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The relationship between anemia indicators and intestinal parasitic infections in Iraqi camels

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ABSTRACT

This cross-sectional study investigated the association between anemia indicators and parasitic infections in dromedary camels and assessed variation in hematological parameters according to parasite type, age, sex, body condition score (BCS), and concurrent infection. A total of 225 camels (122 parasitized and 103 uninfected comparison animals) examined at slaughterhouses in Karbala and Najaf, Iraq, between 1 May 2025 and 31 May 2026 were included. Fecal samples were examined by flotation and sedimentation techniques, and blood smears were used to detect Trypanosoma spp. Blood samples were analyzed for total erythrocyte count (RBC), hemoglobin concentration (Hb), and packed cell volume (PCV). Parasitized camels had lower anemia-related hematological indices than uninfected animals. Haemonchus spp.-infected camels showed marked reductions in RBC, Hb, and PCV (6.12±0.70 × 10^6/µL, 8.20±0.85 g/dL, and 20.40±1.90%, respectively) compared with the uninfected group (9.45±0.85 × 10^6/µL, 13.20±1.10 g/dL, and 32.40±2.50%). Young parasitized camels, infected females, and camels with poor body condition showed the lowest hematological values within their respective classifications. Concurrent gastrointestinal parasitism and Trypanosoma infection was associated with the most severe hematological deterioration (RBC 3.90±0.40 × 10^6/µL, Hb 5.40±0.55 g/dL, and PCV 13.10±1.10%). These findings indicate a strong association between parasitic infection and reduced RBC, Hb, and PCV values in camels. Parasite type, age, sex, body condition, and concurrent infection may modify the severity of the anemic profile. Integrated parasitological screening, hematological monitoring, nutritional management, and control of gastrointestinal and blood parasites are recommended.

Keywords: Anemia, Dromedary camel, Gastrointestinal parasites, Hematological parameters, Haemonchus, Trypanosoma.

Introduction

The dromedary camel (*Camelus dromedarius*) is an important livestock species in arid and semi-arid regions and contributes to food security and the livelihoods of pastoral communities through the production of milk and meat and its adaptation to harsh environments (Hoter et al., 2019; Faye, 2020). Despite this remarkable adaptability, parasitic diseases remain an important constraint on camel health, welfare, and productivity (Swai et al., 2011; Salman et al., 2022; Nawaz and Tharwat, 2026).

Gastrointestinal parasites are widely reported in dromedary camel populations and may be associated with subclinical disease, loss of body condition, reduced productivity, and hematological abnormalities (Bekele et al., 2002; Ibrahim et al., 2016; Bouragba et al., 2020; Ahmed et al., 2020). Important gastrointestinal parasites include blood-feeding strongyle nematodes such as *Haemonchus spp*., other gastrointestinal nematodes including *Trichostrongylus spp.*, coccidian protozoa such as *Eimeria spp*., and cestodes such as *Moniezia spp*.

Hemoparasites, particularly Trypanosoma evansi, may coexist with gastrointestinal parasitism and further compromise camel health (Tehseen et al., 2015; Al-Kharusi et al., 2022; Khan et al., 2023).

Anemia is an important hematological manifestation of parasitic disease. Blood-feeding nematodes can cause chronic gastrointestinal blood loss, while intestinal injury, malabsorption, protein loss, and inflammation may impair erythropoiesis and nutritional status. Hemoparasitic infections may additionally contribute to erythrocyte destruction and systemic inflammatory responses (Haroun et al., 1996; Osman et al., 2015; Azeem et al., 2019; Jafari et al., 2023). Consequently, total erythrocyte count (RBC), hemoglobin concentration (Hb), and packed cell volume (PCV) are useful indicators for assessing the hematological consequences associated with parasitic infection.

Previous studies have described gastrointestinal parasite diversity and hematological abnormalities in camels and other camelids (Locklear et al., 2021; Viesselmann et al., 2019). However, fewer studies have simultaneously considered host factors and concurrent gastrointestinal and blood-parasite infections. Therefore, the present study aimed to investigate the association between parasitic infection and anemia indicators in Iraqi dromedary camels and to compare RBC, Hb, and PCV values according to parasite type, age, sex, BCS, and infection pattern.

