Article

A Quantitative Assessment of Causes of Bovine Liver Condemnation and Its Implication for Food Security in the Eastern Cape Province South Africa

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Abstract: Food production needs to double, with minimum waste, if hunger and poverty is to be alleviated in South Africa. The condemnation of liver during meat inspection represents a huge waste of a protein food resource. This paper measures the quantity of liver condemned in three abattoirs in the Eastern Cape Province of South Africa and assesses the causes and the monetary loss associated with these condemnations. A retrospective study (RS) (n = 51 302) involving the use of abattoir slaughter records from 2010–2012 and a post-mortem meat inspection (PMMI) (n = 1374) was conducted from July to December 2013. The RS revealed the leading cause of liver wastage as fasciolosis (5.95%, 4.48%, and 2.7%), fibrosis (2.74%, 2.37%, and 1.0%), and abscessation (1.11%, 2.78%, and 1.5%) for the 2010, 2011, and 2012 respectively. During the PMMI, the same factors caused liver condemnation in addition to calcification (8.3%, 6.8%, and 3.2%), Cysticercosis bovis (1.7%, 2.4%, and 1.3%) and improper evisceration (4.8%, 12.4%, and 27.1%) for the abattoirs X, Y, and Z respectively. A total of R 343, 330 (USD 45,271.07) was lost due to the condemnation of liver between 2010 and 2012. The further loss of 3290.4 kg of liver was calculated for the six month in 2013, and its financial value was R 59, 227.2 (USD 5889.82). The result of this study provide baseline information on major causes of liver wastage in cattle slaughtered in South Africa as well as the direct financial losses and demonstrate the huge waste of ideal protein food source.

Keywords: food waste; liver condemnation; abattoir; meat; Eastern Cape; fasciolosis

1. Introduction

The world population is currently estimated to be seven billion but is expected to rise to eight billion by 2030 and over nine billion by 2050 [1]. Africa's population is also estimated to double from one billion to two billion people by 2050. The production of sufficient amounts of high quality, affordable, and safe food requires the sustainable use of scarce agricultural resources with less waste. Notably, several biological and non-biological factors affect livestock production negatively, leading to post-slaughter losses. The impact of biological factors such as animal diseases far outweighs other factors because it increases livestock mortality as well as reducing the safety and quality of food supplies.

Meat provides a rich source of animal protein and is an important staple food that is highly demanded in many parts of the world. Consumption of meat in South Africa is said to be 41 kg per capita per year and is second only to Ghana in Africa [2]. Meat plays a crucial role in human nutrition in South Africa. Many studies have alluded to the decline in food production even as population increases [3–5]. Alongside the decline in agricultural output is the issue of food wastages at abattoirs. The liver is basically condemned due to preventable lesions/diseases detected during routine post-mortem meat inspection. Other reasons for condemnation may be for the aesthetics value of the liver and faulty slaughter techniques [6–10]. For livestock productivity to be doubled and to help mitigate food insecurity, the reduction in food wastage, especially along the production line, is crucial.

Many studies [9,11–15] in different African countries have looked at liver condemnation and shown a high prevalence of preventable parasitic and bacterial zoonosis, demonstrating the lack of a proper herd health programme necessary for the promotion of animal health in the various farms where these animals are bred. Meat safety should begin when the animal is conceived and continue to the point of delivery to the slaughterhouse. Furthermore, strategic hygiene assessment and monitoring system through the entire processing and value chain will ensure the safety of meat for consumers [16–18].

Animal products, and meat in particular, can be a source of infection or food poisoning. Two main factors responsible for food poisoning by meat are (i) the presence of animal diseases transmissible to humans by meat consumption and (ii) the contamination of the carcass or meat with external agents such as physical, chemical, or biological agents [16,19–22]. Public health concerns regarding the safety of meat necessitate both antemortem (AMMI) and post-mortem meat inspection (PMMI) at abattoirs using the guidelines by the South Africa Meat Safety Act of 2000 [23,24]. The PMMI of the slaughtered carcass is designed to identify and take away from the food chain all carcasses/offal that present grossly identifiable abnormalities that might affect safety or wholesomeness of the meat product [5,25].

