrence of hydatidosis in the summer and pneumonia in winter were greater than expected (15.1% and 4.3%; respectively, $p < 0.05$). A substantial loss of revenue to the abattoir due to the condemnation of livers and lungs was determined. Meat inspection served as a control point for hydatidosis.

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1. Introduction

Agriculture contributes 10-11.7% to GDP of Namibia and provides livelihood for about 70% of the population. It produces 2% of the manufacturing output and brings in about 11.5% of the country's foreign earnings (1,2,3). The commercial livestock sector, with substantial beef cattle production, contributes up to 85% of the country's agricultural income (1).

Namibia is divided into the northern communal areas (NCA) and a largely commercial southern part by an east-west running veterinary cordon fence (VCF) separating the foot and mouth disease (FMD) prone north from the FMD free south (2,4,5).

The FMD free southern areas supply cattle to abattoirs located in the same zone, which process and supply beef to the lucrative niche markets of the European Union, United Kingdom (UK), Norway and, more recently, China and the United States of America (6). Meat inspection in Namibian abattoirs is a rigorous process that is based on the Meat Safety Act (7) and adheres to the strict hygiene requirements of the importing countries (3). The objective of the meat inspection process is to exclude harmful disease agents,

*Corresponding author. Tel.: +2648135930723

E-mail address: omuzembe@gmail.com

chemical and physical hazards so as to provide wholesome, attractive and safe meat to consumers (3,8-10). The process also captures valuable animal health related data that can be used as an epidemiological tool for the surveillance of animal diseases (11-14). In addition, meat inspection plays a central role in the detection and prevention of transmission of zoonotic diseases into the human population (15,16).

Disease or conditions produce blemishes or lesions of a developmental, degenerative, inflammatory or neoplastic nature that make the organs or offal unacceptable for human consumption (15-17). Infectious (mainly parasitic, bacterial, viral) and non-infectious (traumatic, neoplasia and contamination) conditions, resulting in condemnation of offal have been extensively studied (15,18,19). Parasitic, bacterial and traumatic lesions have been reported as the major cause of lesions in offal (10,20-25). Parasitic and bacterial infections often show annual (18), seasonal (14,26,27) and even monthly patterns. Years of good rains, warmth and moisture of summer months promote intermediate host and parasite multiplication (28), while winter months promote bacterial transmission as a result of animals huddling together in order to keep warm. Reports from previous studies indicate that livers followed by lungs, are the most commonly condemned organs/offal in cattle (17,19,25,29,30). However, other workers, have reported a higher prevalence of lung than liver condemnations (11,16,20,31). With regard to liver condemnation, *Fasciola* (18,28,32-38), followed by metacestode cysts of *Cysticercus bovis* (21) and/or *Echinococcus granulosus* (10,16,39,40) have been reported to be the major causes of condemnation. Bacteria such as *Staphylococcus*, *Streptococcus*, *Proteus* and *Mycobacterium bovis* have also been isolated from abscesses and other lesions in condemned livers and lungs (41-43). Other causes of liver condemnation include, cirrhosis, jaundice and discolouration (10,18,44,45).

With respect to lungs, a number of authors report that pneumonia is the leading cause of condemnation (11,12,20,33,41,46). In other studies, hydatid cysts (8,10,47), *Mycobacterium bovis* (11,41) and *Mycoplasma mycoides mycoides* have been implicated (46,48). Emphysema, congestion, abscesses, atelectasis and haemorrhages are conditions that have also been identified in the lungs (11,15,25,41,47). Causes and the rate of condemnation of heart, kidney and tongue condemnations tend to vary from study to study (3,40,46).

There are a number of studies on meat condemnation from developing countries (23,49) including from West Africa (11,19,31,48,50), East Africa (20,25,33,34,44,51), particularly from Ethiopia (40,45,47,52) and Southern Africa (15,27,32,37,38,53). However, there are limited studies on meat condemnation from Namibia (3,22,54,55), although data on condemnations is available in monthly and annual reports of the Directorate of Veterinary Services in the Ministry of Agriculture Water and Forestry.

