Phenotypic Indicators and Managerial Factors Associated with Gastrointestinal Parasites in Native and Blended Goats in Semi-arid Areas of Central Tanzania

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SUMMARY

Goats raised in semi-arid areas under traditional extensive systems are more susceptible to gastrointestinal parasitic (GIP) infestation due to poor management practices. A cross-sectional study was conducted from February to April 2025 to identify phenotypic indicators and management factors associated with GIP among goat farmers in Mpwapwa District. A total of 110 farmers were randomly selected and interviewed using a structured questionnaire. Additionally, 200 blood and faecal samples were collected for goat health assessments. The intensity of infestation was not affected by age, sex, breed, or physiological status of goats (p>0.05). PCV and BCS, and their interactions with log (FEC), were not statistically associated (p>0.05), indicating no difference in resilience between the two goat breeds. However, physiological status significantly influenced BCS relative to FEC levels, whereas effects on PCV were not statistically significant. Gogo breed and female sex were 54% and 63% less likely to be infected than Blended and male sex, respectively (p<0.05). Goats housed in open shelters had 25.93 times greater odds of falling into a higher infestation category than those in sheds and barns. Daily sanitation was associated with a lower risk of severe infestation (p<0.05). Dry does showed a significant reduction in infestation levels, whereas lactating does had higher odds of infestation (p<0.05). For effective control of GIP, proper management practices and a breeding programme based on resilient genotypes are recommended. Further research targeting molecular genetic factors influencing GIP with larger sample sizes and longitudinal monitoring is emphasised.

Keywords: Gastrointestinal parasite, phenotypic indicator, resilience, resistance, Managerial practice, Breed, Goat.

Article History

***Submitted: 24* Feb 2026**
Revised: 18 May 2026
Accepted: 19 May 2026
Published: 21 May 2026

Tanzania Veterinary Journal Vol. 40(2) 2025
https://doi.org/10.4314/tvj.v41i1.7
ISSN: 0856 - 1451 (Print)
ISSN: 2714-206X (Online)
https://tvj.sua.ac.tz

INTRODUCTION

Goat production plays an essential role in income generation, creating job opportunities, improving food security, and boosting household nutrition, while also supporting the inclusion of youth and women (Michael *et al.*, 2018). A combination of quick wins, genetically-based technologies, a growing human population, and increased nutritional awareness has driven up the demand for livestock products, encouraging farmers to transition from traditional livestock-keeping methods to modern systems that use specialised breeds, such as crosses and purebreds (Mruttu *et al*., 2017). However, the growth of the livestock sector in Tanzania continues to be characterised by increases in livestock numbers rather than productivity gains, resulting in a limited contribution to the national economy (World Bank Group, 2024). This is caused by limiting factors, including the use of low-yield breeds, water and feed shortages due to climate change, limited farmer knowledge, insufficient extension services, and the widespread presence of diseases, including gastrointestinal parasitism (MLF, 2022).

Gastrointestinal parasitic infections pose a significant threat to livestock populations and production in tropical regions, especially within smallholder settings, with reports indicating that 95% of small ruminants are affected by parasitic infestations (Challaton *et al*., 2023). Gastrointestinal parasite (GIP) causes mortality, particularly in young flocks, leading to substantial economic losses. It also reduces animal performance by decreasing feed intake, weight gain, and suppressing immune function (Fayisa *et al*., 2020). The control of GIP requires not only understanding the risk factors that influence their occurrence but also the ability to identify early signs of infestations and assess the health status of affected animals. In many smallholder settings, farmers rely on indigenous knowledge to identify and recognise symptoms associated with GIP in goats, including anaemia, rough hair, and body condition (Chimonyo, 2024).

Estimation of faecal egg count (FEC), packed cell volume (PCV), and body condition score (BCS) is an essential veterinary practice for assessing animal health and parasitic intensity in a clinical setting (Glaji *et al*., 2013). Phenotypic indicators such as parasitological and pathological markers are employed to evaluate the health status of goats and their potential resilience and resistance to GIP infestation (Bishop, 2012; Mpofu, 2022). FEC serves as a phenotypic marker and a secondary indicator of worm burden, reflecting the level or intensity of parasitic infestation and providing a direct measure of pasture contamination (Saddiqi *et al*., 2012). PCV is a pathological marker, alongside BCS, used to determine the volume of circulating red blood cells and estimate anaemic conditions associated with high parasitic burdens and blood-sucking parasites (Glaji *et al*., 2013). The normal range of PCV in goats is between 22-38% and 27-45%, with values below 22% indicating anaemia and reduced resilience to GIP (Glaji *et al*., 2013; Onzima *et al*., 2017; Mpofu, 2020). BCS is measured on a 1-5 scale and is a useful indicator of animal health, with lower scores linked to higher parasitic burdens (Paul *et al*., 2020). Increased FEC values correlate with decreased PCV and BCS, negatively impacting the health of goats (Saddiqi *et al*., 2012). Conversely, lower FEC is associated with higher PCV and BCS, suggesting improved resilience and resistance to GIP (Bishop, 2012).