The monitoring and surveillance of emerging infectious and zoonotic diseases in food animals should be an integral component of every food safety system. Although PMMI has been criticized for its limitations, there is evidence that substantiates the sensitivity of meat inspection for identifying specific diseases of humans and animal importance [5,26,27]. Meat inspection is a veritable tool in data gathering on notifiable diseases, zoonoses, and endemic production diseases. Furthermore, it can be used to monitor disease that may lead to monetary losses associated with meat condemnation and syndromic surveillance system for improved detection of disease outbreaks [5,28–31]. Identifying and quantifying the causes of liver condemnation is the first step in diseases surveillance aimed at preventing further liver losses at the abattoir. Condemnation of the liver represents a reduction in available food resources. Research and discussion on food security and safety are very timely. Hence, the aim of this study was to evaluate causes of liver condemnation and the financial loss of condemnation.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Eastern Cape (EC) Province located in the southeast of South Africa. It is bordered on the north by the Free State and Lesotho, KwaZulu-Natal to the north-east, the Indian Ocean to its south and south-eastern borders, and Western and Northern Cape to the west [32]. EC is the second largest province in the country, stretching approximately 169,580 km^2, i.e., 13.9% of the total land area of South Africa. It has a high population density estimated at 41 persons per square km. About 63% of the province's population lives in rural areas [33]. It has the highest unemployment rate in the country, with the poverty index showing approximately 47% of households living well below the poverty line [32]. In 2006, the greater part of the populace in seven out of the nine provinces of South Africa was living below the upper-bound poverty line. The province with the highest poverty levels was Limpopo, where three-quarters (74.4%) of its inhabitants were poor, followed closely by Eastern

Cape (69.5%) and KwaZulu-Natal (69.1%). The poor were only in the minority in the two provinces of Western Cape (36.9%) and Gauteng (32.4%) [34]. The study was conducted at three abattoirs (X, Y, and Z) located in the Amathole District, Chris Hani District, and in the Buffalo City Metropolitan Municipality of the EC Province, respectively. Abattoir X was included in the study because of its proximity and ease of access by communal farmers, while Y and Z was included in the study due to the high number of animal slaughter per year for local and export markets. The place receives approximately 480 mm of rainfall per year, mostly in the summer months and is averagely-situated 586–2371 meters above sea level, high enough to be occasionally covered in snow. The temperatures in the Eastern Cape during the period of study ranged from 18 °C to 39 °C with mean temperatures of 20.5 °C. The 14 million cattle in South Africa are found in communal areas. Of this number, over 3.2 million resides in the EC Province [35]. The 2011 agricultural census show that 86% of the populace keep an average 1–10 cattle [36], hence the choice of the EC Province is ideal for this research.

2.2. Research Animals

Male and female animals of different ages were included in the retrospective study (RS), antemortem meat inspection (AMMI), and post-mortem meat inspection (PMMI) study. Where retrospective implies the study of abattoir record from 2010 to 2012, antemortem (AMMI) refers to the survey of cattle for signs of diseases prior to slaughter, and the PMMI means post-mortem meat inspection of slaughtered cattle. Young animals' use as veal was not included in the study as these were not expected to harbor diseases that could lead to meat condemnation at the abattoir. These animals were brought from the different locations in the Eastern Cape.

2.3. Sample Size Determination and Sampling

The sample size was calculated based on the formula given by [37] with 95% confidence interval, 50% expected prevalence, and 5% desired absolute precision. The sample size was determined to be 382 for the high throughput abattoirs (Y and Z) and 176 for low throughput abattoir (X). The sizes were adjusted to 1146 and 229, respectively. This adjustment became necessary to increase statistical accuracy beyond the 5% desired absolute precision and to account for the large number of animals slaughtered at the abattoir during the years from which the secondary data was obtained. The number of cattle slaughtered in the three abattoirs varied, and the sample size was maximized proportionally to X (229), Y (458), and Z (687).

