Research Article

Clinical and Histopathological Findings of Brucellosis In Dromedary Camels (*Camelus dromedarius*) from Selected Slaughterhouse for Postmortem Examinations

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Abstract | Camel brucellosis is a chronic infectious disease affecting both animals and humans.Both clinical and histopathological aspects of this disease in camels remain poorly understood. This study aimed to determine the presence of brucellosis in slaughtered camels from northeast Kenya. The main clinical indicators of brucellosis include lameness, swollen lymph nodes, and a history of abortion. Out of 490 samples, 160 camels were selected for testing and were tracked to the slaughterhouse, where their organs were examined both grossly and microscopically for pathological changes. Of the 160 camels tested, 14 (9.37%) were found to have Brucella antibodies. The positive cases included 4 out of 50 camels (8%) from Garissa, 5 out of 50 (10%) from Dadaab, and 6 out of 60 (10%) from Calamvale. Using chi-square statistics, the sensitivity of the serological tests did not differ significantly (p=0.999). During meat inspection, seventy-eight camels (50.7%) were found to have one or more organs that had to be condemned. The most common gross lesions observed included fibrin deposits (1.8%), enlarged lungs (1.2%), pericardial effusions (20.7%), and hepatomegaly with nodular liver lesions (49.3%). Other findings were enteritis (3.1%), as well as hemorrhages and congestion in visceral organs such as the lungs and kidneys (3.7%). Microscopic examination revealed several histopathological changes: cellular infiltration in the lymph nodes (5.6%), reduced numbers of lymphocytes (2.7%), collapsed alveoli (6.1%), edema (1.5%), fatty degeneration in the liver (1.2%), and hemorrhages in the kidneys (0.6%). In conclusion, this study provides definitive evidence of the widespread presence of brucellosis among camels in Kenya. Given the comparable efficacy of serological tests and the practical advantages of the ELISA method affordability, speed, and ease of use its adoption as a primary screening tool is strongly recommended. This proactive measure is vital for effective disease control and the protection of both animal and public health.

Keywords | Clinical, Histopathology, Slaughterhouses, Camel, Brucellosis

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INTRODUCTION

Camels are vital livestock in many arid and semi-arid regions, providing communities with essential resources, including meat, milk, and transportation (Abo-Elnaga and Osman, 2012). Their remarkable ability to thrive in harsh environments makes them indispensable for the livelihoods of pastoralists (Agab, 2006; Ahmad and Nemat, 2007; Abebe *et al*, 2017). particularly in countries like Kenya, where the camel population is significant and growing (Bankole *et al*., 2011). However, camels are susceptible to a range of infectious diseases that can impact both animal health and public safety (Barre, 2023). Among these, brucellosis stands out as a major zoonotic disease with serious economic and health implications. In dry and semi-dry regions (Assenga *et al*., 2015), camels play a crucial role in socio-economic development and agricultural activities (Babeker *et al*., 2013). Their exceptional adaptations make them uniquely suited for hot, arid desert ecosystems, where they actively contribute to combating desertification and ensuring food security (Schwartz and Dioli, 1992). Beyond their resilience, camels serve as an economical power source for various tasks, including drawing water from wells, plowing and leveling land, operating mini-mills for oil extraction, grinding grains, crushing sugarcane, and transporting both goods and people (Barre *et al*., 2023).

Brucellosis in camels is caused primarily by *Brucella melitensis* and *Brucella abortus* (Aljameel *et al*., 2013; Ali *et al*., 2013; Alhaji *et al*., 2016). bacteria that not only reduce productivity (Al-Garadi *et al*., 2015). through reproductive losses but also pose a risk of transmission to humans (Aichouni *et al*., 2010). Infected camels may exhibit a variety of clinical signs, including lameness, swollen lymph nodes, and reproductive disorders such as abortion (Calderón *et al*., 2010). Despite its importance, camel brucellosis often remains underdiagnosed and underreported, partly due to limited surveillance and diagnostic challenges in many regions (Beigh *et al*., 2017).

Slaughterhouses offer a unique opportunity to study the prevalence and pathology of brucellosis in camels (Barre *et al*., 2023), as animals brought for slaughter can be systematically examined for both clinical symptoms and internal lesions (Chakiso *et al*., 2014). By combining clinical assessments with detailed histopathological analysis of tissues, researchers can gain a clearer understanding of the disease's manifestation and progression in camels (Gameel and Yassein, 2010).

When handling slaughtered animals, caution is advised due to the possibility of unknowingly encountering an infected animal; specifically, a hook should be used for handling the uterus and ovary (Chauhan *et al*., 2017). Encouragingly, *Brucella* organisms in the muscles of slaughtered animals have a short lifespan, as they are destroyed by lactic acid. In humans, brucellosis is known as 'undulant fever, characterized by intermittent high fever, headaches, and general malaise (Garcell *et al*., 2016). However, maintaining high levels of hygiene and sanitation significantly minimizes the risk of human infection. This comprehensive study aims to investigate the clinical signs and histopathological changes associated with camel brucellosis in slaughtered animals (Dawood, 2008). The findings will not only contribute to improved disease detection and management but also support efforts to safeguard public health and enhance the economic stability of communities that depend on camels (Elhadi *et al*., 2015).

MATERIALS AND METHODS

Study design

The study design employed a cross-sectional approach to investigate the seroprevalence of brucellosis, along with associated pathological findings, in camels slaughtered within the aforementioned districts of north-eastern Kenya. The selection of these areas was based on animal availability and security considerations. Serological testing was carried out using two methods: The Rose Bengal plate test (RBPT) and the competitive Enzyme-linked immunosorbent assay (ELISA). Upon arrival at the slaughter premises, camels were examined for clinical signs suggestive of brucellosis, such as lameness, swollen lymph nodes, and the presence of hygromas. Veterinary inspection records, including any history of abortion, retained placenta, orchitis, or epididymitis, were also consulted to identify potential cases. Animals exhibiting such signs or clinical history were enrolled in the study, tagged, and monitored through the slaughter process. Any condemned organs were collected, labelled, and visually inspected, with affected parts preserved in formalin for subsequent histopathological analysis. Out of 238 screened animals, 160 met the criteria for inclusion in the study.