Limited knowledge among farmers, especially in smallholder settings, raises the rate of infestations because many farmers struggle to recognise the effects of GIP, which leads to immunosuppression and increased susceptibility of goats to other diseases (Dugassa *et al*., 2018). This is linked to poor managerial practices, such as nutrition, housing, grazing, vaccination, and deworming activities (Wani & Allaie, 2016). Understanding phenotypic indicators of animal health is only one aspect of managing GIP. However, the occurrence and severity of infections are also significantly influenced by how goats are managed within their production environments (Koyan *et al*., 2025). Managerial practices such as grazing systems, housing conditions, feeding strategies, and deworming routines determine both the level of exposure to infective stages of parasites and the animals' ability to resist or recover from infestations. Therefore, connecting phenotypic indicators with management factors provides a more comprehensive understanding of gastrointestinal parasitism and its control in smallholder production systems.

In pastoral and agropastoral communities, the traditional extensive grazing system is commonly practised, and it is strongly linked to an increased risk of infestations, as animals are continually exposed to infected pastures (Mramba and Mapunda, 2023). Conversely, a rotational grazing system based on an epidemiological understanding of parasitic life cycles has been demonstrated to reduce the frequency of GIP in goats (Nor-Azlina *et al*., 2011). The nutritional value of forages in communal rangelands is relatively low, making them less effective in meeting the nutritional requirements of animals (Rogers *et al*., 2020). Proper nutrition plays a vital role in reducing goats' susceptibility to parasitic infestations by supporting overall health and bolstering the immune system (Mramba and Mapunda, 2023). Goats under a plane of nutrition can better withstand the effects of worm infestations compared to those subjected to poor nutrition (Nor-Azlina *et al*., 2011).

Control of GIP in most smallholder farmers relies heavily on anthelmintic drugs, whose effectiveness is often constrained by factors such as limited availability, high cost, and anthelmintic resistance (Namutosi *et al*., 2020). Poor deworming practices result from irregular application, incorrect dosing, and a lack of drug rotation, collectively leading to production loss and increased treatment cost to goat farmers (Wondimu, 2022). Goats tend to develop resistance more quickly than other ruminants, as they can metabolise and eliminate these antihelmintics more efficiently (Rufino-Moya *et al*., 2024). Vaccination against GIP, especially nematodes, is both effective and safe, with no residues or environmental pollution (Adduci *et al*., 2022), but its use remains limited due to availability and cost. Additionally, the integrated parasite management (IPM) approach emphasises non-chemical methods for controlling GIP, such as proper management, utilisation of clean and safe pastures, grazing strategies, nutritional management, and selective breeding for resistance (Wani & Allaie, 2016). However, the successful adoption of these approaches largely depends on the local production environment and farmers' management capacity, which vary significantly across different ecological zones in Tanzania. Understanding how these factors interact in specific settings is crucial for designing practical, location-specific control strategies.

The semi-arid environment of Mpwapwa District is heavily affected by climatic uncertainty, currently receiving adequate rainfall two years out of every seven, thereby making livestock production a key economic activity (Mengele, 2023). Nonetheless, productivity still falls short of its potential due to challenges such as parasitic infestations and management issues, often linked to farmers' knowledge of improved goat husbandry practices (Komwihangilo *et al*., 2012). Consequently, the study was conducted to identify the phenotypic indicators and management factors associated with GIP in goats raised by smallholder farmers in Mpwapwa District. This will help improve goat production, as the information can be used to establish criteria for selective breeding based on resilience and resistance to GIP.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Mpwapwa District, Dodoma Region, central Tanzania, during the rainy season from February to April 2025. The district lies between latitude 6.567° South of the Equator and longitude 36.600° East of Greenwich, covering an area of 7489 square kilometres, and is located 120 km from Dodoma headquarters. Goat production is one of the key economic activities in the district, contributing nearly 45% of the district's GDP (Mengele, 2023). According to Philipo *et al*. (2024), the estimated population of goats in the district is 302,561. Furthermore, Ngongolo & Mmbaga (2022) reported that 99% of the goat population belongs to the indigenous breed, with the remining 1% comprising improved breeds.