Abattoir X is classified as low throughput and statutorily can only slaughter between 2 and 20 cattle per day. A typical case sampling technique of purposeful sampling was used for sample collection at abattoir X during the PMMI. This sampling method allowed the researchers to sample all cases of condemned liver at this abattoir [38]. This sampling method was used because of the small number of animal slaughtered in the low throughput abattoir, whereas a systematic random sampling was the best fit for Y and Z due to the high slaughter output per day [37]. Sampling units for X involved the selection of rejected meat/offal and recording case as per unit, while sampling units for Y and Z were selected at equal intervals with the first animal being selected randomly. The total number of animals slaughtered during the preceding year (2012) was obtained from the abattoir records as 26,401 cattle corresponding to 520, 4078, and 21,803 for X, Y, and Z, respectively. The AMMI and PMMI were carried out for six months in 2013, and during this time the number of slaughtered animal was calculated to be 20,791 cattle, corresponding to 322, 3788, and 16,681 representing X, Y, and Z, respectively. Sampling interval was thus computed as the total number of animals slaughtered during the study period divided by the required sample size [13]. Therefore, the sampling intervals for the Y was 8 (3788/458) and for Z was 24 (16,681/687). The first cattle were chosen randomly from the first eight and 24 animals, respectively. Subsequently, every eight and 24 cattle were included in the sample during the slaughter operation.

2.4. Study Types

A cross-sectional type of study was employed that involved the use of abattoir records (RS) from 2010 to 2012 and an AMMI/PMMI that was conducted from July to December 2013. Slaughter information of 51,302 cattle was obtained from this record. The AMMI and PMMI were done in conjunction with authorized meat inspectors at the various abattoirs to document the causes of meat/offal condemnation. The direct financial loss was estimated using the average liver weight of five different breeds and multiplying the average weight with the market price of liver in 2010 to 2013.

The AMMI and PMMI were done following the procedure specified by the South African Meat Safety Act of 2000 [23]. Briefly, the animals were inspected for the presence of diseases at the lairage and data regarded animal age, sex, breed, body condition score, and distance travelled from farm to abattoir were recorded to assess the possible risk factors. Cattle ageing was done according to the method described by the US Department of Agriculture, Food Safety Inspection Service [39,40], and body condition score (BCS) was carried out using the method described the by the University of Georgia, Cooperative Extension services [41]. The BCS was classified into four categories including thin (1–3), borderline (4), optimum (5–7), and fat (8–9) on a 1–9 scale. For ease of data analysis, these categories were merged into three groups namely, poor (1–4), moderate (5–7), and good (8–9). Cattle breeds were identified using phenotypic appearance, and further information regarding the breed was obtained from the abattoir. Cattle included in the AMMI inspection were thoroughly screened for disease lesions, sick and anorexic animals were detained for further investigation, and healthy animals were passed for slaughter. During the PMMI, organs showing gross abnormality were separated, classified, and recorded in line with the guidelines for meat inspection in developing countries and the South African Meat Safety Act of 2000 [23,42].

The PMMI was performed after the slaughter of the cattle using liver palpation and visual examination. The meat inspectors systematically cut at various suspicious and disease focal point to ascertain the health and aesthetic of the liver. Organs/offal with diseases and lesions were grossly detected based on pathological changes, i.e., size, colour, the presence of lesions or parasites, morphology, and consistency. Bovine livers suspected of *Cysticercosis* were detained for further confirmation by the veterinary personnel in charge of the abattoir. Other condemned organs upon slaughter were passed through a condemn chamber to the condemnation room where they were treated and disposed of. Livers classified as totally condemned were rejected and destroyed to avoid human consumption. In cases of partial condemnation, the liver was trimmed and the weight of the trimmed part taken. The comdemned liver was collected into a measuring drum and weighed using an Ansutek M1/M2 Portable Crane Scale (Ansutek Commercial Ltd., Manukau, New Zealand). The weight of the condemnation drum subtracted to get the accurate kilogram weight of condemned organ. The record of partial condemnation was taken on the days the abattoirs were visited during the six months of the research, and the monetary loss was calculated based on current market price per kilogram of the liver in 2013.