Of the studies on meat condemnation in Namibia, two focused on the condemnation of beef carcasses and organs (3,54), one determined the incidence of cysticercosis at a beef abattoir (55), while another focussed on bruising as a quality issue and a cause of condemnation in beef carcasses (22). None of the studies reported on the proportional condemnation of cattle red offal. Therefore, the objective of this study was to identify the causes and dynamics of red offal condemnations and to estimate the associated financial losses at a high throughput abattoir.

2. Materials and Methods

2.1. Study area

Namibia is located at 22°58'1.42"S and 18°29'34.80"E in the southwestern part of Africa. It is divided into 14 administrative regions. A veterinary cordon fence separates the FMD-free Southern Namibia from the FMD infected and protected regions in the north.

2.2. Study animals, slaughter and dressing procedures

Cattle destined for slaughter at the study abattoir originated from farms and a feedlot south of the Veterinary Cordon Fence of Namibia. The farms and feedlot were under continuous surveillance for animal diseases by the state veterinary service and were approved to send animals for slaughter. Slaughter animals were transported to the abattoir by road in approved transport vehicles. On the day of arrival, cattle were subjected to ante-mortem inspection in holding pens. After overnight rest, slaughter was achieved through jugular vein and carotid artery exsanguination of captive bolt stunned cattle. Thereafter, electrical stimulation and carcass dressing (head, hide and hoof removal, evisceration and splitting of carcasses) were performed as per abattoir standard operating procedures and following hygiene standards based on the Hazard Analysis and Critical Control Point (HACCP).

2.3. Study design and data collection

Daily condemnation records for cattle slaughtered at the export abattoir from 2016-2018 were retrieved and used for this study. Records included results of ante-mortem inspection, number of animals slaughtered and organs condemned at post-mortem or meat inspection. Post-mortem inspection was performed on correlated carcass halves and offal by trained meat inspectors under the supervision of a qualified state veterinarian. The meat inspection service at high throughput or export abattoirs in Namibia is administered by government officials from the Directorate of Veterinary Services (DVS) within the Ministry of Agriculture Water and Forestry (MAWF). Post-mortem inspection was performed through visual appraisal of organ colour and morphology, palpation to ascertain organ consistency and systematic incisions into the visceral organs according to the procedures prescribed by the Meat Safety Act (Act No. 40 of 2000). Suspicious samples were submitted to the Central Veterinary Laboratories (CVL) for confirmatory diagnosis.

Meat that passed inspection was washed, graded, weighed and immediately chilled. Condemned carcasses and offal were passed through a designated condemnation channel to the condemnation room for treatment at the by-products area or for direct disposal. For the purpose of this study, red offal was designated to include the skin-off head, tongue, oesophagus, heart, lung, kidney, liver and spleen. Categories designated for analysis of condemnations included contaminations (floor, milk, pus, rumen fluid and faecal), infections (echinococcosis/hydatidosis, cysticercosis, *Stilesia hepatica*, actinomycosis and actinobacillosis), inflammation (hepatitis, peritonitis, pleuritis, nephritis and oedema) and miscellaneous conditions (haematoma/blood vessel abnormalities, emphysema, melanosis and abscess). For the purpose of seasonal analysis of condemnations in this study, two seasons were designated; the wet season (November to April) and the dry season (May to October). The monetary values assigned to red offal in this study were based on gazetted red offal prices and weights at abattoir at the time of the study.

2.4. Statistical analysis

Data on condemnations were captured onto a Microsoft Excel 2013 spreadsheet. Pivot tables were subsequently used to determine the proportional distribution of animals based on year, season, month, organ type and cause of condemnation categories. The data was exported to the Statistical Package for Social Sciences (SPSS) version 25 for further analysis. The Chi square test was used to test for association of categories and

the Z test was used for comparison of proportions, where $p \leq 0.05$ was considered significant.