Sampling method

The slaughterhouses chosen within the three designated study regions were selected utilizing a convenient sampling technique in collaboration with the sub-county veterinary officials. These establishments were chosen based on criteria including a higher volume of camels earmarked for slaughter, superior security measures in comparison to other facilities within the county, as well as the presence of requisite resources for laboratory operations (inclusive of data documentation, sample procurement, analytical supplies, and logistical support for the transportation of laboratory specimens), along with the availability of post-mortem examination tools. All camels presented for

slaughter during the periods of observation underwent ante-mortem assessments, with scrutiny of records conducted for indications suggestive of brucellosis. The subjects under investigation were deemed to be mature and healthy camels of both genders. Pertinent animal particulars encompassing tag identification, species classification, gender differentiation, breed categorization, age determination, and ownership attribution were meticulously recorded and documented in the interim data compilation form specific to the slaughterhouse (refer to Appendix 7.6). The selection of slaughterhouses within the sub-counties was conveniently undertaken for the research endeavor owing to their substantial camel processing capacities, accessibility, and security assurances. Solely those slaughterhouses specializing in camel processing were enlisted and visited within the stipulated four-week timeframe.

Rose Bengal plate test (RBPT)

The Rose Bengal test (RBT) was conducted following the protocol outlined by Ducrotoy *et al.* (2018) and Hosein *et al.* (2016). The specific antigen utilized in this study was sourced from Spain (Instituto de Salud de Navarra, RSA-RB:330-04:4000; in diagnostics ID vet 149, Spain). Before testing, serum samples were equilibrated to room temperature (21 ˚C). Subsequently, utilizing a micro-titre pipette, 25µl of serum was dispensed onto the shiny surface of a tile, followed by the addition of an equal volume of antigen (25µl). The tile was then gently agitated in a rocking motion for a duration of up to 4 minutes. The manifestation of pink agglutination indicated a positive outcome, while the absence of agglutination was considered a negative response. To ensure the validity of the results, positive and negative controls were also integrated into the experimental procedure.

Comp ELISA enzyme-linked immuno-sorbent assay (C-ELISA) tests

This was done using the Compelisa 160 and 400 kit (APHA Scientific), which is standardised for use in diagnosing brucellosis in animals; instructions followed as given for the kit, using a microtitre plate and ELISA reader. Diluting buffer, Wash solution, Conjugate, stopping solution, and controls were prepared as instructed. In general, the diluting buffer was warmed to room temperature by keeping it on a bench for 20 minutes 20 ul of each test serum was added to the respective plate wells, leaving columns 11 and 12 for positive and negative controls, respectively. Then, 100 ul of the prepared conjugate solution was added to all the wells. This gave a final serum dilution of 1/6. A positive/negative cut-off point was calculated as 60% of the mean of the optical density (OD) of the 4 conjugate control wells. Any test sample giving an OD equal to or below this value was regarded as being positive.

Gross examination

Following the condemnation of organs from experimental animals, a detailed gross and microscopic examination was conducted. During post-mortem assessments, condemned organs were visually inspected and sampled for histopathological analysis. The gross examination of condemned organs from test camels, primarily comprising the lung, lymph nodes, heart, liver, and kidney, involved visual inspection, palpation, and dissection of the affected organs. Emphasis was placed on evaluating organ size, color, and overall appearance to identify potential lesions indicative of brucellosis. Subsequent to the ante-mortem examination and Rose Bengal Plate Test (RBPT) screening at each visited slaughterhouse, animals seropositive for brucellosis were monitored until reaching the slaughter area, where any condemned organs were identified, inspected grossly, and sampled for histopathological evaluation. Following post-mortem examination, carcasses were disposed of in designated slaughterhouse disposal containers after thorough disinfection of all surfaces and equipment using a solution composed of Benzyl, dimethyl, Ammonium-chloride, and Copper, as produced in Kenya. Lesions were documented through photography utilizing a digital camera (Sony DSC-W920 equipped with optical magnifications of X40, X10, X100, and X400), with images subsequently transferred to a computer system and appropriately labeled for further reference.

Histopathological examination

The tissue samples obtained were fixed in a 10% formalin solution and subsequently subjected to staining procedures following the established protocols outlined by the World Organization for Animal Health (Al-Dahouk and Neubauer, 2012) and the Food and Agriculture Organization (Wernery, 2014). Upon fixation, the fresh tissue specimens were immersed in 10% formalin and transported to the Department of Veterinary Pathology, Microbiology, and Parasitology (VPMP) at the University of Nairobi. Following fixation, the tissues were trimmed to a thickness of 5 mm, dehydrated in ethanol at 30-minute intervals over 4 hours, cleared, and infiltrated with liquid paraffin wax (paraplast) at 60˚C in two changes lasting three hours each, and subsequently embedded in the wax-impregnated paper and affixed to wooden blocks using a heated spatula. The tissues were sectioned to a thickness of 5µm by blocking and microtoming processes. Subsequently, dewaxing steps were carried out for 5 minutes in each specimen section, followed by rehydration in distilled water for an additional 5 minutes in each section. The sections were stained with haematoxylin and eosin (H and E) and cover slipped using DPX (Dibutylphthalate xylene). The stained tissue sections were examined under a light microscope at magnifications of x4, x10, and x40, and the observed pathological lesions were documented based on the affected organs.