2.5. Direct Financial Loss

The average weight of liver was taken and the measurement recorded as 5.8 ± 2.39 Standard deviation (kg ± SD), while the price for liver was obtained from the three abattoirs, and the calculated average was R 65 for whole liver and R 18 for 1 kg liver respectively. Monetary losses were calculated based on the average market price of the whole liver (in kg) at the time of the study, while the prices for trimmed liver was estimated based on the price per kilogram of liver using the South African Rand (R). The average annual exchange rate of 1 South African Rand to 7.3, 7.21, and 8.17 United State Dollar (USD) for 2010, 2011, and 2012, respectively, was used for estimating the financial loss associated with liver condemnation. The average exchange rate for the three years was 7.56 USD. Financial losses associated with meat condemnation were in the form of losses due to whole or partial liver condemnation.

2.6. Data Analysis

Data extracted from RS, AMMI, and PMMI were entered into a Microsoft Excel® (MS Excel 2007) spreadsheet. Liver condemnation rates were determined using simple descriptive statistics. The condemnation rate for RS was defined as the proportion of liver condemned to the total number of the carcass slaughtered in a year. The rate of condemnation for PMMI was calculated as the proportion of liver condemned to the total number of liver examined during the six-month PMMI study [13,43]. Monetary loss was calculated using average abattoir market price of the liver at the time of the study.

3. Results

Reasons for Liver Condemnation and Associated Economic Loss

The Retrospective Study (RS) revealed the leading cause of liver condemnation of the total number of animals slaughtered as fasciolosis (5.95%), fibrosis (2.74%), and hepatitis (1.44%) in 2010. In 2011, fasciolosis (4.48%), abscess (2.78%), and fibrosis (2.37%) were the main reasons for liver rejection at the abattoir. In 2012, livers were condemned mostly due to fasciolosis (2.7%), abscess (1.5%), and hepatitis (1.2%). Melanosis, telangiectasis, and cysts were other causes of liver rejection in the three abattoirs studied (Table 1). The nature and type of cysts were not disclosed nor properly documented by the abattoir, hence it was not possible to ascribe the specific etiology of the cysts. Of the total inspected animals during the post-mortem meat inspection (PMMI), fasciolosis (13.1%, 14.2%, and 8.9%), improper evisceration (4.8%, 12.4%, and 27.1%), fibrosis (1.7%, 10.5%, and 9.2%) and abscess (8.7%, 3.7%, and 4.8%) were the leading causes of liver condemnation in the three abattoirs X, Y, and Z, respectively (Table 2). Others causes of condemnation of public health importance were calcification (8.3%, 6.8%, and 3.2%) and *Cysticercosis bovis* (1.7%, 2.4%, and 1.3%) at abattoir X, Y, and Z, respectively. The percentage loss for abattoir X was 19.7%, 11.3%, and 13.5% in the respective retrospective years, while abattoir Y during the same period recorded percentage loss of 25.2%, 10.8%, and 12.8%. Abattoir Z recorded a decrease in percentage condemnation from 17.7% to 7.6% and 7.7% for the year 2010, 2011, and 2012, respectively (Table 1). A summarized monetary loss associated with liver condemnation for 2010 was R 89,245/USD 12,225.34, R 119,405/USD 16,561.03 in 2011, and R 134,680/USD 16,484.70 in 2012. The losses in RS were calculated for whole liver condemnation, whereas during the PMMI both whole liver and partial liver condemnations were recorded, necessitating the use of kg weight in the estimation of financial losses. The result from our estimation revealed a loss of R 59,227.2 (USD 5889.82) during the period in which the PMMI was conducted.

Table 1. Causes of liver condemnation in cattle slaughtered from 2010 to 2012.