3. Results

A total of 251697 cattle were slaughtered at the abattoir under study over a 36-month period (Table 1) giving an overall red offal condemnation rate of 15.56% (39157/251697). The proportion of condemned organs varied with the year of study [$X^2(14) = 587.13, p < 0.001$]. The overall proportion of condemned livers and lungs were significantly greater than those of the rest of the red offal (54.32% and 29.88%, respectively; $p < 0.001$). A total of N\$6 422 586 (US\$364 805) was lost through condemnation of red offal during the study period and the majority of this revenue loss was attributable to liver, lung and head condemnations (62.1%, 18.3% and 10.8%; respectively). Throughout the study period, the proportion of condemned organs was dependent on the month of study [$X^2(77) = 1898.72, p < 0.001$] and the month of June had the highest number and proportion of condemned organs (13.34%, $p < 0.001$).

Throughout the study, the proportional distribution of organ condemnations varied with the season of study [$X^2(7) = 111.12, p < 0.001$], with a higher rate of organ condemnation in winter than in the summer season (60.52% and 39.48%, respectively, $p < 0.001$). The proportion of condemned lungs in the summer (12.29%, $p < 0.05$) and heads, kidneys, and pluck in winter (3.82%, 0.21% and 1.25%, respectively; $p < 0.05$) was significantly greater than expected.

The proportion of organ condemnations according to pathological condition was dependent on the year of study [$X^2(6) = 917.14, p < 0.001$] (Table 2). The proportion of organs condemned due to contaminations and inflammation in 2016 (7.8% and 12.3%, respectively, $p < 0.05$), miscellaneous causes in 2017 (12.29%, $p < 0.05$) and inflammation and infections in 2018 (7.5% and 4.9%, respectively, $p < 0.05$) were greater than expected. Overall, the highest proportion of condemnations were due to miscellaneous causes followed in descending order by inflammation, infections and contaminations (38.3%, 29.4%, 16.6% and 15.8%, respectively, $p < 0.05$).

Overall, the proportion of organs condemned per pathological condition varied with the month [$X^2(33) = 1461.7, p < 0.001$] (Table 3) and season of study [$X^2(3) = 82.61, p < 0.001$]. The proportion of organs condemned due to contaminations in March and April (1.7% and 2.0%; respectively, $p < 0.05$); inflammation in March,

Table 1. Proportions and value of organs condemned at the abattoir from 2016 to 2018

Organ condemned	Year (n=Total slaughter)			Overall (n=251697)	Revenue loss (NAD)
	2016 (n=95106)	2017 (n=84922)	2018 (n=71669)		
Heads (%)	1048 (2.68)*	730 (1.86)	535 (1.37)	2313 (5.91)	693 900 (10.8)
Hearts (%)	148 (0.38)*	81 (0.21)	84 (0.21)	313 (0.80)	43820 (0.7)
Kidneys (%)	37 (0.09)	43 (0.11)	17 (0.04)	97 (0.25)	10.541 (0.2)
Livers (%)	7445 (19.01)	8928 (22.80)*	4898 (12.51)	21271 (54.32)	3990546 (62.1)
Tongues (%)	538 (1.37)*	344 (0.88)	224 (0.57)	1106 (2.82)	203485 (3.2)
Lungs (%)	4708 (12.02)*	4096 (10.46)	2896 (7.40)*	11700 (29.88)	1177313 (18.3)
Gullets (%)	968 (2.47)*	409 (1.04)	318 (0.81)	1695 (4.33)	14018 (0.2)
Plucks (%)	275 (0.70)	265 (0.68)	122 (0.31)	662 (1.69)	288963 (4.5)
Total (%)	15167 (38.73)^a	14896 (38.04)^a	9094 (23.22)^a	39157 (100.00)	6422586 (100.0)

*values were greater than expected since $p \leq 0.05$; values with the same suffix^a in the same row were significantly different since $p \leq 0.05$

Table 2. Annual distribution of organ condemnations at the abattoir per pathological condition

Year	Contaminations (%)	Inflammation (%)	Infections (%)	Miscellaneous [#] (%)	Total (%)
2016	3071 (7.8)*	4835 (12.3)*	2165 (5.5)	5096 (13.0)	15167 (38.7) ^a
2017	2026 (5.2)	3761 (9.6)	2405 (6.1)	6704 (17.1)*	14896 (38.0) ^a
2018	1077 (2.8)	2926 (7.5)*	1912 (4.9)*	3179 (8.1)	9094 (23.2) ^a
Total	6174 (15.8)	11522 (29.4)	6482 (16.6)	14979 (38.3)	39157 (100.0)

