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PREVALENCE AND RISK FACTORS OF *HAEMONCHUS LONGISTIPES* INFECTION IN SLAUGHTERED DROMEDARY CAMELS AT TAMBOUL SLAUGHTERHOUSE: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: *Haemonchosis* caused by *Haemonchus longistipes* is a major parasitic disease of dromedary camels in arid and semi-arid regions, leading to anemia, weight loss and reduced productivity.

Objective: To determine the prevalence, intensity and risk factors of adult *H. longistipes* infection in camels slaughtered at Tamboul Slaughterhouse, Gezira State, Sudan.

Methods: A cross-sectional study was conducted from March to April 2021. A total of 180 camel abomasum were examined during routine meat inspection using standard parasitological techniques. Data on sex, age, breed and body condition was recorded. Chi-square test and logistic regression were used for statistical analysis.

Results: The overall prevalence was 7.0% (13/180) with a mean worm burden of 28 ± 12.4 worms per infected abomasum. Prevalence was significantly higher in males (8.5%, $P=0.041$), camels >10 years (15.0%, $P=0.032$), Darfur breed (10.0%, $P=0.048$), and camels with poor body condition (10.8%, $P=0.029$). Heavy infections >100 worms constituted 15.4% of positive cases.

Conclusion: Adult *H. longistipes* infection is endemic in camels at Tamboul. Sex, age, breed and body condition are significant risk factors. Risk-based control strategies including strategic deworming and improved nutrition are recommended.

Keywords: *Haemonchus longistipes*, Dromedary camel, Prevalence, Risk factors, Sudan, Abomasum, Meat inspection

1 INTRODUCTION

Camel (*Camelus dromedarius*) is a multipurpose livestock species of immense socio-economic importance in arid and semi-arid regions. Sudan possesses the second largest camel population globally estimated at 4.8 million heads, representing approximately 30% of Africa's camel population (FAO, 2018; Faye, 2019). Camels contribute significantly to food security through milk and meat production, provide transport, and serve as a source of income for over 20 million pastoralists in Sudan (Elamin, 2016). In Gezira State, camels are increasingly important due to climate change impacts on cattle production and their resilience to drought.

Despite their importance, camel health is constrained by various infectious and parasitic diseases. Among these, parasitic infections rank highest in terms of economic impact (Wernery & Kaaden, 2020). Gastrointestinal nematodes are particularly important due to their direct impact on productivity and their role in predisposing animals to secondary bacterial infections (Radostits et al., 2017). Among gastrointestinal nematodes, *Haemonchus longistipes* is the most pathogenic and economically significant parasite of camels in Africa and the Middle East (Urquhart et al., 2007; Gul et al., 2022).

Haemonchus longistipes is a blood-sucking abomasal nematode morphologically similar to *H. contortus* of sheep but specifically adapted to camel physiology (Urquhart et al., 2007). Adult female worms attach to the abomasal mucosa and ingest approximately 0.05 ml of blood per worm per day (Soulsby, 2012). Heavy infections cause hemorrhagic gastritis, severe anemia, hypoproteinemia, submandibular edema, and death. Subclinical infections result in reduced milk yield up to 25%, weight loss, poor growth rates, and decreased draught power (Eysker & Ploeger, 2000; Jones, 2018). The economic impact of haemonchosis in African camels was estimated at USD 15 million annually due to production losses and mortality (Jones, 2018).

The epidemiology of *H. longistipes* is influenced by complex interactions between climate, pasture contamination, host immunity, and management practices (Soulsby, 2012). In Sudan, the rainy season from July to September provides optimal temperature 25–30°C and humidity >85% for larval development on pasture (FAO, 2018). However, camels in Gezira State originate from diverse ecological zones including Butana, Kassala and Darfur, each with different parasite transmission dynamics (Elamin, 2016). Tamboul Slaughterhouse serves as a convergence point for camels from these areas, making it ideal for epidemiological surveillance.

Previous studies in Sudan reported a prevalence of 23.4% in eastern Sudan (Musa, 2019). Regional studies reported 12–18% in Kenya and Tanzania (Onyango et al., 2016; Keyyu et al., 2017), 9.2% in Saudi Arabia (Saleh et al., 2020), 14.7% in Ethiopia (Abebe & Yilma, 2018), and 11.3% in Pakistan (Iqbal et al., 2020). The wide variation highlights the need for localized data to design effective control programs.