Data analysis and presentation

The information was collected via a descriptive survey conducted in the research areas, reviewed, compiled, and systematically arranged. Subsequently, the data derived from serological examinations and pathological findings were documented, inputted into a Microsoft Excel spreadsheet, and subjected to analysis using Stata software for Windows (version 14.0). This was followed by the application of the Chi-square test (X2) to compare the incidence of the illness among the designated slaughtered camels based on the pathological manifestations of the infection relative to other presumed diseases.

RESULTS

A total of 238 dromedary camels were presented at the abattoirs and subjected to brucellosis examinations. Among them, 160 camels exhibiting brucellosis symptoms or originating from herds with brucellosis history were included in the investigation. Among the selected camels, 70 (62.5%) were male, and 42 (37.5%) were female adults of the dromedary species. The distribution of breeds among the sampled camels included 87 (54%) of Somali descent, 42 (26%) of Rendilla/Gabbra lineage, and 31 (19%) of Turkana breed. The predominant organs condemned during post-mortem inspections were the lymph nodes, liver, lung, kidney, and heart, with condemnation attributed to various pathological conditions.

Findings of a seroprevalence investigation

The outcomes of two serological assays, namely the Rose Bengal Plate Test (RBPT) and Competitive Enzyme-linked Immuno-Sorbent Assay Test (c-ELISA), were utilized to detect the presence of the disease in camels before their slaughter. Application of the Rose Bengal Plate Test (RBPT) on camel serum samples obtained from specific slaughterhouses in Garissa sub-counties revealed a 9.3% positivity rate, with fifteen out of one hundred sixty-two samples testing positive (Table 1 and Figure 1). Among the samples collected from Garissa-township (n=50), 8.0% (four samples) were found to be positive, whereas from Dadaab slaughterhouses (n=50), 12.0% (six samples) were identified as positive. Moreover, in Balambale (n=60), 8.3% (five samples) were reported positive. Consequently, the Dadaab region exhibited the highest rate of reactivity at 12.0%, contributing to an overall reactivity rate of 9.3% across all samples tested.

Compelisa enzyme linked immunosorbent assay test (C-ELISA)

Upon testing 160 camel serum samples collected from specific slaughterhouses in the Garissa sub-counties utilizing the competitive enzyme-linked immunosorbent assay (cELISA), findings revealed that, out of these, sixteen samples (10.0%) exhibited positive results, as outlined in Table 2. Specifically, within Garissa-township (n= 50), 4 samples (8.0%) tested positive, in Dadaab (n= 50), 6 samples (12.0%) were positive, and in Balambale (n=60) 6 samples (10.0%) showed positive outcomes. Consequently, the analysis identified Dadaab as the location with the highest prevalence of positive reactions at 12.0%; the overall prevalence rate across all sites was recorded at 10.0%.

Table 1: Illustrates the outcomes of the Rose Bengal Plate Test (RBPT) both in aggregate and disaggregated according to the three distinct regions within Garissa County, Kenya.

Study area	No. tested	No. positive	% Positive
Overall	160	15	9.3
Garissa township	50	4	8
Dadaab	50	6	12
Balambale	60	5	8.3

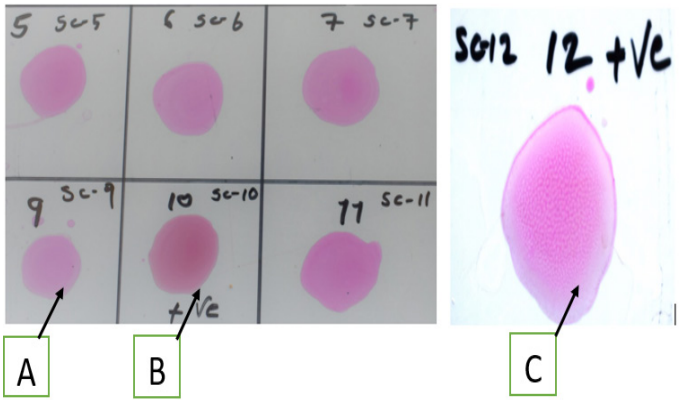

Figure 1: Displays the results of the Rose Bengal plate Test, indicating both positive and negative samples. A= Negative sample B= Positive sample C= Positive control.

Table 2: Displays the outcomes of the Comp ELISA Enzyme-linked Immuno-sorbent Assay (c-ELISA) test, both in a comprehensive overview and concerning the three distinct study regions within Garissa County, Kenya.

Study area	No. tested	No. positive	% Positive
Overall	160	16	10
Garissa township	50	4	8
Dadaab	50	6	12
Balambale	60	6	10

Findings of condemned orgns

Out of the 160 camels subjected to inspection and examination, it was found that 78 camels (48.75%) exhibited at least one pathological condition. Among these, 55 camels (70.5%) displayed a single pathological lesion each, while 19 camels (24.4%) presented with multiple pathological lesions. Furthermore, 38 camels (48.7%) showed no signs of organ condemnation. At the Garissa-township

Table 3: Displays the frequency of organ condemnations per abattoir in relation to the volume of camels processed.

Numbers of condemned organs	Distribution (number and %) per slaughterhouses			Total (%)
Number having pathological lesions	35	18	25	78(48)
Numbers having one pathological lesion	20	13	22	55(70)
Number of condemned organs	7	6	7	19(24)
No condemnation numbers	16	8	14	38(48)
Total animals examined	50	50	60	160

slaughterhouse, a total of 50 camels were slaughtered, with 35 camels (70%) showing a solitary pathological lesion, 7 camels (14%) having more than one pathological lesion, and 8 camels (16%) exhibiting no organ condemnation. In Dadaab, from the 50 camels slaughtered, 30 camels (60%) displayed one pathological lesion each, 10 camels (20%) manifested the same pathological conditions, and another 10 camels (20%) had no organ condemnation. Regarding the Balambale slaughterhouses, out of the 60 camels slaughtered, 40 camels (66.6%) did not show any signs of organ condemnation, 15 camels (25%) had multiple pathological lesions, and 5 camels (8.3%) were found to have a single consistent pathological lesion at the time of slaughter (Table 3).

