

In vivo anthelmintic efficacy and physiological effects of *Swertia chirata* in Barbari goats naturally infected with *Haemonchus contortus*

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Research Article

Keywords: Anthelmintic resistance, Antioxidant status, Barbari goat, faecal egg count reduction, *Haemonchus contortus*, *Swertia chirata*

Posted Date: February 26th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-8910788/v1>

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Version of Record: A version of this preprint was published at Tropical Animal Health and Production on July 8th, 2026. See the published version at <https://doi.org/10.1007/s11250-026-05204-5>.

Abstract

Haemonchus contortus remains one of the most economically devastating gastrointestinal nematodes in small ruminants, with escalating anthelmintic resistance threatening sustainable parasitic control. The present study evaluated the in vivo efficacy, safety, and physiological effects of an aqueous whole-plant extract of *Swertia chirata* against naturally occurring *H. contortus* infections in Barbari goats under field conditions. Thirty goats with faecal egg counts (FEC) ≥ 1000 eggs/g were randomly allocated into five groups (n = 6): untreated control, closantel (10 mg/kg), and *S. chirata* extract at 50, 250, and 500 mg/kg body weight. Infection was confirmed as mono-specific *H. contortus* by ITS-2 PCR and phylogenetic analysis. Anthelmintic efficacy was assessed using WAAVP-compliant faecal egg count reduction tests (FECRT), and associated haematological, biochemical and antioxidant alterations were evaluated over 28 days. Closantel achieved a 100% FEC reduction by day 14. The highest extract dose (500 mg/kg) produced a significant, dose-dependent reduction in egg shedding, reaching 60.65% by day 28 ($P < 0.05$), whereas lower doses showed minimal efficacy. Notably, high-dose treatment resulted in significant improvements in haemoglobin, packed cell volume, total serum protein, and ferric reducing antioxidant power, accompanied by a reduction in eosinophilia, without evidence of hepatic or renal toxicity. Although the efficacy did not meet the $\geq 95\%$ WAAVP threshold for standalone anthelmintic classification, the extract demonstrated measurable in vivo activity and adjunct physiological benefits. These findings provide field-based evidence supporting *S. chirata* as a safe complementary phyto-therapeutic candidate for integrated parasite management strategies aimed at reducing reliance on synthetic anthelmintics in small ruminant production systems.

Highlights

- Parasitological examination confirmed the presence of strongyle species through microscopy, along with the mono-infection of identified via PCR and sequencing.
- The in vivo effectiveness of at a dosage of 500 mg/kg demonstrated a notable decrease of 60.65% by the 28th day in the natural infection of in goats.
- Dose rate of 500 mg/kg aqueous extract of whole plant improved Hb, PCV, and antioxidant status in goats.
- The aqueous extract of the whole plant showed no harmful effects on the hepatic or renal functions of goats.

1. Introduction

Gastrointestinal nematode (GIN) infections remain among the most significant biological constraints to small ruminant production worldwide, with *H. contortus* recognized as the most pathogenic and economically devastating species in tropical and subtropical systems (Dutta et al. 2016; Selemon 2018). *H. contortus* is a highly hematophagous parasite of the abomasum that causes severe anemia, hypoproteinemia, growth retardation, and mortality, particularly in young animals (Urquhart et al. 1996; Abakar and Osman 2004). In regions with warm and humid climates, continuous larval availability facilitates persistent transmission, compounding the production losses (Ramakant et al. 2024a; Zvinorova et al. 2016).

For over five decades, parasite control has relied almost exclusively on synthetic anthelmintics. However, *H. contortus* has demonstrated a remarkable capacity to develop resistance to all major drug classes, including benzimidazoles, macrocyclic lactones, and salicylanilides (Kaplan 2004; Kotze and Prichard 2016). Multidrug-resistant populations have been widely reported, threatening the sustainability of conventional chemotherapeutic approaches (Parmar et al. 2020; Westers et al. 2016). This escalating resistance crisis has intensified the search for alternative or complementary control strategies that can reduce chemical selection pressure while maintaining clinical efficacy.