*values were greater than expected since $p < 0.05$; [#]Abscess, angioma, melanosis and emphysema; values with the same suffix within columns were significantly different since $p \leq 0.05$

Table 3. Monthly distribution of organ condemnations according to pathological condition at the abattoir

Month	Contaminations (%)	Inflammation (%)	Infections (%)	Miscellaneous [#] (%)	Total (%)
January	110 (0.3)	321 (0.8)	168 (0.4)	454 (1.2)*	1053 (2.7)
February	341 (0.9)	554 (1.4)	335 (0.9)	989 (2.5)*	2219 (5.7)
March	666 (1.7)*	1188 (3.0)*	606 (1.5)	1215 (3.1)	3675 (9.4)
April	794 (2.0)*	788 (2.0)	961 (2.5)*	1709 (4.4)	4252 (10.9)
May	756 (1.9)	924 (2.4)	1206 (3.1)*	1457 (3.7)	4343 (11.1)
June	852 (2.2)	1679 (4.3)*	922 (2.4)	1772 (4.5)	5225 (13.3)
July	630 (1.6)	1234 (3.2)	407 (1.0)	1822 (4.7)*	4093 (10.5)
August	639 (1.6)	1322 (3.4)*	608 (1.6)	1475 (3.8)	4044 (10.3)
September	450 (1.1)	1076 (2.7)*	380 (1.0)	1265 (3.2)	3171 (8.1)
October	412 (1.1)	1105 (2.8)*	375 (1.0)	929 (2.4)	2821 (7.2)
November	370 (0.9)	997 (2.5)	332 (0.8)	1493 (3.8)*	3192 (8.2)
December	154 (0.4)	334 (0.9)	182 (0.5)	399 (1.0)	1069 (2.7)
Total	6174 (15.8)	11522 (29.4)	6482 (16.6)	14979 (38.3)	39157 (100.0)

*values were greater than expected since $p \leq 0.05$

Table 4. The seasonal distribution of organ condemnations by pathological condition

Season	Contaminations (%)	Inflammation (%)	Infections (%)	Miscellaneous (%)	Total
Summer	2435 (6.2)	4182 (10.7)	2584 (6.6)	6259 (16.0)*	15460 (39.5)
Winter	3739 (9.5)	7340 (18.7)*	3898 (10.0)	8720 (22.3)	23697 (60.5)
Total	6174 (15.8)	11522 (29.4)	6482 (16.6)	14979 (38.3)	39157 (100.0)

*values were greater than expected since $p \leq 0.05$

Table 5. Annual distribution of liver condemnations by pathological condition

Reason for condemnation	Year			Overall
	2016	2017	2018	
Abscess (%)	3137 (14,75)	4283 (20,14)*	2054 (9,66)	9474 (44,54)
Contamination (%)	287 (1,35)*	243 (1,14)	138 (0,65)	668 (3,14) ^a
Haematomas/blood vessel lesions (%)	627 (2,95)*	555 (2,61)	251 (1,18)	1433 (6,74)
Hydatidosis (%)	161 (0,76)	134 (0,63)	403 (1,89)*	698 (3,28) ^a
Peritonitis (%)	2924 (13,75)*	2386 (11,22)	1882 (8,85)*	7192 (33,81)
<i>Stilesia hepatica</i> (%)	255 (1,20)	856 (4,02)*	146 (0,69)	1257 (5,91)
Melanosis (%)	53 (0,25)	346 (1,63)*	7 (0,03)	406 (1,91)
Septicaemia (%)	1 (0,005)	3 (0,01)	0 (0,00)	4 (0,02)
Blood splash (%)	0 (0,00)	109 (0,51)*	0 (0,00)	109 (0,51)
Actinomycosis (%)	0 (0,00)	13 (0,06)	17 (0,08)*	30 (0,14)
Total (%)	7445 (35,00)	8928 (41,97)	4898 (23,03)	21271 (100,00)

*values were greater than expected since $p \leq 0.05$; values with the same suffix^a within the same column were not significantly different since $p > 0.05$.