Types of organs condemned

The types of organs deemed unsuitable from the 160 slaughtered camels were as follows: 78 (48.7%) were identified as lymph nodes. Specifically, in Garissa-township, 48 (61.5%) were condemned entirely, while at Dadaab, 18 (23%) were wholly condemned, and in Balambale, 12 (15.3%) were partially condemned. Additionally, 28 (17.5%) of the livers were condemned, with 12 (42.8%) condemned entirely in Garissa-township, 9 (32.2%) partially condemned in Dadaab, and 7 (25%) condemned entirely in Balambale slaughterhouses. Furthermore, 18 (11.2%) of the lungs were condemned, with 5 (27.7%) entirely condemned in Garissa-township, 7 (38.8%) entirely condemned in Dadaab, and 3 (16.6%) partially condemned in Balambale slaughterhouses. Moreover, 20 (12.5%) kidneys were condemned, with 9 (45%) entirely condemned in Garissa-township, 6 (30%) entirely condemned in Dadaab, and 5 (25%) entirely condemned in Balambale slaughterhouses. Finally, 16 (10%) heart muscles were condemned, with 4 (25%) partially condemned in the Township, 5 (31.2%) partially condemned in Dadaab slaughterhouses, and 7 (43.7%) partially condemned in Balambale slaughterhouses, indicating a notable frequency of condemned organs as demonstrated in Table 4.

Clinical, gross, and histopathology study results

A total of 160 camels were examined in the research study based on clinical signs and medical records that indicated the presence of brucellosis. Throughout the study duration, clinical observations from ante-mortem records revealed various manifestations including lameness in 48 camels (30.0%), lymph node swelling in 39 camels (24.0%), orchitis in 6 camels (3.70%), infertility in 7 camels (4.3%), abortion in 8 camels (5.0%), abdominal pain in 7 camels (4.3%), decreased milk yield in 7 camels (4.3%), testicular inflammation in 6 camels (3.7%), epididymitis in 6 camels (3.7%), anorexia in 7 camels (4.3%), inappetence in 7 camels (4.3%), urogenital infections in 7 camels (4.3%), and placental infections in 6 camels (3.7%). Figure 1 illustrates a swollen lymph node observed in one of the camels, while detailed clinical manifestations for each individual examined are provided in Table 5. Organs and tissues that were condemned were gathered and scrutinized both macroscopically and microscopically from the slaughtered camels. The macroscopic condemned lesions identified included fibrin depositions in 7 camels (4.3%), lung enlargement in 6 camels (3.7%), pericarditis in 38 camels (23.7%), hepatomegaly with nodular liver lesions in 79 camels (49.3%), enteritis in 5 camels (3.1%), haemorrhages in 6 camels (3.7%), congestion in 8 camels (5.0%) of visceral organs (lung and kidney), and lymph node abscesses in 3 camels (1.8%). Detailed descriptions of macroscopic pathological findings from specific examinations are presented in Garissa County in Table 6.

The histopathological analysis revealed various findings, including cellular infiltrations (15 cases, 6.2%), hypoplasia (3 cases, 1.8%), alveolar collapse (7 cases, 4.3%), edema (4 cases, 2.5%), congestion (6 cases, 3.7%), fatty degeneration (5 cases, 3.1%), haemorrhages (9 cases, 5.6%), immunoblastic

Table 4: Presents the condemnation rates of organs, both collectively and with regard to the three distinct study regions.

Condemned organs	Township	Dadaab	Balambale	Overall
Lymph node	48(61.5%)	18(23%)	12(15.3%)	78(48.7%)
Liver	12(42.8%)	9(32.2%)	7(25%)	28(17.5%)
Lung	6(33.3%)	7(38.8%)	5(27.7%)	18(23%)
Heart muscle	4(25%)	5(31.2%)	7(43.7%)	16(10%)
Kidney	9(45%)	6(30%)	5(25%)	20(12.5%)
Total camel examined	79	45	36	160

Table 5: Displays the various clinical presentations observed in camels slaughtered within North-eastern Kenya.

Clinical symptoms	Slaughterhouses			Total (%)
	Garissa township	Dadaab	Balambale	
Lameness	11	15	21	47(29.3)
Placental infection	2	1	3	6(3.7)
Anorexia	1	1	4	6(3.7)
Abdominal pain	2	1	4	7(4.3)
Abortion	1	2	5	8(5.0)
Inflammation of testes	2	1	3	6(3.7)
Swollen of lymph nodes	8	12	19	39(24.3)
In appetence	2	2	3	7(4.3)
Decreases milk yield	1	1	5	7(4.3)
Epididymitis	2	2	2	6(3.7)
Infertility	2	1	4	7(4.3)
Weight loss	1	0	0	1(0.6)
Infection of urogenital	2	1	4	7(4.3)
Orchitis	1	2	3	6(3.7)
Total:	38	42	80	160

Table 6: Presents the gross pathological lesions observed in various slaughterhouses in North-eastern Kenya.