Phyto-therapeutics have emerged as promising candidates because of their structural diversity and multi-target modes of action, which may slow the development of resistance (Wangchuk et al. 2016). Ethnoveterinary practices in Africa and Asia document the use of medicinal plants for helminth control (Lans et al. 2007; Kumsa and Hagos 2020). Among these, *S. chirata* (Gentianaceae) has attracted attention for its rich content of secoiridoid glycosides such as amarogentin and swertiamarin, as well as phenolic compounds including mangiferin, which exhibit antiparasitic and antioxidant properties (Aleem and Kabir 2018; Du et al. 2018; Sinha et al. 2023). Although in vitro studies have demonstrated the anthelmintic potential of *S. chirata* extracts against GINs (Iqbal et al. 2006; Ramakant et al. 2024b), the translation of these findings into rigorously designed in vivo studies remains limited. Existing in vivo reports often lack molecular confirmation of parasite species, standardized efficacy assessment according to the World Association for the Advancement of Veterinary Parasitology (WAAVP) guidelines, or integrated evaluation of host physiological responses (Arora et al. 2009; Jain and Sahni 2009). Given that *H. contortus* predominates in Indian goat populations (Veena et al. 2020; Ramakant et al. 2025), species-level confirmation is critical to ensure the interpretive validity of efficacy outcomes. Moreover, helminth infections induce oxidative stress through host inflammatory responses and parasite-derived metabolites, contributing to systemic metabolic disturbances (Halliwell and Gutteridge 1999; Alam et al. 2020). Few phytotherapeutic studies have simultaneously evaluated parasitological efficacy and redox modulation under natural infection conditions, despite the potential for dual antiparasitic and antioxidant effects.

Therefore, the present study integrated molecular diagnostics (ITS-2 rDNA sequencing), WAAVP-compliant faecal egg count reduction testing, and comprehensive hematological, biochemical, and antioxidant profiling to evaluate the in vivo efficacy and physiological impact of aqueous *S. chirata* extract in goats naturally infected with *H. contortus*. By combining species-confirmed field infection with multidimensional host response assessment, this study aimed to provide translational evidence for the potential role of *S. chirata* within integrated parasite management frameworks designed to mitigate anthelmintic resistance in tropical small ruminant systems.

2. MATERIALS AND METHODS

2.1 Study area, animals and ethical approval

The study was conducted from March 2023 to February 2024 at the Instructional Livestock Farm Complex-II, Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUAT), Meerut, Uttar Pradesh, India. Thirty female Barbari goats aged between 8 and 14 months were screened for gastrointestinal nematode infections. Animals were included in the study based on the following criteria: presence of strongyle-type

eggs on qualitative faecal examination, a faecal egg count (FEC) of ≥ 1000 eggs per gram (EPG), absence of anthelmintic treatment during the preceding eight weeks, and absence of concurrent systemic illness. All selected goats were maintained under uniform housing and management conditions and were provided standard concentrate feed and ad libitum access to clean drinking water throughout the experimental period.

2.2 Parasitological examination and coproculture

Fresh faecal samples were collected per rectum and subjected to qualitative examination using direct smear and flotation techniques as described by Soulsby (1982). Strongyle-type eggs were identified based on their morphological characteristics under light microscopy. For species differentiation, pooled positive samples were cultured to obtain third-stage larvae (L3) using the method described by Roberts and Sullivan (1950). After seven days of incubation at room temperature, L3 larvae were harvested and morphologically identified based on their tail morphology, sheath characteristics, and intestinal cell arrangement.