Table 6. Reasons for condemnation and seasonal distribution of liver condemnations

Reason for condemnation	Season		Overall
	Summer	Winter	
Abscess (%)	3743 (17.60)	5731 (26.94)	9474 (44.54)
Contamination (%)	302 (1.42)	366 (1.72)	668 (3.14)
Hematomas/blood vessel lesions (%)	781 (3.67)*	652 (3.07)	1433 (6.74)
Hydatidosis (%)	464 (2.18)*	234 (1.10)	698 (3.28)
Peritonitis (%)	2555 (12.01)	4637 (21.80)*	7192 (33.81)
<i>S. hepatica</i> (%)	248 (1.17)	1009 (4.74)*	1257 (5.91)
Melanosis (%)	339 (1.59)*	67 (0.31)	406 (1.91)
Septicaemia (%)	0 (0.00)	4 (0.02)	4 (0.02)
Blood splash (%)	0 (0.00)	109 (0.51)*	109 (0.51)
Actinomycosis (%)	13 (0.06)	17 (0.08)	30 (0.14)
Total (%)	8445 (39.70)	12826 (60.30)	21271 (100.00)

*values were greater than expected since $p \leq 0.05$

June, August, September and October (3.0%, 4.3%, 3.4%, 2.7% and 2.8%; respectively, $p<0.05$); infections in April and May (2.5% and 3.1%; respectively, $p<0.05$) and miscellaneous causes in January, February, July and November (1.2%, 2.5%, 4.7% and 3.8%, $p<0.05$) were greater than expected.

More organs were condemned due to inflammation in winter (18.7%, $p<0.05$) and miscellaneous causes in the summer (16.0%, $p<0.05$) (Table 4). Condemnations of livers due to contaminations, hematomas/blood vessel lesions and peritonitis in 2016 (1.35%, 2.95% and 13.75%; respectively, $p<0.05$), abscess, *S. hepatica*, melanosis and blood splash in 2017 (20.14%, 4.02%, 1.63% and 0.51%; respectively, $p<0.05$) and hydatidosis, peritonitis and actinomycosis in 2018 (1.89%, 8.85% and 0.08%; respectively, $p<0.05$) were greater than expected (Table 5). A greater proportion of livers were condemned in winter than in summer (60.3% and 39.7%; respectively, $p<0.001$). The proportion livers condemned due to hematomas/blood vessel lesions, hydatidosis and melanosis were greater in the summer (3.67%, 2.18% and 1.59%; respectively, $p<0.05$), while those due to peritonitis, *S. hepatica* and blood splash were greater in winter (21.8%, 4.74% and 0.51%; respectively, $p<0.05$) (Table 6).

A higher proportion of lungs were condemned due to contamination and emphysema in 2016 (7.74% and 10.24%; respectively, $p<0.05$); contamination, pleuritis and melanosis in 2017 (6.28%, 3.44% and 2.09%; respectively, $p<0.05$) and hydatidosis in 2018 (10.34%, $p<0.05$). The proportion of lungs condemned in winter were significantly greater than those in summer (58.9% and 41.1%; respectively, $p<0.05$) (Table 7). The proportional condemnations due to hydatidosis in summer and that of pneumonia were significantly greater than expected (15.1% and 4.3%; respectively, $p<0.05$).

Table 7. Reasons for condemnation and seasonal distribution of lung condemnations

Reason for condemnation	Season		Overall
	Summer	Winter	
Abscess (%)	573 (4.9)	824 (7.0)	1397 (11.9)
Contamination (%)	787 (6.7)	1142 (9.8)	1929 (16.5)
Pleuritis (%)	329 (2.8)	500 (4.3)	829 (7.1)
Hydatidosis (%)	1761 (15.1)*	2294 (19.6)	4055 (34.7)
Emphysema (%)	901 (7.7)	1372 (11.7)	2273 (19.4)
Pneumonia (%)	231 (2.0)	498 (4.3)*	729 (6.2)
Melanosis (%)	230 (2.0)	258 (2.2)	488 (4.2)
Total	4812 (41.1)^a	6888 (58.9)^a	11700 (100.0)

* values were greater than expected since $p\leq 0.05$; values with the same suffix^a within the same row were significantly different since $p<0.05$.