Materials and Methods

Study design and animals: A cross-sectional study was conducted on dromedary camels examined at slaughterhouses in Karbala and Najaf, Iraq, from 1 May 2025 to 31 May 2026. Based on the numerical distributions reported in the study tables, 225 camels were included: 122 parasitized camels and 103 uninfected comparison animals. Animals were classified according to infection status, age, sex, BCS, and infection pattern. The uninfected animals were used as a comparison group rather than an experimental control group.

Animal classification and clinical assessment: Each camel underwent clinical assessment before sample collection. Animals were classified into three age categories: young (<1 year), adult (1–7 years), and senescent (>7 years). Sex was recorded as male or female. Body condition was categorized as poor/emaciated (BCS ≤2), moderate (BCS =3), or good/excellent (BCS ≥4).

Fecal sample collection and parasitological examination: Fecal samples were collected directly from the rectum into clean, labeled plastic bags and transported under cooled conditions approximately (4°C) for laboratory examination. Standard flotation and sedimentation procedures were used to detect parasitic eggs and oocysts. Parasites were identified microscopically according to their morphological characteristics. The genera considered in the present analysis included *Haemonchus spp., Trichostrongylus spp., Eimeria spp., and Moniezia spp.* (Mohammedsalih et al., 2025; Ray et al., 2023).

For the analysis of infection patterns, animals were classified as having a single infection, a concurrent *Haemonchus spp. and Eimeria spp.* infection, or a mixed infection involving gastrointestinal parasites and *Trypanosoma spp*. thin and thick blood smears were examined microscopically for *Trypanosoma spp*. The limited sensitivity of smear microscopy in animals with low parasitemia should be considered when interpreting negative findings.

Blood sample collection and hematological analysis: Approximately 5 mL of blood was collected from the jugular vein into sterile EDTA tubes. RBC count, Hb concentration, and PCV were determined using routine hematological procedures. RBC was expressed as $\times 10^6$/µL, Hb as g/dL, and PCV as a percentage. The exact analyzer model, manufacturer, country of manufacture, sample-processing interval, and the specific Hb determination method should be inserted from the laboratory record before journal submission.

Statistical analysis: Data were analyzed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA, 2019). Continuous hematological parameters—including total erythrocyte count (RBC), hemoglobin concentration (Hb), and packed cell volume (PCV)-were presented as mean ± standard deviation (±SD). The normality of data distribution and homogeneity of variances were evaluated using the Shapiro –Wilk test and Levene's test, respectively. For comparisons between two independent groups (such as infected vs. uninfected camels, and sex-based comparisons within infection categories), the student's two-sample t-test was applied. For multiple-group comparisons-including parasite species categories (Table 1), age categories (Table 2), body condition scores (Table 4), and single versus concurrent infection patterns (Table 5)-a one-way Analysis of Variance (ANOVA) was performed. When significant differences were identified among groups, Tukey's honest significant difference (HSD) post-hoc test was utilized for pairwise comparisons. All statistical hypotheses were tested as two-tailed, and a $p < 0.05$ was considered statistically significant.

Results and Discussion

Table (1) shows lower RBC, Hb, and PCV values in parasitized camels than in the uninfected comparison group. Among the parasite categories examined, Haemonchus spp. infection was associated with the lowest values (6.12 ± 0.70 ×10⁶/µL, 8.20 ± 0.85 g/dL, and 20.40 ± 1.90%, respectively). This pattern is biologically compatible with the blood-feeding behavior of Haemonchus and chronic gastrointestinal blood loss. Trichostrongylus spp. and Eimeria spp. were also associated with lower hematological indices, potentially through mucosal injury, impaired nutrient utilization, inflammation, and protein loss. Moniezia spp. showed a comparatively milder hematological profile. Similar clinical-pathological abnormalities have been described in camels with gastrointestinal parasitism (Locklear et al., 2021), while epidemiological studies have confirmed the diversity and importance of gastrointestinal parasites in dromedaries (Bouragba et al., 2020; Bekele et al., 2022). Eimeria infection is also well documented in camels (El-Seadawy and Dubey, 2019; Metwally et al., 2020). Because the present study was cross-sectional, these findings should be interpreted as associations rather than proof of a direct causal effect.