2.3 Molecular confirmation of *Haemonchus contortus*

Genomic DNA was extracted from individual L3 larvae following exsheathment in 3.5% sodium hypochlorite for 20 min. The larvae were rinsed thoroughly with distilled water prior to DNA extraction using the QIAamp® DNA Mini Kit (QIAGEN, Germany), according to the manufacturer's instructions. Species-specific identification was performed by polymerase chain reaction (PCR) targeting the internal transcribed spacer-2 (ITS-2) region of ribosomal DNA using primers described by Bott et al. (2009). PCR amplification was carried out in a 25µl reaction mixture containing 12.5µl of 2X Master Mix (Promega), 1µl of each primer (10pmol), 2µl of template DNA, and nuclease-free water to volume. The thermal cycling conditions consisted of initial denaturation at 94°C for 5 min, followed by 35 cycles of denaturation at 94°C for 30 s, annealing at 55°C for 30 s, and extension at 72°C for 30 s, with a final extension at 72°C for 7 min. PCR products were resolved by electrophoresis on a 1.5% agarose gel containing ethidium bromide and visualized under ultraviolet illumination. Amplicon sizes were compared with a 100bp DNA ladder. Representative PCR-positive samples were purified and sequenced using Sanger sequencing. Sequence editing and alignment were performed using MEGA X. Phylogenetic relationships were inferred using the neighbour-joining method with 1000 bootstrap replicates.

2.4 Preparation of aqueous extract of *S. chirata*

Whole *S. chirata* plants were shade-dried and pulverized into a fine powder using an electric grinder. Aqueous extraction was performed by decoction, in which 100 g of plant powder was suspended in 1000 ml of distilled water and heated at 100°C for 30 min in a water bath. The suspension was filtered sequentially through a muslin cloth and Whatman No. 1 filter paper. The filtrate was concentrated under reduced pressure using a rotary evaporator at 55°C and subsequently dried in a hot air oven at 40°C to obtain a solid extract. The dried extract was weighed to calculate percentage yield using the formula-

Yield (%) = (weight of dried extract / weight of plant powder) X 100

The extract was stored in airtight containers at 4°C until further use.

2.5 Experimental design and treatment protocol

The study was conducted using a completely randomized design. The thirty selected goats were randomly allocated into five groups of six animals each. Group I served as untreated control. Group II received closantel at a dose of 10 mg/kg body weight as a single oral administration. Groups III, IV, and V received aqueous extract of *S. chirata* at doses of 50 mg/kg, 250 mg/kg, and 500 mg/kg body weight, respectively, administered orally as a single dose. Honey (10–15 grams) was used as a vehicle to ensure palatability and facilitate uniform oral administration of the extract.

2.6 Faecal egg count and faecal egg count reduction test

Approximately, 30 grams of faecal material was collected per rectum from each goat on day 0 (pre-treatment) and on days 7, 14, 21, and 28 post-treatment. Quantitative faecal egg counts were determined using the McMaster technique according to Wood et al. (1995), and results were expressed as EPG. Anthelmintic efficacy was assessed using the faecal egg count reduction test (FECRT) in accordance with WAAVP guidelines (Coles et al. 1992; Wood et al. 1995). The percentage reduction was calculated using the formula-

$$\text{FEER} (\%) = 100 \times (1 - T_2/C_2)$$

Where T_2 represents the mean post-treatment EPG of the treated group and C_2 represents the mean post-treatment EPG of the control group. Interpretation of efficacy followed WAAVP criteria.

2.7 Haematological and biochemical analysis

Blood samples were collected from the jugular vein of each goat on day 0 and on days 7, 14, 21, and 28 post-treatment. Two millilitres of blood were collected in EDTA-coated tubes for haematological analysis, and 3 ml were collected in plain tubes for serum separation. Haematological parameters, including haemoglobin concentration (Hb), packed cell volume (PCV), total erythrocyte count (TEC), total leukocyte count (TLC), and differential leukocyte count, were determined using an automated veterinary hematology analyzer (Mindray BC-30 Vet). Serum biochemical parameters, including aspartate aminotransferase (AST), alanine aminotransferase (ALT), blood urea nitrogen (BUN), creatinine, total serum protein, albumin, and globulin, were measured using an automated biochemical analyzer (Mindray BS-240) with commercial diagnostic kits.