Study design and sample size determination

This was a cross-sectional study carried out purposely to determine phenotypic indicators and managerial factors associated with the occurrence of GIP in goats. The study population involved goat farmers who keep Blended and/or native (Gogo) in a traditional extensive management system with no deworming routine for eight to ten weeks before sampling. The sampling approach employed was a multistage sampling technique, combining both purposive and random sampling procedures. Three wards were selected purposively within the district based on the population of the two goat breeds and the availability of accessible infrastructure. Then, three villages within each ward were also chosen purposely based on the population of the two breeds. The chosen wards were Mazae, Mjini, and Chunyu. Households were randomly selected using systematic sampling, and within households, individual goats were randomly chosen for blood and faecal sample collection (Mgalla *et al*., 2025). The number of animals sampled was estimated using the formula described by Thrusfield (1995), given as $n=1.96^2.p.q/L^2$, where n = sample size, p = expected prevalence, q = 1-p, and L = absolute precision at a 95% confidence interval. The expected prevalence of 85% was used for worm infection, leading to a total of 200 goats being sampled, of which 94 were Blended, and 106 were Gogo goats.

Data collection

Field and laboratory methods were used to collect information about the epidemiological, management, and physiological factors influencing the occurrence of GIP. The recorded field parameters included breed, age, sex, BCS, physiological status (breeding bucks, dry does, lactating does, pregnant does, and weaners), and household details obtained through a structured questionnaire. Laboratory data, such as FEC/OPG and PCV, were measured after analysing blood and faecal samples collected from two goat breeds.

Determination of faecal egg count/oocyst per gram

A fresh faecal sample, approximately 10g, was collected directly from the rectum of a live animal using a gloved index finger, wrapped, labelled, and immediately put in a cool box with ice packs before being transported to the laboratory at Sokoine University of Agriculture (SUA), College of Veterinary Medicine and Biomedical Sciences (CVMBS) for parasitological analysis. For nematode, cestode, and coccidia oocysts, a simple floatation method was used to separate eggs from faecal material and concentrate them using sodium chloride as a floatation fluid with an appropriate specific gravity (Hansen & Perry, 1994). For trematode eggs, the sedimentation method was used, as most of the trematode eggs are relatively larger and heavier (Hansen & Perry, 1994). In the presence of one or more parasitic eggs, a sample was considered positive and subjected to quantitative analysis using a two-chambered simple McMaster technique with a sensitivity of 50 eggs/oocysts per gram. By using a 100x magnification, the total number of eggs/oocysts was calculated separately inside the grid area in both chambers (C_1+C_2) x 50, as suggested by Paul *et al*. (2020). The intensity of infestation based on FEC was then categorised as light, moderate, or heavy according to the range of less than 500, between 500 and 1000, and over 1000, respectively (Rani *et al*., 2020).

Determination of packed cell volume

Using sterile needles, 5 mL of blood was collected from goats at the jugular vein and placed into EDTA-coated tubes. The tubes were stored in a cool box with ice packs and transported to Morogoro at SUA- CVMBS for pathological analysis. PCV was determined within 24 hours of blood collection using the microhaematocrit centrifugation (MHC) technique. Microhaematocrit tubes were filled with fresh blood in duplicate and sealed at one end with a sealer. Centrifugation was carried out at 2000 rpm for 5 minutes. A microhaematocrit reader (PCV reader) was used to determine the PCV value as a percentage of the sample's average.

Determination of body condition score

The BCS was assessed on a 1 to 5 scale, with a score below 2 indicating poor or emaciated, between 2 and 3 indicating normal or good, and above 3 indicating fat or obese goat, according to (Moje *et al*., 2021). The BCS was determined by palpating the amount of fat covering the lumbar region and the fat pad at the sternum. Two individuals conducted the BCS throughout the study to ensure consistency, and the average score was used.

Household Survey

A total of 110 farmers were visited and interviewed. The selected farmers were recognised by their names, and animals were identified by their physical features, such as white colour (Gogo) and droopy ears (Blended). A structured questionnaire comprising both open and closed-ended questions was used to collect data on socio-demographic aspects of households, goat housing, feeding strategies, diseases, and parasite management practices, deworming activities, knowledge about GIP, training, and education levels of farmers. Visual observations of the goat housing were also recorded.

Statistical Analysis

Data were analysed using IBM SPSS (version 27, 2020). Descriptive statistics were used to summarise the households' demographic information, management practices and overall trends in GIP infestation. Because GIP involves multiple biologically distinct processes, different statistical models were applied to address complementary research questions. Specifically, the analyses were structured to distinguish between host physiological response to parasite burden (resilience/tolerance), likelihood of infection (susceptibility), and severity of infestation among infected goats. Phenotypic resilience to GIP infestation was assessed using a tolerance-based framework by modelling packed cell volume (PCV) and body condition score (BCS) as continuous responses to parasitic burden using a General Linear Model (GLM):

$$Yijkl=\mu+Bi+Sj+Ak+Pl+\log(FEC)+(Bi \times \log(FEC))+\varepsilon ijkl,$$

Where *Y* represents PCV or BCS, *Bi* is breed, *Sj* is sex, *Ak* is age group, *Pl* is physiological status, and *εijkl* is the random error term. Adjusted means (LSMeans ± SE) were estimated across biological factors. Due to linear dependence on other class variables in the model, especially sex and age group, pregnant and weaner goats were assigned as reference categories and set as redundant (multicollinearity effect).