Organ Affected	Causes of Condemnation	Number (%) of Condemned Organs during the Three Years (n = 51302)												
		2010 (*n* = 10276)				2011 (*n* = 14625)				2012 (*n* = 26,401)				
		(*n* = 502) (*n* = 2127) (*n* = 7647)				(*n* = 437) (*n* = 4414) (*n* = 9774)				(*n* = 520) (*n* = 4078) (*n* = 21,803)				
		X	Y	Z	Total (%)	X	Y	Z	Total (%)	X	Y	Z	Total (%)	Sum Total
Liver	Abscess	19	39	56	114 (1.11)	10	42	355	407 (2.78)	13	51	342	406 (1.5)	393
	Fasciolosis	44	90	477	611 (5.95)	63	281	311	655 (4.48)	36	187	484	707 (2.7)	671
	Fibrosis	8	41	232	281 (2.74)	13	45	288	346 (2.37)	9	32	225	266 (1.0)	257
	Hepatitis	11	32	105	148 (1.44)	12	41	130	183 (1.25)	20	19	266	305 (1.2)	285
	Cyst	4	9	38	51 (0.5)	5	11	48	64 (0.44)	0	11	22	33 (0.12)	33
	Melanosis	5	15	71	91 (0.89)	7	32	77	116 (0.79)	5	0	149	154 (0.6)	149
	Telangiectasis	8	15	54	77 (0.75)	0	25	41	66 (0.45)	9	10	182	201 (0.8)	192
Total		99	241	1033	1373 (13)	110	477	1250	1837 (13)	92	310	1670	2072 (8)	1980
Loss in *R*		6435	15,665	67,145	89,245	7150	31,005	81,250	119,405	5980	20,150	108,550	134,680	343,330
Loss in USD		881.51	2145.89	9197.95	12,225.34	991.68	4300.28	11,269.07	16,561.03	731.95	2466.34	13,286.41	16,484.70	45,414.02
% loss in condemnation		19.7	11.3	13.5	13.4	25.2	10.8	12.8	12.6	17.7	7.6	7.7	9.5	10.2

N/B: *R* means South African Rand, X means low through-put abattoir, Y and Z means high through-put abattoir.

Table 2. Conditions that led to the condemnation of liver (X = 229, Y = 458, and Z = 687) and associated monetary loss (R) during the post-mortem meat inspection (July to December 2013).

Causes of Condemnation	Number Affected (Loss in %)			Loss in Kg			Monetary Loss (*R*)					
	X	Y	Z	X	Y	Z	X	Y	Z	Total (kg)	Total (R)	Total (USD)
Abscess	20 (8.7)	17 (3.7)	33 (4.8)	63	78.6	171.4	1134	1414.8	3085.2	313	5634	560.27
Calcification	19 (8.3)	31 (6.8)	22 (3.2)	72.2	119.8	97.6	1299.6	2156.4	1756.8	289.6	5212.8	518.38
Fasciolosis	30 (13.1)	65 (14.2)	61 (8.9)	114	217	253.8	2052	3906	4568.4	584.8	10526.4	1046.79
Fibrosis	4 (1.7)	48 (10.5)	63 (9.2)	12.2	208.4	215.4	219.6	3751.2	3877.2	436	7848	780.44
Hepatitis	19 (8.3)	23 (5)	35 (5.1)	58.2	73.4	113	1047.6	1321.2	2034	244.6	4402.8	437.83
C. bovis	4 (1.7)	11 (2.4)	9 (1.3)	23.2	60.8	42.2	417.6	1094.4	759.6	126.2	2271.6	225.90
Melanosis	6 (2.6)	14 (3.1)	34 (4.9)	18.8	71.2	157.2	338.4	1281.6	2829.6	247.2	4449.6	442.49
Imp. Env.	11 (4.8)	57 (12.4)	186 (27.1)	33.8	130.6	778.5	608.4	2350.8	14013	942.9	16972.2	1687.79
Telangiectasis	7 (3.1)	11 (2.4)	13 (1.9)	20.6	43.9	41.6	370.8	790.2	748.8	106.1	1909.8	189.92
Total	120 (52.4)	277 (60.5)	456 (66.4)	416	1003.7	1870.7	7488	18066.6	33672.6	3290.4	59227.2	5889.82

Imp. Env means improper evisceration, *C. bovis* means *Cysticercus bovis.* R means South African Rand, X means low through-put abattoir, Y and Z means high through-put abattoir.