Gross pathology lesions	Slaughterhouses			Total (%)
	Garissa township	Dadaab	Balambale	
Fibrin depositions	2	1	4	7 (4.3)
Enlargement of lung	1	2	3	6 (3.7)
Abscess of lymph nodes	1	1	1	3 (1.8)
Congestion	3	1	4	8 (5.0)
Hepatomegaly	19	26	34	79(49.3)
Haemorrhages	1	2	3	6 (3.7)
Enteritis	3	2	5	10 (6.2)
Pericarditis	8	13	17	38 (23.7)
Emaciations	1	1	1	3 (1.8)

infiltrations (8 cases, 5.0%), increased lymphocyte count (9 cases, 5.6%), pneumonia (10 cases, 6.2%), lymphoblastic infiltrations (8 cases, 5.0%), fibrosis (7 cases, 4.3%), presence of macrophages and neutrophils (10 cases, 6.2%), inflammatory cell infiltration (9 cases, 5.6%), cellular injuries (8 cases, 5.0%), accumulation of blood cells (8 cases, 5.0%), compensatory emphysema (9 cases, 5.6%), increased hepatocyte count (10 cases, 6.2%), inflammatory skin lesions (8 cases, 5.0%), and myocardial necrosis (7 cases, 4.3%). Consequently, the pathological alterations of sero-reactants within the condemned organs are delineated in Table 7 and Figures 2-7, illustrating the diverse histopathological manifestations observed in the selected condemned organs. Specific examinations provide detailed descriptions of gross histological lesions. Subsequently, the pathological changes resulting from the gross lesions identified in conjunction with the respective presence of Brucella Positive are itemized in Table 7, offering a comprehensive overview exclusively of positive outcomes in the serological tests, while the negative test results are presented accordingly.

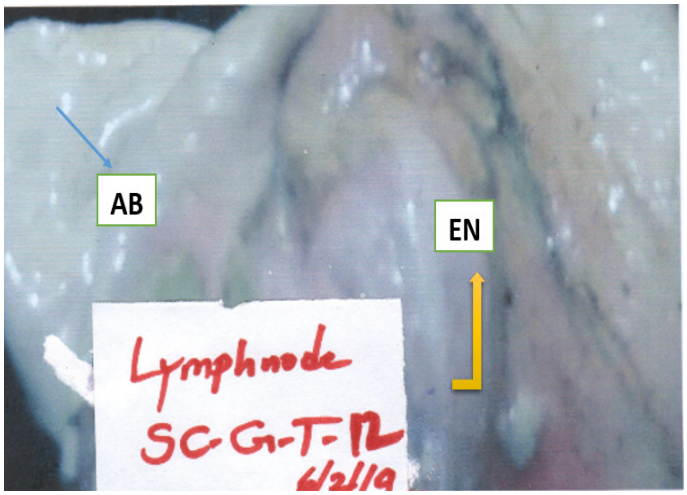

Figure 2: Displays the affected organ, specifically the mammary glands, of a positive lymph node test from Sample camel designated as SC-GT-12, which revealed conditions of enlargement (EN) and abscesses (AB) upon serological examination.

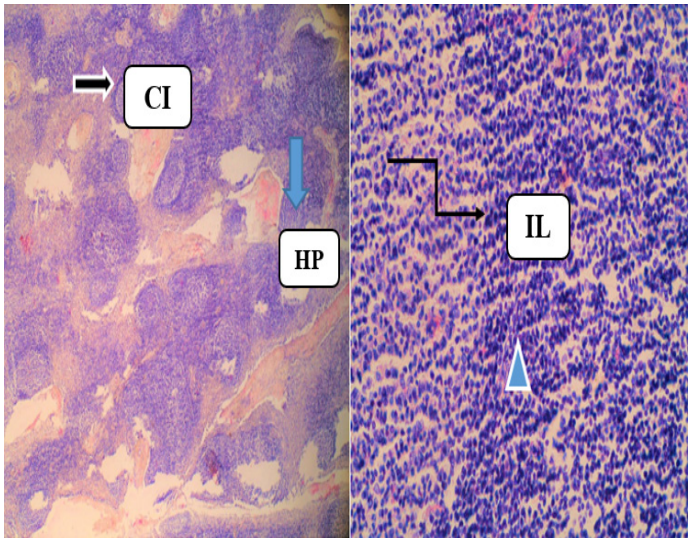

Figure 3: The histopathological examination of a lymph node from a camel diagnosed with brucellosis (Case SC-12) reveals the presence of immunoblastic infiltration, cellular infiltration (CI), lymphocyte hypoplasia (HP), as well as an elevated count of lymphocytes (IL). This is illustrated through microscopic images taken at magnifications of 40x and 400x, stained with hematoxylin and eosin (H and E).

Table 7: Displays the pathological alterations observed in condemned organs of slaughtered camels in north-eastern regions concerning Brucella sero-reactants.

Camel No.	Cond. organs	Clin. signs	Gross lesions	Histopathology
SC-GT-12	Lymph node	Swollen	Enlargement and abscess	Cellular infiltration
	Stomach	Loss of appetite	Discoloration	Haemorrhages
SC-GT-14	Lung	Lameness	Change in colure, white spots	collapse of alveoli, pinkish fluid materials with the alveoli (Oedema)
SC-GT-24	Liver	Lameness	Distended	Fatty degeneration
	Liver	Placental infection	Thickened of bile duct	Diffuse of fatty infiltrations
SC-GT-29	Lymph node	Swollen of lymph nodes	Swollen	immunoblastic infiltration
SC-GT-30	Heart	Anorexia	fibrins and haemorrhages	destructions of fibrins
SC-DA-64	Lung	In appetence	Discoloration	Pneumonia
SC-DA-69	Heart	Placental infection	Congested	Lymphoblastic infiltrations
SC-DA-70	Kidney	Epididymitis	Congested	Congestion and haemorrhages
SC-BA-120	Heart	Infertility	Fibrins	Slightly destruction of fibrins
SC-BA-132	Lung	Abdominal pain	Congested	Polymorph-nuclei in Alveoli
SC-BA-143	Kidney	Abortion	--	--
SC-BA-144	Lymph node	Swollen of lymph nodes	Enlarged in some areas	Increase number
SC-BA-150	Heart	Infection of urogenital	Haemorrhages	Macrophages and neutrophil infiltrations
SC-BA-155	Liver	Anoxia	Hepatomegaly	Oedematous mononuclear cells
SC-BA-158	Kidney	Abortion	Congested	Congested and haemorrhages