2.8 Assessment of antioxidant status

Antioxidant parameters were evaluated on day 0 and day 28. Superoxide dismutase (SOD) activity was estimated according to the method of Marklund and Marklund (1974), catalase activity was determined using the method described by Aebi (1984), and ferric reducing antioxidant power (FRAP) was measured following the procedure of Benzie and Strain (1999). All assays were performed spectrophotometrically according to standard protocols.

2.9 Statistical analysis

Data were analyzed using IBM SPSS version 20. Normality of data distribution was assessed using the Shapiro–Wilk test. A repeated measures analysis of variance (ANOVA) was applied to evaluate the effects of

treatment, time, and their interaction. When significant differences were detected, Tukey's post hoc test was used for pairwise comparisons. Results are presented as mean±standard error (SE), and differences were considered statistically significant at $P < 0.05$.

3 Results

3.1 Parasitological and molecular findings

Qualitative faecal examination revealed strongyle-type eggs in all selected goats (Fig. 1). Coproculture of pooled samples yielded third-stage larvae morphologically consistent with *Haemonchus* spp., characterized by elongated sheath tails and typical intestinal cell morphology. Species-specific PCR amplification targeting the ITS-2 region produced a distinct 265bp amplicon in all examined samples (Fig. 2), confirming mono-infection with *H. contortus*. Sequencing and phylogenetic analysis demonstrated high nucleotide similarity with previously reported Indian isolates (Fig. 3). The generated sequences clustered within the established *H. contortus* clade, supported by strong bootstrap values, indicating genetic homogeneity among regional isolates.

3.2 Faecal egg count (FEC)

Pre-treatment faecal egg counts did not differ significantly among groups ($P > 0.05$), confirming uniform baseline infection levels prior to treatment allocation (Table 1). In the untreated control group, mean EPG values remained high throughout the 28-day observation period, with a progressive increase observed by day 28, indicating persistence and progression of infection under natural conditions. Administration of closantel resulted in a rapid and sustained reduction in FEC. A marked decline was evident by day 7, and complete suppression of egg shedding was achieved by day 14, which persisted through day 28 ($P < 0.001$ compared to control). The aqueous extract of *S. chirata* exhibited a dose-dependent response. The lowest dose (50 mg/kg) failed to produce a meaningful reduction in FEC and showed fluctuations comparable to the control group. The intermediate dose (250 mg/kg) resulted in a modest decline in egg counts, although reductions were not statistically significant when compared to the control at most time points ($P > 0.05$). In contrast, the highest dose (500 mg/kg) produced a progressive reduction in FEC, reaching maximal suppression by day 28 ($P < 0.05$ compared to control), although egg counts were not completely eliminated. Repeated measures ANOVA demonstrated a significant effect of treatment ($P < 0.001$), time ($P < 0.001$), and treatment X time interaction ($P < 0.01$), confirming differential responses among groups over the study period.

Table 1

Mean ($\pm$ SE) fecal egg counts (EPG) in Barbari goats following treatment with aqueous whole-plant extract of *S.chirata* and closantel over a 28-day period

Days	Control group	Positive control group	T1	T2	T3
0	1083.33 $\pm$ 16.67	1300.00 $\pm$ 73.60	1866.67 $\pm$ 93.69	2033.33 $\pm$ 198.08	1912.50 $\pm$ 108.16
7th	1108.33 $\pm$ 16.67	62.50 $\pm$ 10.70	1641.67 $\pm$ 85.07	1745.83 $\pm$ 171.32	1529.17 $\pm$ 89.77
14th	1133.33 $\pm$ 16.67	0.00 $\pm$ 0.00	1754.17 $\pm$ 89.31	1554.17 $\pm$ 150.06	1225.00 $\pm$ 69.82
21st	1175.00 $\pm$ 19.36	0.00 $\pm$ 0.00	1958.33 $\pm$ 98.46	1462.50 $\pm$ 143.72	929.17 $\pm$ 51.00
28th	1233.33 $\pm$ 16.67	0.00 $\pm$ 0.00	2075.00 $\pm$ 103.28	1679.17 $\pm$ 167.51	354.17 $\pm$ 19.81
Mean $\pm$ SE	1146.67^b$\pm$17.21	272.50^a$\pm$16.86	1859.17^d$\pm$93.96	1695.00^c$\pm$166.14	1190.00^b$\pm$67.71

a, b, c, d Mean bearing different superscripts in a row showed a statistical difference at $P < 0.001$