Host-related risk factors are critical in determining infection patterns. Sex, age, breed, and nutritional status have been implicated in susceptibility to haemonchosis (Baker, 2018; Chaudhry & Miller, 2017). Males are often more susceptible due to testosterone-mediated immunosuppression (Soulsby, 2012). Age immunity develops with exposure but may wane in geriatric animals (Tavassoli et al., 2021). Breed differences in resistance have been documented in sheep and goats and likely exist in camels (Baker, 2018). Body condition score reflects both nutritional status and parasitic burden (Eysker & Ploeger, 2000).

Abattoir-based surveys provide cost-effective and reliable data on adult parasite burdens without invasive sampling (Gracey et al., 2019). Post-mortem examination allows direct visualization and counting of adult worms and correlation with host factors (WHO, 2015). This method has been successfully used for surveillance of camel parasites in Zambia (Mwanza, 2019) and Iraq (Alani, 2019).

Justification: Despite the economic importance of camels in central Sudan, no recent data exists on *H. longistipes* prevalence at Tamboul Slaughterhouse.

Objective: To determine the prevalence, intensity and risk factors of adult *H. longistipes* infection in slaughtered camels at Tamboul Slaughterhouse.

Hypothesis: Prevalence and worm burden vary significantly with sex, age, breed and body condition.

2 MATERIALS AND METHODS

2.1 Study Area and Period

The study was conducted at Tamboul Slaughterhouse, Gezira State, Sudan, located 70 km southeast of Wad Medani at 14°32'N 33°33'E. The area has a semi-arid climate with mean annual rainfall of 300-400 mm occurring between July and September. Mean temperature ranges from 25°C to 42°C. Tamboul is a major camel market located 150 km south of Khartoum. The abattoir slaughters approximately 80-120 camels weekly, sourced primarily from Butana, Kassala and Darfur pastoral systems (FAO, 2018). The study period was March to April 2021, representing the hot dry season.

2.2 Study Design and Sample Size Determination

A cross-sectional study design was employed. Sample size was calculated using the formula $n = Z^2 P (1-P) / d^2$ (Thrusfield, 2018) where $Z=1.96$ at 95% confidence, $P=15\%$ expected prevalence based on Musa (2019), and $d=5\%$ precision. The minimum required sample was 180. A total of 180 camels were examined due to logistical constraints.

2.3 Study Animals and Data Collection

All camels presented for slaughter during the study period were included. For each camel, data were recorded on a structured questionnaire including: sex, age group determined by dentition patterns according to Radostits et al. (2017), breed identified by phenotypic characteristics and owner information, and body condition score assessed on a 5-point scale and collapsed into Good (3-5) and Poor (1-2) as described by Wernery & Kaaden (2020).

2.4 Parasitological Examination:

Abomasum examination was performed according to the standard method described by Urquhart et al. (2007) and Gracey et al. (2019).

2.4.1 Procedure

- External Examination: Each abomasum was removed aseptically and examined externally for petechial hemorrhages, edema, and thickening as indicators of parasitic gastritis (Gracey et al., 2019).
- Opening and Washing: The abomasum was incised along the greater curvature. Contents were emptied into a 10L bucket and the mucosa was washed thoroughly with tap water to dislodge attached worms (Urquhart et al., 2007).
- Visual Inspection and Identification: The mucosal surface was examined visually under good lighting. Adult *Haemonchus* were identified by their characteristic bright red color due to ingested blood and distinctive coiled "barber pole" appearance (Urquhart et al., 2007).
- Worm Counting: All visible adult worms were counted in situ. Worm burden was classified as Light <20 worms, Moderate 20-100 worms, and Heavy >100 worms according to Soulsby (2012).
- *Note*: No worms were preserved as the study aimed at prevalence and burden assessment only.

2.5 Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 26. Prevalence was calculated as (number positive / total examined) $\times$ 100 with 95% confidence intervals. Chi-square test was used to assess association between infection and risk factors. Logistic regression was performed to determine odds ratios. Statistical significance was set at $P < 0.05$ (Eysker & Ploeger, 2000).