4. Discussion

Results of this study show an overall condemnation rate of 15.65% for offal over a three-year period. Our findings are much higher than the condemnation rates of less than 10% reported by other studies (11,18,35,48), but are comparable to rates of 14-18% documented by other studies (25,31,51). Offal condemnation rates reported in literature are very variable (36,42,56). This variation may be explained by differences in the animal characteristics (ages, breeds, sex, body condition) (36,38,42,57), environment (season, year, month, low lying or highland geographical location) (17,18,26) and management factors (nutrition, production system) between studies.

The cost of the red offal condemnation in this study (US\$364 805.10) represents a substantial loss of revenue in the operations of an abattoir over a relatively short period. Our findings show a higher loss of revenue than a previous study in Namibia in which both carcass and organ condemnations cost the abattoir about US\$143711.00 over a four year period (3). In this study, revenue lost due to liver condemnation was estimated at US\$226664.33 over the three year study period. Our finding was greater than the US\$79 251.60 loss that was associated with liver condemnations in a group of abattoirs in Nigeria in a five-year study (26). However, comparisons of financial losses with previous studies are complicated by variations due to differences in climate, breed studied, types of animals slaughtered,

disease situations, length of the studies, meat inspection procedures and record keeping procedures among other factors.

The highest condemnation rate of livers as compared to other organs is not surprising, given its anatomical position as well as its physiological function in the body. Being the largest and central organ with a high blood flow responsible for detoxification, the liver is the organ most frequently exposed to noxious substances and infectious material (58-61), hence the high number of livers condemned due to abscesses. According to a number of studies, the major afflictions of the liver include fasciolosis, abscessation, cirrhosis, hydatid cysts and tuberculosis (10,26,31,44,45,51). Parasite larvae that penetrate the wall of the intestines or ingested infectious agents and chemicals are first carried to the liver by the portal veins, which may explain why the liver was the most condemned organ in this study.

In this study, the high rate of liver condemnation (54.32%) was primarily due to abscesses and extension of peritonitis to the liver. This rate was higher, but comparable to a condemnation rate of 51.5% reported by a similar study in the Zambezi Region (3). This finding is rather surprising considering that study cattle originated from semi-arid to arid regions, while the Zambezi Region is the wettest part of the country, where internal parasite burden on the liver is expected to contribute to a higher condemnation rate. A number of studies have identified parasites, particularly *Fasciola* (18,35-37) and hydatid cysts (10,16,40) as the main causes of liver condemnation. It is not surprising that *Fasciola* spp. was not identified in the current study because ideal environmental conditions (swamps) for the survival, multiplication and transmission of the parasite are absent in the majority of the areas supplying slaughter cattle to the abattoir. Moreover, the mostly commercial farmers south of the VCF, follow strict internal parasite drenching protocols. Liver condemnation figures from literature vary from 0.09% (27) in arid Botswana to as high as 84% (34) in tropical Uganda. One would have expected similar condemnation figures between the current study and reports from Botswana (27) with notably similar climatic conditions to those in Namibia. Reports with figures closest to those from the current study were from Western Zambia (around the Zambezi river basin) where the parasite burden is high (38).

Abscessation was the major cause of liver condemnation, leading to significant economic losses.

It has been suggested that there is a strong link between rumen acidosis and liver abscessation (62,63). According to some studies, liver abscesses develop when *Fusobacterium necrophorum* bacteria in rumen wall lesions secondary to rumen acidosis, associated with grain overload or concentrate feeding, are carried to the liver by the blood circulatory system (62-65). Abscessation is a primary lesion of the livers of feedlot cattle (66,67). The parent company that owns the study abattoir operates a feedlot from which it draws most of its cattle for slaughter including cattle from communal areas, which may explain the high number of livers and lungs condemned due to abscesses. However, the possibility that farmers fed their cattle high grain rations to hasten weight gain before sending them for direct slaughter cannot be ruled out. Prophylactic treatment of cattle on high energy diets with Tylosin and vaccination to prevent abscessation has proved futile (67). Perhaps farmer education may be the most viable solution to reduce occurrence of liver abscesses in feedlot cattle.