Table (1): Distribution of intestinal parasitic infections and anemia indicators in camels

Parasite category	No.	RBC (×10⁶/µL)	Hb (g/dL)	PCV (%)
Uninfected comparison group	103	9.45 ± 0.85	13.20 ± 1.10	32.40 ± 2.50
Haemonchus spp.	60	6.12 ± 0.70	8.20 ± 0.85	20.40 ± 1.90
Trichostrongylus spp.	28	7.40 ± 0.65	10.10 ± 0.90	25.20 ± 2.10
Eimeria spp.	23	7.15 ± 0.80	9.80 ± 1.05	24.80 ± 2.30
Moniezia spp.	11	8.10 ± 0.55	11.40 ± 0.75	28.30 ± 1.85

Table (2) indicates that the hematological profile associated with parasitic infection varied by age. Young parasitized camels had the lowest RBC, Hb, and PCV values, whereas infected adults retained comparatively higher values. Senescent infected camels also showed marked reductions. Greater vulnerability in young animals may be related to immature acquired immunity, rapid growth, and limited physiological reserves. In older animals, reduced physiological resilience, cumulative parasite exposure, and concurrent chronic conditions may contribute to poorer hematological status. Age and other host-related factors have been identified as epidemiologically relevant in camel parasitic infections (Fikru et al., 2015; Selim et al., 2022; Bekele et al., 2022). The present data therefore suggest greater hematological vulnerability at the youngest and oldest age categories; however, formal interaction testing is required before describing a statistically confirmed U-shaped pattern.

Table (2): Age categories and parasite-associated anemia indicators

Age category	Status	No.	RBC (×10⁶/µL)	Hb (g/dL)	PCV (%)
Young (<1 year)	Uninfected	35	9.10 ± 0.65	12.80 ± 0.95	31.10 ± 2.10
Young (<1 year)	Parasitized	42	5.02 ± 0.50	7.10 ± 0.60	18.10 ± 1.40
Adult (1–7 years)	Uninfected	50	9.60 ± 0.70	13.50 ± 1.00	33.20 ± 2.20
Adult (1–7 years)	Parasitized	55	7.30 ± 0.85	10.40 ± 1.15	25.90 ± 2.80
Senescent (>7 years)	Uninfected	18	9.20 ± 0.90	12.90 ± 1.20	31.80 ± 2.60
Senescent (>7 years)	Parasitized	25	5.90 ± 0.75	8.40 ± 0.95	21.20 ± 1.95

Table (3) shows lower RBC, Hb, and PCV values in parasitized animals of both sexes, with a more pronounced reduction in females. Infected females had RBC, Hb, and PCV values of 5.80 ± 0.80 ×10⁶/µL, 8.10 ± 1.10 g/dL, and 19.90 ± 2.40%, compared with 6.85 ± 0.70 ×10⁶/µL, 9.50 ± 0.85 g/dL, and 23.60 ± 1.90% in infected males. Pregnancy and lactation could increase nutritional and hematopoietic demands; however, reproductive status was not reported in the present dataset and therefore should not be assumed to explain the observed difference. Previous studies have considered sex and reproductive consequences among host-related aspects of camel trypanosomosis (Gutierrez et al., 2006; Fikru et al., 2015; Selim et al., 2022; Khan et al., 2023). Further multivariable analysis is needed to determine whether sex independently predicts the severity of anemia after adjustment for age, BCS, parasite type, and reproductive status.