4. Discussions

Abattoir meat inspection and slaughter records contribute to disease surveillance and control [44]. Meat inspection assists in monitoring diseases in the national herd and flock by providing database information to the veterinary department to control or eradicate diseases, produce wholesome products, and protect the public from zoonotic hazards [13,25,45]. Information obtained from such inspection can reveal causes of meat condemnation even in apparently healthy animals, and as such can be communicated back to the farmer to improve farm management and husbandry.

4.1. Factor Responsible for Bovine Liver Condemnations

Despite it small size, the highest relative losses (19.7%, 25.2%, and 17.7%) of liver from 2010 to 2012 was at the low throughput abattoir (X) contrary to the 11.3%, 10.8, and 7.6% and 13.5, 12.8%, and 7.7% losses recorded at the high throughput abattoirs (Y and Z) (Table 1). The proximity of abattoir X to rural/smallholder farmers encourages patronage by them. Therefore, it was presumed that the high level of condemnation was a direct result of poor animal management. Farming in rural communities is characterized by low input and poor animal husbandry. Many farmers in these communities lack access to veterinary inputs necessary for the enhancement of livestock productivity [46].

The leading cause of liver rejection at the abattoirs was fasciolosis, and a significant proportion of the liver was condemned either due to the presence of a cyst, *Cysticercosis bovis*, or calcification (Tables 1 and 2). A number of factors could be responsible for the level of condemnation recorded in this study including, the presence of parasite (*F. hepatica*, *F. gigantica*, *C. bovis*, and *T. saginata*), changes in seasonal rainfall pattern, or animal ingesting metacercaria through ingestion of raw contaminated aquatic plants or drinking contaminated stagnant water or effluent from sewage treatment plant [47–51]. The presence of various *Fasciola* spp. in the EC Province has been previously reported, and the lack of adequate rainfall further encourages stagnant streams and rivers that harbour these parasites. The unsupervised irrigation fields often flooded with water promotes the proliferation of the infectious larval stages of the parasite. There are several studies [11,30,52] that support the findings of this study, others [9,53,54] reported a higher rate of condemnation due to fasciolosis.

The prevalence of cysticercosis reported in this study may be low, but the consequence of its zoonotic potential should not be ignored. The use of guard dogs for control and regulation of livestock movement in the rural communities may play a role in the observe prevalence. Dogs are the definitive host for *Echinococcus granulosus* and can disseminate and contaminate the environment with the parasite, leading to disease transmission to ruminants and humans [15,55]. Furthermore, the high rate of cysticercosis in developing countries is often associated with poor sanitary infrastructure, lack of public knowledge of the condition, and indiscriminate disposal of sewage [56].

Fasciolosis and cysticercosis are important parasitic zoonosis of both veterinary and public health concerns. Even though humans are the accidental host, 2.4 million people in 61 countries are infected annually with *Fasciola* spp., and about 180 million are at risk of infection. A significant percentage of human fasciolosis occur in Africa, while production losses due to the livestock industry are estimated over USD 2 billion [20,57,58]. Furthermore, infection with *Fasciola* is associated with decrease milk, meat, and wool yield, and with financial loss associated with the cost of veterinary medication [59]. Severe damage to the bile duct and gall bladder of animals may lead death [60].