A multivariable binary logistic regression model was employed to identify factors associated with the likelihood of GIP. The model incorporated both animal-level factors and management-level factors (including BCS monitoring, quarantine, access to training, and access to information) as independent variables:

$$Log\ (p/1\text{-}p)= \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta n X n + \varepsilon jkl,$$

Where *p* denotes the probability of being infected or not, βo represents the intercept, $X_{1\text{-}n}$ are the predictor variables, and *εjkl* accounts for the residual random error. Results were expressed as odds ratios (OR) with 95% confidence intervals.

Moreover, ordinal logistic regression analysis was used to determine infestation severity among infected goats, with infestation intensity classified as light, moderate, or heavy based on FEC/OPG thresholds:

$$Logit\ [P(Y \leq j)]=\alpha j\text{-}(\beta_1 x_1+\beta_2 x_2 \ldots\ldots \beta n x n+ \varepsilon jkl),$$

Where *Y* indicates the infestation category, *j* is the threshold level, *αj* signifies the cutoff or intercept, *β* represents the coefficients of predictor variables X_1, X_2, X_n (*i.e.*, animal-level and management-level factors), and *εjkl* is the random residual error. Model parameters (β) were estimated via maximum likelihood estimation, with results expressed as odds ratios (OR = e^β) alongside 95% confidence intervals. A positive coefficient suggests that higher values of the predictor variable increase the odds of a goat falling into a higher infestation category. In contrast, a negative coefficient indicates a decrease in odds, corresponding to a lower category. The proportional odds assumption (parallel line test) was assessed and found to be satisfactory ($p>0.05$).

RESULTS

General characteristics of the households

Household participation in this study consisted of 80% males and 20% females, with the majority having a primary school education (70.9%) and 1.8% possessing post-secondary education. About 97.4% of goat farmers in the study area rely on communal grazing lands where goats share rangeland resources with other animals, including cattle, sheep, and donkeys, with only 4.5% practising a rotational grazing system. The majority of the farmers (90%) were self-employed in livestock keeping and crop cultivation, as shown in Table 1.

Table 1: General characteristics of the households

Characteristics	*Variables*	*Number (n=110)*	*Percentage (%)*
Geo-location (ward)	Chunyu	35	31.8
	Mazae	45	40.9
	Mjini	30	27.3
Gender	Male	88	80.0
	Female	22	20.0
Age group	18-35	31	28.2
	36-45	41	37.3
	46& above	38	34.5
Education level	No formal education	18	16.4
	Primary school	78	70.9
	Secondary school	12	10.9
	Tertiary education	2	1.8
Employment status	Employed	4	3.6
	Self-employed	90	81.8
	Un-employed	16	14.5
Land ownership	Communal	107	97.3
	Private	3	2.7

Mean age = 42, Median = 42, Mode = 35, Minimum = 18, Maximum = 65

Farm management characteristics of goat farmers in Mpwapwa District

The farming characteristics of the interviewed households indicated that about 83.4% of them did not supplement their goats; they relied solely on grazing pastures and fodders. The remaining provided their herd with mineral blocks, protein-rich feed, and concentrates such as maize bran. Only 26.4% of farmers received training on proper management practices of goats, with 71.8% of them practising deworming. Most farmers interviewed (66.4%) cleaned their goat houses every week, with the majority keeping their herds in shed-type housing, as shown in Table 2.

Table 2: Farm management characteristics

Characteristics	*Variables*	*Number (n=110)*	*Percentage (%)*
Access to training	Yes	29	26.4
	No	81	73.6
Feed supplementation	Yes	18	16.4
	No	92	83.6
Grazing type	Rotation	5	4.5
	No rotation	105	95.5
Deworming practice	Yes	79	71.8
	No	31	28.2
Housing type	Barns	18	16.8
	Sheds	70	63.6
	Open shelter	22	20.0
Sanitation routine	Daily	12	10.9
	Weekly	73	66.4
	Every month	6	5.5
	Not frequently	19	17.3

Intensity of parasitic infestation in examined goats

Based on the adopted range of FEC/OPG, the intensity of GIP in goats was classified as light, moderate, and heavy infestations. The overall trends in the intensity of parasitic infestation indicated that 70.7%, 25.2%, and 4.1% of examined goats were lightly, moderately, and heavily infested with GIP, respectively (Figure 2). Unadjusted comparisons showed no significant differences (p>0.05) in infestation intensity across breed, age, sex, physiological status and BCS.