3. 3 Faecal egg count reduction test(FECRT)

Closantel achieved 100% faecal egg count reduction by day 14, fulfilling WAAVP criteria for effective anthelmintic activity (Table 2). The effect was sustained until day 28. The aqueous extract at 500 mg/kg produced a maximum reduction of 60.65% by day 28. The 250 mg/kg group showed moderate but inconsistent reductions, none of the extract-treated groups achieved $\geq 95\%$ threshold required to classify the treatment as fully effective according to WAAVP guidelines. These findings indicate that although the extract possesses measurable in vivo activity at higher doses, its efficacy remains substantially lower than that of the reference anthelmintic.

Table 2

Percent fecal egg count reduction (FECRT) following administration of aqueous *S.chirata* extract and closantel in naturally infected goats

Days	Positive control group	T1	T2	T3
7th	95.29 $\pm$ 0.66	12.10 $\pm$ 0.23	14.16 $\pm$ 0.24	20.08 $\pm$ 0.50
14th	100.00 $\pm$ 0.00	6.04 $\pm$ 0.20	23.53 $\pm$ 0.28	35.96 $\pm$ 0.18
21st	100.00 $\pm$ 0.00	-4.91 $\pm$ 0.12	28.07 $\pm$ 0.30	51.39 $\pm$ 0.44
28th	100.00 $\pm$ 0.00	-10.97 $\pm$ 0.22	17.51 $\pm$ 0.36	60.65 $\pm$ 0.44
Mean $\pm$ SE	98.82^d$\pm$0.16	0.57^a$\pm$0.19	20.82^b$\pm$0.29	42.02^c$\pm$0.39

a, b, c, d Mean bearing different superscripts in a row showed a statistical difference at $P < 0.001$

3.4 Haematological parameters

At baseline, infected goats exhibited reduced haemoglobin concentration, packed cell volume, and total erythrocyte count, consistent with anaemia associated with haemonchosis (Table 3). No significant differences were observed among groups prior to treatment ($P > 0.05$). Closantel-treated goats showed significant improvement in haemoglobin, PCV, and TEC values beginning on day 14, with near normalization by day 28 ($P < 0.01$ compared to control). The high-dose extract group (500 mg/kg) demonstrated gradual but significant improvement in erythrocytic parameters by day 28 ($P < 0.05$), whereas lower doses did not produce consistent hematological recovery. Total leukocyte count remained within physiological limits across groups. However, marked eosinophilia observed at baseline declined significantly in the closantel and high-dose extract groups by day 28 ($P < 0.05$), reflecting reduced parasitic burden. No adverse hematological effects were observed in any treatment group.

Table 3
Hematological parameters (mean $\pm$ SE) in goats treated with aqueous *S.chirata* extract and closantel at different time intervals post-treatment