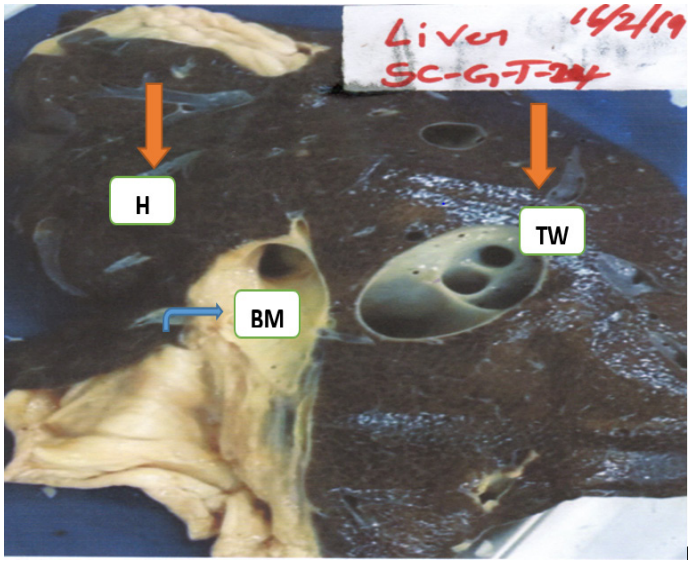

Figure 4: Displays the liver organ of a camel specimen (SC-24) exhibiting hepatomegaly, thickening of the bile duct wall, and the presence of black substances within the bile duct, testing positive for condemnation.

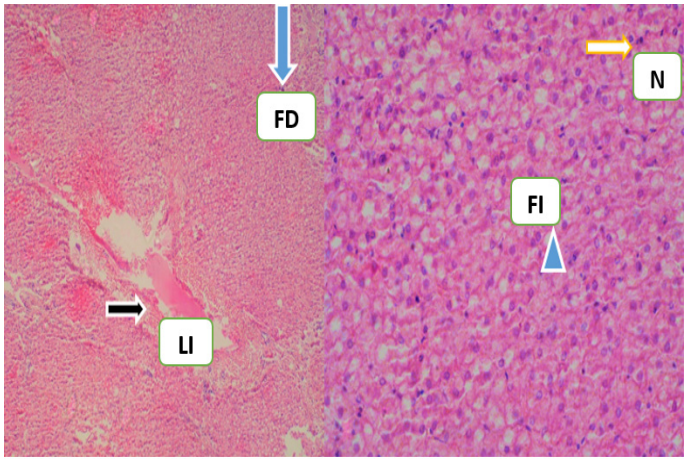

Figure 5: Displays a histological examination of a liver deemed unfit for consumption, extracted from a camel designated as sample camel Number (SC-24) and confirmed seropositive. The section illustrates characteristics such as fatty degeneration (FD), the presence of Neutrophils (N), liver injuries (LI), and diffuse fatty infiltration (FI), as observed under high magnification (H/E × 40x and 100x).

The macroscopic morphology and histopathological characteristics of the organs condemned due to seropositivity

The analysis of lymph node samples obtained from a camel slaughtered in Garissa-Township, which tested positive for brucellosis in its sera, revealed the presence of immunoblastic infiltrations, hypoplasia, decreased numbers of mature lymphocytes, and an elevated count of lymphocytic cells in both gross and histopathological examinations. This is illustrated in Figures 1 and 2.

DISCUSSIONS

This research was conducted in camel abattoirs in northeast Kenya to ascertain the prevalence of brucellosis in camels through the utilization of serological methods and examination of pathological lesions at both macroscopic and microscopic levels. A total of 160 camel specimens were subjected to analysis to determine the presence of Brucella antibodies by employing two serological assays, specifically the Rose Bengal Plate Test (RBPT) and

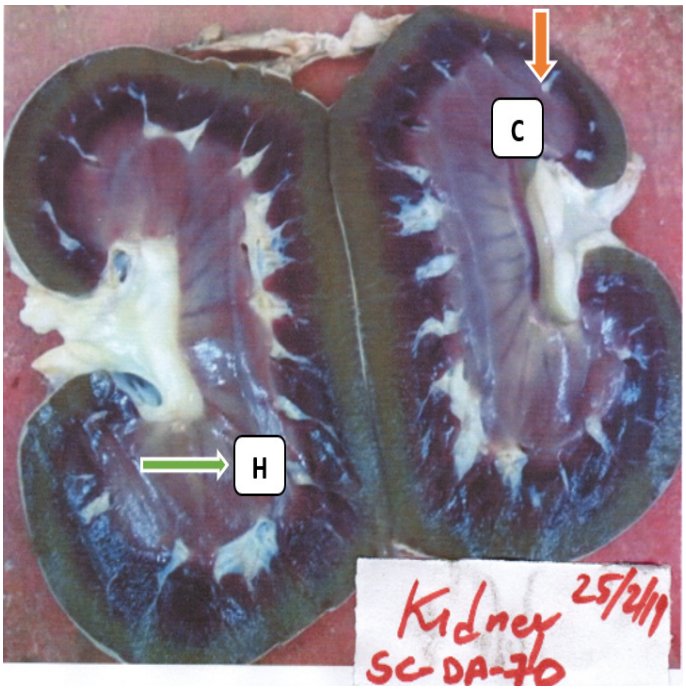

Figure 6: Displays the pathological examination of a kidney organ from a camel sample denoted as SC-DA-70, illustrating pronounced congestion (C) and hemorrhagic manifestations (H) confirmed by positive testing.