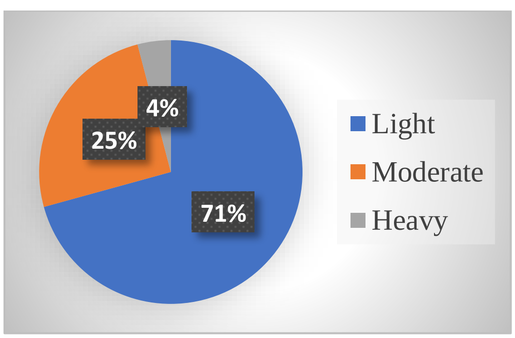

Figure 1: Overall trend of gastrointestinal parasitic intensity in examined goats

Adjusted means of PCV and BCS across biological groups of goats

The adjusted mean BCS varied significantly with sex and physiological status (p<0.05) but not with breed type or age group of goats (Table 3). Males had a significantly higher BCS (2.67 ± 0.19) than female goats (2.08 ± 0.06). Breeding bucks recorded the highest score (3.08 ± 0.49), followed by pregnant (2.50 ± 0.17) and lactating goats (2.10 ± 0.13). Dry does exhibited the lowest score (1.93 ± 0.14), while weaners had an intermediate score (2.17 ± 0.09). Breed-wise, Blended goats recorded a higher score (2.36 ± 0.10) than Gogo (2.17 ± 0.11), but the difference was not statistically significant (p>0.05). Regarding age, adults recorded a higher score (2.33 ± 0.10) than young goats (2.17 ± 0.09), and the difference was not significant (p>0.05). PCV was not influenced by breed, age, sex or physiological status (p>0.05) as indicated in Table 3. PCV was similar between Blended (25.00 ± 0.50) and Gogo goats (25.43 ± 0.57). Adults (25.52 ± 0.90) recorded slightly higher PCV values than young goats (24.69 ± 0.80). Likewise, PCV values were comparable between females (25.10 ± 0.50) and male goats (25.53 ± 1.71). Regarding the physiological status category, no statistical significance was noted (p>0.05).

Table 3: Adjusted means (LS Means ± SE) of BCS and PCV across biological groups of goats

Factor	Category	BCS (Mean ± SE)	P-value	Category	PCV (Mean ± SE)	P-value
Breed	Blended	2.36 ± 0.10	0.238	Blended	25.00 ± 0.52	0.605
	Gogo	2.19 ± 0.11		Gogo	25.40 ± 0.57	
Age group	Adult	2.33 ± 0.10	0.228	Adult	25.52 ± 0.90	0.493
	Young	2.17 ± 0.09		Young	24.69 ± 0.81	
Sex	Female	2.08 ± 0.06[b]	0.04*	Female	25.10 ± 0.50	0.811
	Male	2.67 ± 0.19[a]		Male	25.53 ± 1.71	
Physiological status	Dry does	1.93 ± 0.144[c]	0.034*	Dry does	24.82 ± 1.22	0.958
	Buck	3.08 ± 0.49[a]		Buck	26.49 ± 4.45	
	Lactating	2.10 ± 0.133[ac]		Lactating	25.22 ± 1.20	
	Pregnant	2.50 ± 0.17[ab]		Pregnant	25.87 ± 1.54	
	Weaner	2.17 ± 0.09[ac]		Weaner	24.69 ± 0.81	

*Notes: PVC=Packed cell volume, BCS = Body condition score, *=values are statistically significant at p<0.05, ab=values with different letters in the same column differ significantly at p<0.05.*

PCV and BCS as indicators of resilience against GIP infestation

PCV and BCS were analysed as indicators of resilience to GIP infestation using FEC as a measure of parasitic burden in goats (Table 4). Parasitic burden had a negative but non-significant association with PCV (β = -1.112, p = 0.109), indicating a tendency for PCV to decline with increasing infestation levels. Blended goats did not differ significantly (p>0.05) from Gogo in baseline PCV. Importantly, the Breed × log (FEC) interaction was also found not significant (p>0.05), indicating that PCV as a measure of tolerance declined at a similar rate with increasing FEC in both goat breeds. Sex, age, and physiological status did not significantly influence PCV (p>0.05). BCS was not significantly affected by increasing parasitic burden (β = 0.012, p = 0.783). Similarly, breed had no significant effect on BCS, with Blended goats showing comparable scores to Gogo (p>0.05). The Breed × log (FEC) interaction was not significant (p>0.05), indicating that Blended and Gogo goats did not differ in maintaining their body conditions, suggesting similar tolerance levels to GIP infestation. In contrast, several biological factors significantly influenced BCS. Sex indicated that female goats had significantly lower scores than males (p<0.05). Age-wise, adults were recorded with significantly higher scores than young goats (p<0.05). Physiological status also significantly influenced BCS, with dry does showing lower scores compared to other counterparts (p<0.05).