Parameters	Days	Control group	Positive control group	T1	T2	T3
Hb(gm/dl)	0	8.38 $\pm$ 0.21	8.47 $\pm$ 0.10	8.83 $\pm$ 0.12	9.05 $\pm$ 0.22	8.77 $\pm$ 0.17
	7th	8.20 $\pm$ 0.16	8.87 $\pm$ 0.10	8.92 $\pm$ 0.12	9.25 $\pm$ 0.22	8.95 $\pm$ 0.17
	14th	8.10 $\pm$ 0.14	9.37 $\pm$ 0.10	8.73 $\pm$ 0.13	9.47 $\pm$ 0.21	9.13 $\pm$ 0.16
	21st	8.03 $\pm$ 0.16	10.37 $\pm$ 0.09	8.45 $\pm$ 0.12	9.58 $\pm$ 0.20	9.27 $\pm$ 0.15
	28th	8.00 $\pm$ 0.16	10.82 $\pm$ 0.11	8.20 $\pm$ 0.08	9.18 $\pm$ 0.20	9.38 $\pm$ 0.15
	Mean $\pm$ SEM	8.14 $\pm$ 0.17^a	9.58 $\pm$ 0.10^d	8.35 $\pm$ 0.11^b	8.93 $\pm$ 0.21^{cd}	9.35 $\pm$ 0.16^c
PCV (%)	0	26.50 $\pm$ 0.92	26.67 $\pm$ 0.49	27.33 $\pm$ 0.67	28.33 $\pm$ 1.05	26.83 $\pm$ 0.79
	7th	26.17 $\pm$ 0.70	28.00 $\pm$ 0.58	27.83 $\pm$ 0.60	29.50 $\pm$ 1.31	27.83 $\pm$ 0.79
	14th	25.67 $\pm$ 0.61	29.67 $\pm$ 0.49	26.67 $\pm$ 0.61	30.33 $\pm$ 1.15	28.83 $\pm$ 0.79
	21st	24.83 $\pm$ 0.79	31.50 $\pm$ 0.43	26.17 $\pm$ 0.48	31.33 $\pm$ 1.26	29.67 $\pm$ 0.84
	28th	24.67 $\pm$ 0.80	33.50 $\pm$ 0.43	24.83 $\pm$ 0.31	28.67 $\pm$ 1.15	30.33 $\pm$ 0.76
	Mean $\pm$ SEM	25.57 $\pm$ 0.76^a	29.87 $\pm$ 0.48^b	26.20 $\pm$ 0.53^a	28.50 $\pm$ 1.18^b	30.10 $\pm$ 0.79^b
TEC($\times 10^6/\mu\text{l}$)	0	8.72 $\pm$ 0.21	8.30 $\pm$ 0.17	8.60 $\pm$ 0.12	8.83 $\pm$ 0.22	8.60 $\pm$ 0.17
	7th	8.48 $\pm$ 0.11	8.70 $\pm$ 0.17	8.70 $\pm$ 0.12	9.02 $\pm$ 0.22	8.75 $\pm$ 0.17
	14th	8.38 $\pm$ 0.14	9.20 $\pm$ 0.17	8.48 $\pm$ 0.11	9.18 $\pm$ 0.20	8.93 $\pm$ 0.16
	21st	8.23 $\pm$ 0.22	10.20 $\pm$ 0.17	8.22 $\pm$ 0.09	9.38 $\pm$ 0.20	9.03 $\pm$ 0.16
	28th	8.10 $\pm$ 0.19	10.73 $\pm$ 0.17	8.07 $\pm$ 0.03	8.93 $\pm$ 0.23	9.17 $\pm$ 0.14
a, b, c Mean bearing different superscripts in a row showed a statistical difference at P < 0.05						