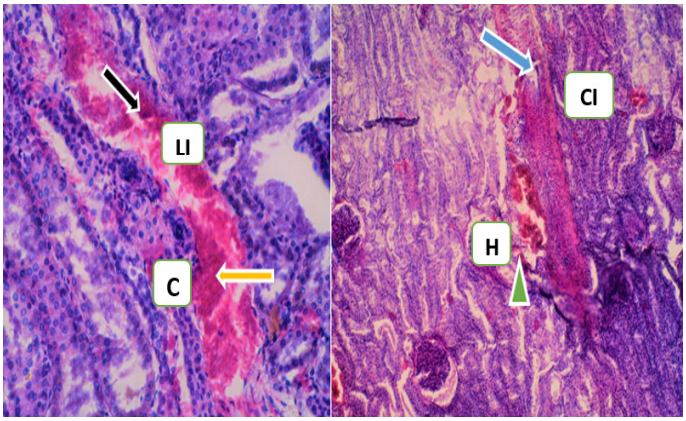

Figure 7: Displays the histological characteristics of a kidney from a seropositive tested camel sample identified as SC-70. The images illustrate lymphoblastic cell infiltration, congestions, cellular infiltrations, and haemorrhages (H/E magnified at 40x, 400x, and 100x).

Competitive Enzyme Linked Immuno Sorbent Assay (c-ELISA). The collective sero-prevalence rate, derived from the mean results of both assays, was estimated at approximately 10% (15-16 out of 160), a figure consistent with a study by Alhaji *et al.* (2016), which reported a sero-prevalence of 10.6%. Statistical analysis indicated no significant variance between the outcomes of the two serological tests (χ^2= 0.0999). Nonetheless, the Rose Bengal Plate Test (RBPT) identified the highest proportion of positive reactors at 9.3%, marginally surpassing the detection rate of c-ELISA at 10.0%. These testing methodologies were also evaluated in previous research involving cattle and camels, aligning with the present findings. Specifically, the Rose Bengal Plate Test (RBPT) was administered on 160 camel serum specimens collected from slaughterhouses in Garissa, with 8.0% (4 out of 50) testing positive in the Garissa district, 12.0% (6 out of 50) in Dadaab, and 8.3% (5 out of 60) in Balambale. These results corroborate with similar investigations by (Gwida *et al.*, 2012; Wanjohi *et al.*, 2012).

The sero-prevalence findings of the current study (10%) are consistent with previous reports from various countries (Junaidu *et al.*, 2006; Dawood, 2008; Wanjohi *et al.*, 2012). However, these findings are lower than those reported in studies conducted in Somalia (Abbas and Agab, 2002), Somaliland (Ghanem *et al.*, 2009), Tanzania (Assenga *et al.*, 2015), Ethiopia (Teshome *et al.*, 2003), Nigeria (Junaidu *et al.*, 2006; Madu *et al.*, 2016), Saudi Arabia (Racloz *et al.*, 2013), and Yemen (Al-Garadi *et al.*, 2015). The sero-prevalence observed in this study differs from findings in neighbouring countries such as Kenya (specifically in the Afar region of Northeast Ethiopia) (Hadush *et al.*, 2013). The lower sero-prevalence observed in this study contradicts previous findings suggesting a higher prevalence of Brucellosis among nomadic slaughterhouses in Garissa. The sero-prevalence of Brucellosis in camels was lower in extensively kept pastoralists of camels in Garissa-Township and Dadaab slaughterhouses, while it was higher in intensively kept pastoralists of camels in Balambale slaughterhouses. Various factors may influence the serological outcomes, including the production system, overcrowding of animals, contacts between animals, immune suppression due to trypanosomiasis in camels, cross-reactivity with bacteria like *E. coli, Salmonella,* and *Yersinia*, and the use of less specific tests. These factors could impact serological findings, along with differences in sampling methods and animal selection for the study. The higher prevalence of brucellosis poses significant economic and public health challenges. The increased frequency of abortion and reproductive failures may elevate the risk of exposure for livestock owners and their families. The Rose Bengal Plate Test (RBPT) demonstrated good diagnostic sensitivity compared to other serological tests conducted in the survey (Gessese *et al.*, 2014). Therefore, the RBPT is considered a reliable screening test, as recommended by the Sprague *et al.* (2012) for diagnosing camel brucellosis. Although camels are not natural hosts of Brucella organisms, they are susceptible to Brucella abortus and *Brucella melitensis*. The disease can be transmitted among wildlife and domestic animals to humans through direct contact and environmental contamination during parturition and abortion. While camel infections have been reported in various countries, including Saudi Arabia, Sudan, Kenya, Tanzania, Ethiopia, and Somalia, controlling the disease in both animals and humans requires improved hygiene practices, public awareness campaigns, and proper disposal

of infected materials to prevent transmission. Thus, the current investigation has confirmed the presence of brucellosis in slaughterhouses located in Garissa, Kenya, indicating a notable seroprevalence of 10% as determined by Rapid Brucella Plate Test (RBPT) and Enzyme-Linked Immunosorbent Assay (ELISA). Further research is warranted to enhance camel production and reduce the risk of infection transmission to humans, particularly slaughterhouse workers. The cross-sectional study revealed that 48% of camels slaughtered at Garissa Township, Dadab, and Balambale slaughterhouses exhibited one or more instances of organ contamination. The histological analysis identified circulatory disturbances and inflammatory conditions as primary causes of contamination, in addition to brucellosis.