Table 4: PCV and BCS responses as indicators of resilience to GIP infestation in goats

		Variables							
		PCV				BCS			
Effect	Parameter	Estimate (β)	Std. Error	t	Sig.	Estimate (β)	Std. Error	t	Sig.
	Intercept	28.494	1.640	17.294	0	2.158	0.183	11.787	0
	FEC	-1.112	0.690	-1.611	0.109	0.021	0.077	0.276	0.783
Breed	Blended	-0.256	2.180	-0.117	0.907	0.112	0.243	0.461	0.645
	Gogo	0[a]				0[a]			
Sex	Femae	-0.877	1.058	-0.829	0.408	-0.289	0.118	-2.463	0.015
	Male	0[a]				0[a]			
Age	Adult	0.767	0.729	1.053	0.294	0.246	0.810	3.039	0.003
	Young	0[a]				0[a]			
Physiological status	Dry does	-0.253	1.091	-0.232	0.817	-0.38	0.121	-3.139	0.002
	Buck	-0.91	2.090	-0.453	0.651	0.23	0.223	1.033	0.303
	Lactating	-0.549	0.865	-0.634	0.527	-0.109	0.110	-1.136	0.257
	Pregnant	0[a]				0[a]			
	Weaner	0[a]				0[a]			
*Breed*log FEC*	Blended * log FEC	-0.041	0.098	-0.042	0.967	0.038	0.080	0.353	0.725
	Gogo * log FEC	0[a]				0[a]			

a. This parameter is set to zero because it is redundant

Managerial practices of goat farmers associated with the likelihood of parasitic infestation

A binary logistic regression revealed that breed and sex of goats were significantly associated with the likelihood of GIP infestation ($p<0.05$) (Table 5). Gogo goats were 54% less likely to be infected than to Blended (OR=0.46, C.I=0.24-0.884). Female goats had 63% lower odds of infestation than males (OR=0.371, C.I=0.139-0.991, p=0.048). Goats with poor body condition had a tendency ($p<0.1$) for increased likelihood of infestation, 6.83 times more than their counterparts. Furthermore, none of the management-related variables, such as quarantine, BCS monitoring, and access to training and information, were significantly associated with the likelihood of parasitic infestation ($p>0.05$).

Table 5: Binary logistic regression analysis of factors associated with GIP infestation in goats

Factor	Coefficient (β)	S. E	Wald	Sig.	Exp (B)	95% C.I. for Exp (B) Lower	Upper
Breed	-0.776	0.333	5.437	0.020*	0.460	0.24	0.884
Sex							
Male	2.029	0.401	0.067	0.872	7.606	0.675	26.217
Female	-0.992	0.502	3.915	0.048*	0.371	0.139	0.991
BCS monitoring							
Yes	-1.970	0.402	0.523	0.244	0.139	0.124	0.814
No	-0.585	0.444	1.732	0.188	0.557	0.233	1.331
Quarantine	0.227	0.562	0.163	0.686	1.255	0.417	3.775
Access to training							
Yes	1.197	1.533	0.610	0.435	3.311	0.164	66.795
No	0.082	0.415	0.039	0.843	1.086	0.481	2.45
Access to information	0.299	0.370	0.654	0.419	1.349	0.653	2.788
Age group	0.301	0.380	0.627	0.428	1.351	0.642	2.845
BCS categories							
Good	1.492	1.164	1.644	0.200	4.445	0.454	43.483
Normal	1.829	1.174	2.427	0.119	6.227	0.624	62.171
Poor	1.921	1.113	2.979	0.084	6.829	0.771	60.52
Constant	-1.531	1.278	1.434	0.231	0.216		

Ordinal logistic regression revealed that physiological status, housing type, and sanitation frequency were significant predictors of infestation levels (Table 6). Dry does were noted to be less likely (OR=0.05, P=0.0004) to belong to a higher infestation category. Likely lactating does were recorded to have a significantly higher chance (OR=3.279, P=0.0493) of being in a higher infestation category. Goats kept in open shelter were 26 times more likely to belong to a higher infestation category (OR=25.93, P=0.006) than those housed in sheds and barns. Daily sanitation was associated with a reduced chance of high infestation by 91% (OR=0.09, P=0.044), whereas monthly sanitation routines showed a tendency ($p<0.1$) of reduced chance of higher infestation. Other factors such as age, breed, sex, supplementation, deworming, training, and grazing type were not significant predictors of the extent of GIP infestation ($p>0.05$). Additionally, the main coping strategies employed by farmers in the study area to manage GIP in goats included regular treatments, deworming, adherence to the required managerial routines, supplementation, and culling of sick animals.