It is similarly, not surprising that lungs were the second most condemned organ. The lungs receive all the blood for oxygenation and are at the internal organ/air interface and are thus exposed to most airborne environmental pollutants and pathogens from the air as well as from blood (58,68-70). In fact, a number of studies have cited the lung as the most condemned organ (11,16,17,20). The current lung condemnation rate of 29.88% is much higher than the 10% reported in a number of sub Saharan studies (8,19,25,31,33,41,51). However, the rate is less than the 48.8% reported in the Zambezi Region of Namibia (3). Our findings are comparable to a condemnation rate of 33.9% (17), but lower than the rate of 45.66% (11) and 96.6% (47) reported by previous studies. In this study, the major causes of lung condemnations were hydatidosis, emphysema, contamination and abscesses in descending order. It is recommended that public awareness of the hydatidosis as a potential zoonosis be created through education campaigns and that farmers periodically deworm farm dogs, but the involvement of wild carnivores as definitive or intermediate hosts may complicate control (71). The emphysema and contamination observed in the lungs is most likely a product of slaughter techniques and poor hygiene practices respectively, which require the attention of the abattoir operator.

The lower rate of condemnation in 2018 (23.22%), when compared to 2016 and 2017 (38.7 and 38% respectively)

may be attributable to the higher precipitation received in 2016 and 2017. According to an official Namibian weather site, the years 2016 and 2017 each received an average of 313 mm of rain, while 2018 received 295 mm (<http://weather.namsearch.com/wdhrainsummary.php>). It has been confirmed that meat condemnation may increase under wet conditions when the hide is heavily contaminated with mud and dung (72). Furthermore, increased organ condemnations in the wetter 2016 and 2017 may have been a result of accelerated parasite life cycle under the hot moist conditions (17,26).

The spike in the proportion of condemnations in the month of June (13.34%) is particularly noteworthy. In Namibia, June and July are the coldest months of the year, in which respiratory conditions such as pneumonia predominate when animals huddle together in order to conserve heat (73,74). Furthermore, the month of June is associated with peak slaughter numbers at the study abattoir. According to veterinary officials, the number of cattle slaughtered in June often lead to piling of offal, delayed cleaning, packaging or freezing, which results in condemnation.

The results of the current study show more than expected lung condemnations in summer, and more than expected condemnations of heads and kidneys in winter. The high number of condemnations of lungs were due to higher rates of hydatidosis. The high prevalence of hydatidosis in winter is in agreement with those reported in other studies (75,76). According to these studies the survival and longevity of *Echinococcus* protoscolices is higher in the cold season (thereby increasing their chances of being consumed alive by dogs) than in summer.

In summer, wet conditions contribute to higher hide contamination with dung and mud (72). However, it is not clear why inflammatory conditions would increase in winter nor is there any satisfactory explanation as to why miscellaneous conditions would be higher in 2017 than 2018 and why inflammatory and infectious conditions would show the opposite trend.

From the foregoing argument, condemnation of red offal is costing beef farmers, abattoirs and the Namibian fiscus necessitating the implementation of measures to arrest the avoidable loss of income. The following measures are recommended to reduce the rate of condemnations at abattoirs: farmer education on the major causes of condemnations and mitigation measures thereof at farm level; improved

communication between abattoirs or official veterinarians and farmers, especially with respect to condemnation data and ways of reducing future condemnations; and abattoir operators should ensure that all procedures and activities carried out on their premises do not promote meat condemnations.

5. Conclusion

We determined a substantial loss of revenue to the abattoir and country due to cattle organ condemnations. Livers and lungs were found to be the organs most condemned at the abattoir, mostly due to miscellaneous conditions such as abscesses, hematomas, melanosis and emphysema. The high condemnation rates for red offal have the potential to impact the food security situation in the country. Meat inspection served to prevent the transmission of hydatidosis to humans. Red offal condemnations varied with season and year.

Conflict of interest

The authors have no conflict of interest.

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