The slaughtered camel exhibited various clinical manifestations (Wareth *et al*., 2014), including swollen lymph nodes (24%), severe lameness (30%), and abortion (5%). Analysis of the sero-reactant samples indicated that lameness was the most prominent clinical manifestation (Kagunyu and Wanjohi, 2014), while abortion had the lowest occurrence among the observed clinical manifestations in the study (Wernery, 2014). Swollen lymph nodes in camels affected by Brucellosis showed enlargement and abscess formation, likely due to obstruction and fluid discoloration (Kaindi *et al*., 2011). Microscopically, stained slides revealed disorganization, cellular infiltrations, mononuclear inflammatory cells, immunoblastic infiltrations, an increased number of lymphocytes, and hypoplasia, indicating incomplete tissue development (Kumar, 2013). Similar lesions were reported in studies conducted in Sudan (Aljameel *et al*., 2013) and Yemen (Hamza *et al*., 2017) on camel lymph nodes. Liver samples from Brucellosis-positive camels (1.8%) showed clinical manifestations of lameness in anti-mortem records. Histopathological examination revealed fatty degeneration, diffuse fatty infiltrations, fibrosis, hepatocyte denegation, and necrosis. Comparable findings were reported in studies from Iran (Khaniki *et al*., 2013) and Saudi Arabia (Mohamed, 2013), showing injury, congestion, inflammatory cell infiltration, and hepatocyte degenerations in affected liver areas. These gross and histopathological findings align with previous studies (Khaniki *et al*., 2013; Mohamed, 2013). Two lungs (1.2%) from Brucellosis-positive slaughtered camels were rejected at the slaughterhouses due to enlargement, discoloration, the presence of white and red spots, and cyst-filled fluid on the surface. Microscopic examination revealed collapsed alveoli, edematous pinkish fluid in alveoli, mononuclear cell infiltrations, vessel blockages, macrophages, and hepatocyte cell enlargement. Adjacent bronchioles showed congestion and mild inflammatory cell infiltration. Similar findings were reported in studies from Saudi Arabia (Gameel and Yassein, 2010; Beigh *et al*., 2017). Four hearts (2.5%) of Brucellosis-positive camels rejected at slaughterhouses displayed fibrins and hemorrhages. Gross and histopathological examinations revealed fibrins, hemorrhages, lymphoblastic and inflammatory cell infiltrations, fatty degenerations, and inflammatory cells (Fromsa and Jobre, 2011; Gyuranecz *et al*., 2016). Comparable findings were documented in studies from Tanzania (Tembo *et al*., 2015) and in Bangladesh (Mazumder *et al*., 2012). Two kidneys (1.2%) from slaughtered camels were condemned during post-mortem inspections due to discoloration, congestion, haemorrhages, and white-dark-red areas under the renal cortex. Microscopic examination confirmed inflammatory cell infiltration, macrophages, haemorrhages, and congestion. Previous studies from Kenya (Devrajani *et al*., 2010; Mutua *et al*., 2017; Ducrotoy *et al*., 2018) also reported similar findings in lung tissue from slaughtered camels in Athi River (Dunlop *et al*., 2015). Additionally, two lungs (1.2%) from slaughtered camels, which tested negative serologically, were condemned during post-mortem inspections due to red-dark discoloration under the pleural cavity (El-Bahrawy *et al*., 2015). Histological examination indicated the presence of erythrocytes and pinkish materials in bronchi and bronchioles, suggesting inflammation in the lung tissue (El-Sayed *et al*., 2017). A similar study conducted in Ethiopia (Mamo *et al*., 2011) reported comparable findings with the absence of inflammatory cells in the lung tissue (Muendo *et al*., 2012; Manish *et al*., 2013; Madu *et al*., 2016). The correlation between gross pathology and microscopic examination was evident (Onono *et al*., 2010; Njeru *et al*., 2016). The 10% seropositivity observed in camels brought in for slaughter indicates the zoonotic nature of the disease in the area (Hassan-Kadle, 2015), albeit at a lower rate than reported in other regions of the country (Paixao *et al*., 2009; Salih, 2015). This infection holds economic and public health significance (Scolamacchia *et al*., 2010). Camels from Balambale slaughterhouses exhibited higher seropositivity using four different serological tests, with seropositive camels displaying clinical and pathological lesions consistent with Brucellosis. Several organs were condemned due to infectious and non-infectious causes, attributed to poor sanitation practices during animal slaughtering, affecting the economic losses of slaughterhouses in the county.

CONCLUSION

Livestock farmers and veterinarians in North-eastern Kenya must diligently investigate cases of Brucellosis, particularly those involving abortion and retained placenta, on their farms. Accurate disease diagnosis and effective control measures necessitate thorough screening

of all affected slaughtered animals to prevent cross-contamination. Further studies should be conducted to explore the contribution of Brucellosis to the pathology and histopathology in livestock, including wildlife, to enhance understanding of the disease's prevalence and impact in slaughterhouses, particularly camel slaughterhouses, in the county and the country.

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NOVELTY STATEMENT

This study presents novel insights by combining clinical evaluation with detailed histopathological examination of brucellosis in dromedary camels sourced directly from slaughterhouses. This area has received limited attention in previous research. Unlike most existing studies that focus primarily on serological or molecular detection, this research correlates observable clinical signs with specific postmortem tissue lesions, providing a comprehensive understanding of the disease's pathology in naturally infected camels. The investigation of slaughterhouse samples also offers a unique epidemiological perspective on the prevalence and manifestation of both clinical and subclinical brucellosis, thereby highlighting the zoonotic risks in these settings. These findings contribute significantly to improving diagnostic accuracy and informing more effective control and prevention strategies for brucellosis in camel populations, particularly in regions where camels are economically and culturally critical.

This novelty underscores the integration of multidisciplinary approaches-clinical, pathological, and epidemiological-to deepen understanding of brucellosis in dromedary camels under field conditions, filling gaps in the literature and guiding future research and veterinary public health interventions.

AUTHOR'S CONTRIBUTION

A Barre led the conception and design of the study, coordinated sample collection at the slaughterhouses, and conducted the clinical examinations of the camels. F F A, Jesse, and PT Bura participated in data acquisition, including performing postmortem examinations and histopathological analysis. K N Balakrishnan and Muhammed Mikail contributed to the interpretation of histopathological findings and reviewed the manuscript critically. E L. T Chung and Aminu Shittu assisted in serological and molecular diagnostics, helping to validate the clinical and pathological results. Joshua Onyango was involved in data analysis and interpretation, as well as drafting sections of the manuscript. All authors contributed to revising the manuscript for important intellectual content and approved the final version for publication.

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During the preparation of this work, the author(s) did not use any AI and AI-assisted technologies

Conflict of interest

The authors have declared no conflict of interest.

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