Table 6: Ordinal logistic regression analysis of managerial factors associated with the likelihood of GIP in goats

Variable	Category	Estimate(β)	S. E	Wald (F)	p-values	OR	95% C.I	
							Lower Bound	Upper Bound
Age group	Adult	-0.215	0.395	0.298	0.585	0.809	-0.989	0.558
	Young	0						
Breed	Gogo	-0.404	0.334	1.467	0.226	0.667	-1.059	0.249
	Blended	0						
Sex	Male	-0.086	0.600	0.021	0.886	0.917	-1.263	1.090
	Female	0						
Physiological Status	Dry does	-2.986	0.840	12.633	0.0004**	0.05	-4.632	-1.339
	Breeding buck	2.322	3.257	0.508	0.476	10.194	-4.062	8.705
	Lactating does	1.188	0.604	3.867	0.049*	3.279	0.004	2.371
	Pregnant does	0						
	Weaner	0						
Deworming	Yes	-0.173	0.406	0.181	0.671	0.842	-0.969	0.623
	No	0						
Grazing type	Rotation	-1.828	1.132	2.609	0.106	0.161	-4.046	0.390
	No rotation	0						
Type of housing	Sheds	0.887	0.606	2.151	0.142	2.429	-0.298	2.073
	Open shelter	3.255	1.185	7.542	0.006**	25.929	0.932	5.579
	Barns	0						
Supplementation	Yes	-0.167	0.437	0.145	0.703	0.846	-1.024	0.690
	No	0						
Sanitation	Monthly	-0.724	0.443	2.669	0.102	0.485	-1.593	0.144
	Weekly	-1.119	0.796	1.977	0.159	0.327	-2.679	0.441
	Daily	-2.375	1.178	4.068	0.044*	0.09	-4.683	-0.067
	Not frequent	0						
Training access	Yes	-0.779	0.624	1.558	0.212	0.459	-2.003	0.445
	No	0						

DISCUSSION

The generally high level of infestation confirms that gastrointestinal parasitism remains a significant challenge impacting goats' health and overall productivity, consistent with the report by Challaton *et al*. (2023). The trend of infestations indicated that goats in the study area were lightly, moderately, and a few were heavily infested, with the majority maintaining fat and normal body conditions. Since there was no statistical support regarding the difference in intensity of infestation among the two breeds, no definitive conclusions about genetic resistance to infection can be drawn from this dataset. However, although not demonstrated in the present study, previous studies have reported that indigenous breeds, such as the Gogo goat, often exhibit greater adaptive resistance to endemic parasites compared with crossbred populations (Verma *et al*., 2018; Ngongolo & Mmbaga, 2022; Onzima *et al*., 2017).

Regarding sex, the high adjusted means BCS was recorded in male goats compared to females. This was attributed to increasing stress and physiological demands in female goats, which deplete body reserves (Moje *et al*., 2021). In the physiological category, breeding bucks and pregnant does recorded the highest scores compared to weaners and dry does. Breeding bucks generally exhibit a higher BCS due to their lower physiological demands compared to dry does or weaner goats, which relates to sex differences and an underdeveloped immune system (Verma *et al*., 2018; Moje *et al*., 2021). On the other hand, pregnant does maintained higher scores, possibly reflecting increased nutritional requirements during pregnancy as reported by Nor-Azlina *et al*. (2011). Despite the differences observed in BCS, PCV remained unaffected across all physiological categories, indicating that none of the groups experienced clinically significant anaemia. This could again be explained by the fact that over 70% of the farmers practised regular deworming, as reflected by the low infestation level (Table 2).

PCV, as an indicator of resilience, showed a negative association with increased parasitic burden, suggesting that parasitic infestation did not induce marked anaemia in the studied population. Nonetheless, as the infestation level increases, there was a marked decline in PCV values, as also supported by Paul *et al*. (2020) and Mpofu (2020). The absence of a significant breed × log (FEC) interaction indicates that Blended and Gogo goats maintained PCV similarly across increasing levels of infestation, demonstrating comparable tolerance-based resilience to GIP by the two breeds. It also implies a general tolerance-based resilience to GIP infestation by the two breeds, with the ability to maintain haematological parameters despite variations in parasitic burdens. Similarly, the absence of a significant association between BCS and FEC indicated that goats in this study were generally able to maintain body condition despite variations in parasitic burdens. Importantly, the non-significant breed × log (FEC) interaction further demonstrates that Blended and Gogo goats exhibited similar resilience to GIP under a relatively uniform environment, as reflected by a comparable BCS-FEC relationship. In this study, therefore, the difference in BCS was basically attributed to host biological factors such as sex, age, and physiological factors, rather than genetic variations, as also noted by Paul *et al*. (2020).

The binary outcomes revealed that breed and sex of the goats significantly influenced the likelihood of GIP in the study area. The notably lower odds in Gogo goats indicate increased resilience compared to Blended goats, consistent with previous reports that indigenous breeds often possess adaptive advantages in immunity and tolerance to endemic parasites (Onzima *et al*., 2017). In contrast, the higher likelihood of infestation observed in Blended goats may be associated with increased productivity and limited adaptation to the semi-arid environments of Mpwapwa District, as reported by Ngongolo & Mmbaga (2022). With respect to sex, the lower likelihood of infestation of female compared to male goats is possibly due to behavioural differences, although management practices such as preferential feed supplementation, as has also been suggested by Khoirunnisa *et a*l.