Human cases of cysticercosis appear to be most prevalent in the Eastern Cape Province of South Africa, particularly in the poor rural areas of Ciskei and Transkei, where pigs are allowed to move freely and sanitation facilities are scarce or nonexistent. In West Africa, studies have shown epilepsy to be associated with neurocysticercosis in human and further suggest that it is prevalent in low or middle-income endemic countries in which approximately 30% of epilepsy may be attributable to neurocysticercosis [49,61,62]. In animals, cysticercosis is associated with economic loss mainly due to condemnation, refrigeration, and downgrading of infected carcasses [63–66]. The high rate of condemnation of the liver points to the failure of proper animal health management techniques at the farm level.

Liver abscessation, hepatitis, and fibrosis were responsible for a significant food waste during the RS and PMMI at the X, Y, and Z abattoirs for 2010, 2011, 2012, and 2013, respectively. An abscess is a localized collection of pus (dead neutrophils) separated from the surrounding tissue by a fibrous capsule formed following an infection. Grossly, it is an enlarged palpable lesion with fluctuating fluid. The most common pyogenic bacteria that causes abscesses in animals include *Arcanobacterium* (*Actinomyces*) *pyogenes*, *Streptococcus* spp., *Staphylococcus* spp., and *Fusobacterium* (*Sphaerophorus*) *necrophorum* [11]. Both liver abscesses and fibrosis are common complications of migratory actions of parasite larvae, which elicit inflammatory responses, progressing to a fibrotic or granulomatous formation of tissues along the biliary tract. Ultimately, the tissue reaction pre-optimizes the conditions necessary for secondary bacteria to flourish [26,67].

The common causes of hepatitis in animals include but are not limited to parasites such as *Fasciola* spp., *Dicrocoelium dendriticum* invasion and tunneling of the bile duct, and viruses and bacteria such as Hepatitis E virus, and *Streptococcus* spp. (*S. agalactiae/dysgalactiae/pyogenes/zooepidemicus*) [28]. The rate of condemnation due to hepatitis reported in this study may be related to the animal origin, as cattle from *Fasciola* infested areas are likely to increase the number of livers condemned for hepatitis. More so, animals from poorly resourced farmers lack adequate veterinary care and good husbandry [44,46].

Several non-disease conditions such as melanosis, telangiectasis, and improper evisceration contributed considerably to liver rejection in this study. Although melanin is a natural pigment that occurs in the skin, hair nails and membranes, its abnormal accumulation in the liver causes dark pigmentation of the tissues leading to its condemnation. A report by Alton et al. [68] concurs with the 2.6–4.9% condemnation rate of the liver due to pigmentation obtained in this study.

Telangiectasis is a visible dark purple, red sunken area of the liver that may be caused by focal necrotizing hepatitis, fibrosis, metabolic disturbance, and hepatic abscesses [69,70]. In this study, the rejection of 3.1%, 2.4%, and 1.9% liver at abattoirs X, Y, and Z, respectively, due to telangiectasis was mainly because of the poor quality of its aesthetic value. Currently, abattoirs Y and Z export red meat to Europe, America, and Asia. There is a high demand for live animals as well as meat by consumers in these continents. For example, the value of red meat exports from South Africa has increased from R 791 million in 2013 to R 2.14 billion in 2016 [71]. Such export market may be influenced by the quality of meat produced especially from diseases. Disease and pathologic conditions affecting the aesthetic of organs designated for the export market either directly or indirectly cause the rejection of such organs by the importer countries due to zoonoses threat and aesthetic reasons. Import restriction could adversely affect South Africa's gross domestic product, the sustainable production of livestock, and farmers' livelihoods.

Improper eviscerations led to a high number of liver wastage (4.8%, 12.4%, and 27.1%) during the PMMI (Table 2). A study by Regassa et al. [13] revealed similar finding to what was obtained in the present study. Evisceration problems are commonly associated with poor slaughter process [70] and may lead to faecal contamination of organs with potentially infectious gut pathogens such as *Salmonella* and Shiga toxin–producing *Escherichia coli* [72]. In this study, evisceration problems were possibly due to untrained, inadequate and overburdened workers who usually rush to meet daily slaughter limits, hence the reduction in precision.