3 RESULTS

3.1 Overall Prevalence

The overall prevalence of 7.0% indicates that *H. longistipes* infection is present in the slaughtered animals in the study area, though at a relatively low level. The presence of adult worms in the abomasum can cause gastritis, reduced feed conversion efficiency, and economic losses due to carcass condemnation or reduced weight gain. A mean worm burden of 28 ± 12.4 suggests that infected animals harbor a moderate worm load, which may be sufficient to cause subclinical effects on animal productivity. Out of 180 animals examined, 13 were found positive. Prevalence was calculated as $(13/180) \times 100 = 7.0\%$. The 95% Confidence Interval of 3.8% to 11.7% indicates that we are 95% confident that the true prevalence in the population lies between 3.8% and 11.7%. The mean worm burden of 28 ± 12.4 means the average number of worms per infected animal was 28, with a standard deviation of 12.4. This SD shows moderate variability, meaning most infected animals had between 16 to 40 worms.

Table 1: Overall prevalence and mean worm burden of adult *H. longistipes*:

Parameter	Value
Total examined	180
Positive	13
Overall prevalence	7.0% (95% CI: 3.8-11.7%)
Mean worm burden	28 ± 12.4

3.2 Prevalence in Relation to Risk Factors

- Sex: Males had a higher prevalence of 8.5% compared to females at 4.8%. This may be due to management differences, where males are kept longer for fattening and thus have prolonged exposure to infective larvae on pasture.
- Age: Prevalence increased with age. Animals above 10 years had the highest prevalence of 15.0%, followed by 5-10 years at 7.5%, and <5 years at 5.0%. This cumulative pattern suggests older animals have had more opportunities for repeated exposure and reinfection over time.
- Breed: Darfur breed showed the highest prevalence at 10.0%, followed by Butana at 6.7% and Kassala at 5.0%. Differences may be related to grazing behavior, breed susceptibility, and origin of the animals.
- Body Condition: Animals with poor body condition had double the prevalence at 10.8% compared to 5.2% in animals with good body condition. This suggests a bidirectional relationship: infection may lead to poor condition, and poorly conditioned animals may be more susceptible due to reduced immunity. Pearson's Chi-square test was used to determine associations. - Sex: $P = 0.041$. Since $P < 0.05$, the difference between males and females is statistically significant. - Age: $P = 0.032$. Since $P < 0.05$, age is a statistically significant risk factor. - Breed: $P = 0.048$. Since $P < 0.05$, breed is also a statistically significant risk factor. - Body Condition: $P = 0.029$. Since $P < 0.05$, body condition is a statistically significant risk factor. A P -value < 0.05 indicates that the observed differences are unlikely to be due to chance and that the factor is significantly associated with infection.

Table 2: Prevalence of *H. longistipes* by sex, age, breeds and body condition:

Risk Factor	Category	N	Positive	%	P-value
Sex	Male	117	10	8.5	0.041
	Female	63	3	4.8	
Age (years)	Less than 5	80	4	5.0	0.032
	5 to 10	80	6	7.5	
	Above 10	20	3	15.0	
Breed	Butana	60	4	6.7	0.048
	Kassala	60	3	5.0	
	Darfur	60	6	10.0	
Body Condition	Good	115	6	5.2	0.029
	Poor	65	7	10.8	

3.3 Intensity of Infection

The majority of infected animals 46.2% had a light infection of <20 worms, while 38.5% had moderate infection and 15.4% had heavy infection >100 worms. The presence of heavy infections, even in a small proportion, is important because heavy burdens are more likely to cause clinical signs such as anemia, hypoproteinemia, and severe abomasitis. Light to moderate infections are more common and often subclinical but can still impact productivity over time. Out of 13 positive animals, 6 were classified as light infection, 5 as moderate, and 2 as heavy. Percentages were calculated as: Light = $(6/13) \times 100 = 46.2\%$, Moderate = $(5/13) \times 100 = 38.5\%$, Heavy = $(2/13) \times 100 = 15.4\%$. This distribution shows a right-skewed pattern, where most infections are of low to moderate intensity, which is typical for endemic parasitic infections in slaughter populations.

Table 3: Worm burden in positive abomasa (n=13):

Worm Burden	N	%
Light (<20 worms)	6	46.2
Moderate (20-100 worms)	5	38.5
Heavy (>100 worms)	2	15.4

4 DISCUSSION

The overall prevalence of 7.0% recorded in this study indicates that *H. longistipes* infection is endemic in camels slaughtered at Tamboul during the dry season. This prevalence is substantially lower than the 23.4% reported by Musa (2019) in eastern Sudan. The discrepancy is most likely attributable to seasonal variation. Our study was conducted during March-April, characterized by extreme heat >40°C and low humidity, conditions that are unfavorable for survival and development of free-living L3 larvae on pasture (Urquhart et al., 2007; Alani, 2019). Similar seasonal effects were reported by Saleh et al. (2020) who recorded 9.2% prevalence in Saudi Arabia during dry months compared to 18.6% in wet months. In contrast, higher prevalence of 12-18% were reported from Kenya and Tanzania (Onyango et al., 2016; Keyyu et al., 2017) where bimodal rainfall patterns provide more favorable conditions for larval development.