(2022). However, this finding contrasts with the findings of Kalacho (2024), who indicated that female goats are more susceptible to GIP compared to males, highlighting the context-specific nature of sex effects on GIP infection. Goats with poor body condition showed a tendency toward increased likelihood of infection, which may be attributed to poor nutrient utilisation and compromised immune systems, which heighten the risk of infection and reinfection (Nor-Azlina *et al*., 2011; Islam *et al*., 2017).

Ordinal regression analysis further indicated that the chance of belonging to a higher infestation category in dry does was 95% lower compared to other counterparts within the physiological status group. This may be attributed to the fact that dry does have a developed immune system resulting from repeated parasitic challenges over time, as noted by Verma *et al.* (2018). Conversely, lactating does exhibit a significant increase in the probability of being in a higher infestation category, possibly due to increased nutritional stress and reproductive hormones such as prolactin and progesterone, which heighten the risk of GIP infestation as reported by Islam *et al*. (2017) and Verma *et al*. (2018). Although most farmers reported grazing their herds on communal rangelands without rotation, grazing type did not significantly influence parasitic infestation levels. Nonetheless, continuous grazing is known to facilitate infestations and reinfestations through repeated exposure to heavily contaminated pastures, whereas rotational grazing is associated with the reduction in transmission of parasitic eggs and larvae (Temesgen *et al*., 2023).

Access to training and deworming practices were not significantly associated with infestation severity in the present study, despite the fact that access to training has been reported to help farmers acquire skills in herd management, thereby reducing the intensity of infestations (Ndlela *et al*., 2022). This may be due to inconsistent implementation of management practices such as deworming, which was reported by many farmers to be based on visual assessment of body condition or clinical signs rather than consistent strategic or targeted control programmes.

Housing and sanitation emerged as important determinants of infestation severity. Goats kept in open shelters were significantly more likely to belong in the high infestation category, possibly due to frequent exposure and re-infestation from GIP, as also reported by Aiman Batool *et al.* (2022). This is attributed to the fact that maintaining cleanliness in open shelters is difficult, particularly during the wet season, hence the increased risk of higher infestations, as also suggested by Fulsoundar & Niranjan (2016). Although not statistically significant, goats housed in sheds had increased odds of high infestation, possibly due to improper flooring that retains humidity and creates microclimates favourable for parasitic transmission, especially nematodes (Sharma *et al*., 2020). Frequent sanitation, particularly daily cleaning, was significantly associated with a reduced chance of belonging to a higher infestation category. Regular sanitation creates an unfavourable microenvironment for the survival of parasite eggs and larvae, thereby limiting their development and reducing the risk of new infestations and reinfestations, as reported by Aiman Batool *et al*. (2022).

CONCLUSION AND RECOMMENDATIONS

The observed trend of predominantly low to moderate infestation intensity indicates that most goats carried limited parasite burdens under the prevailing management and environmental conditions. Breed, sex, and physiological status influenced both the likelihood of infection and the probability of progression to higher infestation categories, underscoring the importance of effective herd management practices. The study also indicated that goats in the semi-arid region of central Tanzania possess potential resilience to GIP, as PCV and BCS largely remained unaffected by parasitic burden in both breeds, despite a physiological link between BCS and varying infestation levels. This suggests that tolerance to gastrointestinal parasitism in the study population was influenced more by host biological factors than by breed differences.

It is therefore recommended that integrated control strategies combining targeted deworming, improved nutrition, adequate housing, regular sanitation, and strengthened farmer training and knowledge exchange be put in place in order to reduce gastrointestinal parasite burden in goats. A strategic breeding programme that promotes resilient genotypes against GIP is recommended to support goat production in semi-arid regions of Tanzania. Further research, especially molecular studies with larger sample sizes and longitudinal monitoring, is also needed to explore the genetic basis of resilience and resistance to GIP in goat breeds in semi-arid Tanzania.

ACKNOWLEDGEMENTS

The authors acknowledge the Department of Animal, Aquaculture, and Range Sciences (DAARS) staff, Mr Frank Mhonzya from the Department of Veterinary Medicine and Public Health, goat farmers, and staff at Mpwapwa district for their active participation in the study.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the research, authorship, and publication of this article.

ETHICAL APPROVAL

The study was approved by Sokoine University of Agriculture with clearance permit No. SUA/ADM/R.1/8/1333. Ethical concerns were taken into consideration by adhering to local animal welfare regulations and practices for animal use in research (TLRI/CC.21/046).

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