The EC Province is popular for livestock production, yet it is among the poorest in the country [34]. Disease and non-disease factors described in this study impact negatively on food security, taking into account the high rate of fasciolosis and other conditions reported in this study, we assume that many preventable disease agents hamper livestock productivity. Disease, especially infectious disease, "is a main constraint of biologically efficient livestock production and both endemic and exotic disease results in mortality and morbidity and hence less food than should ideally be available in current farming systems" [19]. The critical role of primary animal health in the production of healthy meat capable of supplying the protein needs of the populace and sustaining human health cannot be overstated. Food security programmes aimed at the sustainable production of sufficient amounts of

affordable, high quality, safe food required to support the health and wellbeing of human populations is attainable if farms and production units adhere rigorously to strict and appropriate herd health plan.

4.2. Financial Loss Associated with Liver Condemnation

Food waste in the form of condemnation of the liver impacts negatively on food security, economy, export and domestic market. A total of R 343,330 (USD 45271.07) was lost due to the condemnation of liver in 2010, 2011, and 2012. Further loss calculated from the PMMI was R 59,227.2 (USD 5889.82). These findings are consistent with those of Tembo et al. [73] in Dodoma, Tanzania, where USD 32,465.50 annual loss due to the condemnation of liver was reported. Furthermore, a high loss of USD 230,088 was reported by Yibar et al. [74] in Bursa Province, Turkey. Apart from the monetary loss reported in this study, the amount of liver thrown away could substantially resolve hunger and food insecurity in an impoverished province such as the Eastern Cape where these condemnations are taking place. Beef liver has a protein content of 26%, and the average human protein requirement is 56 g per day [75]. The condemned liver of only three months would be enough to feed 45 adults humans for a year. These condemnation rates may be grossly underestimated due to differences in the skills and experience of meat inspectors, the speed of the slaughtering activity, the meat inspection facilities, and sampling technique. Furthermore, considering the limitations of the traditional visual appraisal method of meat inspection, cysticerci could easily be missed as most cases of cysticercosis are light infections [12,15].

Generally, some of the limitations encountered in this study included the use of only visual inspection for the detection of pathologic conditions; thus, only those liver with gross lesions were likely to be diagnosed. The abattoir records may also have been underestimated because of poor meat inspection and generally poor record keeping. Furthermore, the sampling technique used in abattoirs Y and Z may have excluded some animals with the pathologic liver. In spite of the limitations mentioned, the impact of this food waste on food security cannot be overemphasized. This study also shows the relevance of meat inspection and abattoir records in safeguarding public and animal health through preventive medicine and syndromic surveillance.

5. Conclusions

This study highlighted the causes of liver condemnation and monetary loss associated with it. Food wastages at any point in the production chain affect farmer income, the sustainability of agricultural enterprise, and the domestic and export markets with severe consequences for food security. The leading cause of liver condemnation was fasciolosis, abscessation, and hepatitis. Other conditions were the cysts, calcification, cysticercosis, melanosis, fibrosis, and improper evisceration. Despite the limitations of this study, when huge financial losses are taken into account, there is clear evidence of the failure of disease prevention strategies at the farm level. Adopting a sound herd health programme and disease preventative measures will mitigate the losses observed in the study. Continuous farmer education through adequate veterinary service is vital to understanding the risk factors of disease, and effective treatment regimens are needed for disease prevention and control. Good slaughtering practices need to be implemented at abattoirs to reduce liver wastage due to improper evisceration. The use of modern diagnostic tests such as histopathology, immunohistochemistry, parasite identification, bacterial culture, antimicrobial susceptibility testing, surveillance of anthelmintic resistance, and molecular techniques for parasites, viruses, bacteria, and fungi detection could significantly improve meat inspection and disease detection in an abattoir. Considering the high prevalence of fasciolosis lesions at the abattoirs and the high rate of liver wastage due to improper eviscerations, this study recommends further study into possible anthelminthic resistance and capacity building and work related fatigue among slaughterhouse employees.

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