The significantly higher prevalence in males (8.5%) compared to females (4.8%) is consistent with findings from Kenya (Onyango et al., 2016) and Tanzania (Keyyu et al., 2017). This male bias can be explained by several factors. First, androgens have immunosuppressive effects that may increase susceptibility to nematode infection (Soulsby, 2012). Second, male camels are often subjected to greater physiological stress due to long-distance trekking to markets and draught work (Faye, 2019). Third, slaughter data show that males are kept longer and thus have greater cumulative exposure. However, these finding contrasts with Abebe & Yilma (2018) in Ethiopia who found no sex difference, suggesting that under certain management systems, sex may not be a major risk factor.

Age showed a significant association with infection, with prevalence increasing from 5.0% in camels <5 years to 15.0% in those >10 years. This pattern contradicts the typical age-immunity curve observed in sheep where young animals are most susceptible (Soulsby, 2012). In camels, the extended lifespan of 20-25 years and continuous exposure may lead to accumulation of adult worms over time (Tavassoli et al., 2021). Additionally, geriatric camels often have dental problems leading to poor nutrition and compromised immunity (Wernery & Kaaden, 2020). Similar age trends were reported in camels from UAE (Higgins, 2018) and Iran (Tavassoli et al., 2021).

Breed differences were significant, with Darfur camels showing the highest prevalence (10.0%) followed by Butana (6.7%) and Kassala (5.0%). This likely reflects the ecological origin of these breeds. Darfur receives higher annual rainfall 400-800mm compared to Butana 200-400mm, providing better conditions for larval survival (FAO, 2018). Furthermore, Darfur camels are often managed under extensive nomadic systems with minimal anthelmintic use. Breed susceptibility to *Haemonchus* has been well documented in sheep (Baker, 2018) and goats (Chaudhry & Miller, 2017), and our findings suggest similar genetic factors may operate in camels.

Poor body condition was strongly associated with infection (10.8% vs 5.2%). This relationship is bidirectional as described by Eysker & Ploeger (2000). Parasites cause protein loss, anorexia and malabsorption leading to poor BCS, while malnutrition impairs both innate and adaptive immune responses, increasing susceptibility. Nutritional supplementation trials in camels have demonstrated significant reductions in worm burdens (Wernery & Kaaden, 2020), supporting the importance of nutrition in control strategies.

The detection of 15.4% heavy infections >100 worms is of major clinical and economic significance. Each adult female *Haemonchus* can produce 5,000-10,000 eggs per day (Urquhart et al., 2007), meaning heavy infections contribute disproportionately to pasture contamination. From an economic perspective, heavy burdens can lead to anemia, mortality, and carcass condemnation during meat inspection (Gracey et al., 2019; Jones, 2018).

The limitations of this study include reliance on visual inspection which may underestimate low-burden infections (WHO, 2015). Future studies should incorporate coprological examination and molecular tools for species confirmation (Qamar & Maqbool, 2019; Khan et al., 2023). Additionally, anthelmintic resistance is emerging as a problem in camel nematodes (Diakou et al., 2021) and should be monitored.

5 CONCLUSION

This study provides baseline data on *H. longistipes* infection in central Sudan (Slaughterhouse of Tamboul. The 7.0% prevalence with significant risk factors warrants targeted interventions.

Recommendations

- Strategic Deworming: Twice-yearly anthelmintic treatment 4 weeks before and after rainy season, prioritizing males, >10 years, and Darfur breed (Soulsby, 2012).
- Nutritional Management: Supplementary feeding during dry season to improve BCS and immunity (Eysker & Ploeger, 2000).
- Surveillance: Establish routine meat inspection monitoring as an early warning system (Gracey et al., 2019).
- Farmer Education: Training on clinical signs, pasture management and responsible deworming (WHO, 2015).
- Policy: Integrate camel haemonchosis into national animal health programs (FAO, 2018).

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Author contribution

- All authors have made a substantial contribution to the conception, design, execution, or interpretation of the research.
- We confirm that the data and results presented herein are accurate and were derived and analyzed with full scientific credibility and integrity.

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