Table (3): Sex and hematological parameters during parasitic infection

Sex	Status	No.	RBC (×10⁶/µL)	Hb (g/dL)	PCV (%)
Females (She camels)	Uninfected	65	9.35 ± 0.75	13.00 ± 0.95	32.10 ± 2.30
Females (She camels)	Parasitized	72	5.80 ± 0.80	8.10 ± 1.10	19.90 ± 2.40
Males	Uninfected	38	9.55 ± 0.80	13.40 ± 1.05	32.80 ± 2.45
Males	Parasitized	50	6.85 ± 0.70	9.50 ± 0.85	23.60 ± 1.90

Table (4) demonstrates a graded association between BCS and anemia indicators among parasitized camels. Poor or emaciated animals had the lowest RBC, Hb, and PCV values, whereas animals in good or excellent body condition had higher values. Poor body condition may be both a consequence and a modifier of chronic parasitism because reduced intake, malabsorption, protein loss, and chronic inflammation can coexist with impaired immune and erythropoietic responses. Clinical and pathological abnormalities associated with gastrointestinal parasitism have been reported in camels (Locklear et al., 2021), and the broader welfare consequences of parasitic disease have recently been emphasized (Nawaz and Tharwat, 2026). BCS may therefore be a useful field-level screening indicator, but it cannot replace parasitological and hematological confirmation.

Table (4): Body condition score and anemia indicators in parasitized camels

BCS group	Status	No.	RBC (×10⁶/µL)	Hb (g/dL)	PCV (%)
Poor/emaciated (≤2)	Parasitized	48	4.85 ± 0.45	6.90 ± 0.70	17.20 ± 1.30
Moderate (=3)	Parasitized	54	6.90 ± 0.60	9.20 ± 0.85	22.80 ± 1.95
Good/excellent (≥4)	Parasitized	20	8.20 ± 0.55	11.50 ± 0.90	27.90 ± 1.60

Table (5) compares selected infection-pattern groups. Single *Haemonchus spp.* infection was associated with lower hematological indices than single *Eimeria spp.* infection. Concurrent *Haemonchus spp. and Eimeria spp*. infection showed a more severe anemic profile, and the lowest RBC, Hb, and PCV values occurred in camels with gastrointestinal parasitism and Trypanosoma infection. Gastrointestinal blood loss, intestinal injury, malabsorption, and protein depletion may combine with the systemic hematological consequences of trypanosomosis, producing a greater overall burden. The hematological importance of *T. evansi* in dromedary camels is supported by previous investigations (Gutierrez et al., 2006; Tehseen et al., 2015; Boushaki et al., 2019; Jafari et al., 2023). Molecular and epidemiological studies also confirm the continuing importance of camel trypanosomosis across different geographical regions (Mirshekar et al., 2019; Al-Kharusi et al., 2022; Khan et al., 2023). These results support screening severely anemic camels for concurrent gastrointestinal and blood-parasite infections. The groups in Table 5 represent selected infection patterns and should not be summed to infer the overall prevalence of infection.

Table (5): Anemia indicators in selected single and concurrent infection patterns

Infection pattern	No.	RBC (×10⁶/µL)	Hb (g/dL)	PCV (%)
Single *Haemonchus spp.*	60	6.12 ± 0.70	8.20 ± 0.85	20.40 ± 1.90
Single *Eimeria spp.*	23	7.15 ± 0.80	9.80 ± 1.05	24.80 ± 2.30
Haemonchus spp. + Eimeria spp.	18	4.20 ± 0.50	6.05 ± 0.65	14.90 ± 1.15
GI parasites *+ Trypanosoma spp.*	12	3.90 ± 0.40	5.40 ± 0.55	13.10 ± 1.10

Conclusions

Parasitic infection was associated with reductions in RBC count, Hb concentration, and PCV in Iraqi dromedary camels. The lowest hematological indices were observed in Haemonchus-associated infection, young parasitized camels, infected females, animals with poor body condition, and camels with concurrent gastrointestinal and Trypanosoma infections. The cross-sectional design does not establish causality, and the independent effects of host and infection-related factors require appropriate inferential and multivariable statistical analyses. Routine parasitological examination, hematological monitoring, nutritional assessment, and integrated control of gastrointestinal and blood parasites may help reduce the burden of anemia and improve camel health and welfare.

Recommendations

1. Veterinary Practice: Routine parasitological and hematological screening, targeted deworming, nutritional support, and screening for mixed infections in anemic camels.

2. Future Research: Longitudinal and therapeutic studies, quantitative parasitology (egg counts, qPCR), molecular characterization, and multivariable analysis including reproductive status.

3. Policy and Training: National surveillance, field diagnostic capacity building, and community awareness on husbandry and One Health approaches.

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