Parameters	Days	Control group	Positive control group	T1	T2	T3
	Mean ± SEM	8.38 ± 0.17^a	9.43 ± 0.17^b	8.16 ± 0.09^a	8.73 ± 0.21^a	9.10 ± 0.16^{ab}
TLC($\times 10^3/\mu\text{l}$)	0	10.63 ± 0.11	10.42 ± 0.11	10.55 ± 0.12	10.50 ± 0.12	10.40 ± 0.10
	7th	10.58 ± 0.10	10.62 ± 0.11	10.63 ± 0.11	10.62 ± 0.13	10.50 ± 0.10
	14th	10.52 ± 0.10	10.82 ± 0.11	10.48 ± 0.09	10.70 ± 0.13	10.60 ± 0.10
	21st	10.48 ± 0.07	11.00 ± 0.10	10.32 ± 0.06	10.80 ± 0.13	10.73 ± 0.11
	28th	10.47 ± 0.06	11.10 ± 0.10	10.18 ± 0.05	10.68 ± 0.10	10.78 ± 0.09
	Mean ± SEM	10.54 ± 0.09^{ab}	10.83 ± 0.11^c	10.21 ± 0.09^a	10.54 ± 0.12^{bc}	10.47 ± 0.10^{ab}
Neutrophils (%)	0	38.00 ± 0.73	38.67 ± 0.61	40.83 ± 0.48	40.00 ± 0.26	40.67 ± 0.80
	7th	38.17 ± 0.79	38.17 ± 0.60	40.17 ± 0.40	40.00 ± 0.26	40.17 ± 0.79
	14th	37.67 ± 0.71	37.33 ± 0.56	39.83 ± 0.40	39.67 ± 0.33	40.17 ± 0.79
	21st	37.33 ± 0.80	37.33 ± 0.56	39.50 ± 0.56	39.50 ± 0.34	39.33 ± 0.61
	28th	36.83 ± 0.70	38.00 ± 0.58	39.00 ± 0.37	39.33 ± 0.33	39.17 ± 0.54
	Mean ± SEM	37.60 ± 0.75^a	37.90 ± 0.58^a	38.53 ± 0.44^b	39.00 ± 0.30^b	39.97 ± 0.71^b
Lymphocytes (%)	0	47.83 ± 1.08	49.17 ± 0.70	46.50 ± 0.56	47.17 ± 0.31	46.33 ± 0.88
	7th	48.33 ± 1.17	50.17 ± 0.70	48.17 ± 0.48	47.50 ± 0.34	48.00 ± 0.82
	14th	50.83 ± 1.85	51.50 ± 0.43	48.33 ± 0.42	48.50 ± 0.56	48.67 ± 0.92
	21st	51.00 ± 1.88	53.33 ± 0.49	48.17 ± 0.31	49.00 ± 0.63	49.83 ± 0.70
	28th	51.33 ± 1.84	54.00 ± 0.52	48.33 ± 0.42	48.67 ± 0.76	50.33 ± 0.76

a, b, c Mean bearing different superscripts in a row showed a statistical difference at $P < 0.05$

Parameters	Days	Control group	Positive control group	T1	T2	T3
	Mean $\pm$ SEM	49.86 $\pm$ 1.56^b	51.63 $\pm$ 0.57^b	50.00 $\pm$ 0.44^a	49.23 $\pm$ 0.52^a	48.30 $\pm$ 0.82^{ab}
Eosinophils (%)	0	5.83 $\pm$ 0.31	7.17 $\pm$ 0.40	7.00 $\pm$ 0.26	7.83 $\pm$ 0.17	7.67 $\pm$ 0.33
	7th	6.17 $\pm$ 0.31	6.67 $\pm$ 0.33	6.67 $\pm$ 0.21	7.50 $\pm$ 0.22	6.83 $\pm$ 0.31
	14th	6.50 $\pm$ 0.22	6.17 $\pm$ 0.31	6.83 $\pm$ 0.31	6.83 $\pm$ 0.31	6.17 $\pm$ 0.17
	21st	6.67 $\pm$ 0.33	4.33 $\pm$ 0.21	7.33 $\pm$ 0.49	6.50 $\pm$ 0.34	5.83 $\pm$ 0.31
	28th	6.83 $\pm$ 0.31	3.00 $\pm$ 0.26	7.67 $\pm$ 0.42	7.00 $\pm$ 0.45	5.50 $\pm$ 0.43
	Mean $\pm$ SEM	6.40 $\pm$ 0.30^b	5.47 $\pm$ 0.30^a	6.53 $\pm$ 0.34^c	6.77 $\pm$ 0.30^c	6.80 $\pm$ 0.31^b
a, b, c Mean bearing different superscripts in a row showed a statistical difference at P < 0.05						

3.5 Serum biochemical parameters

Serum AST and ALT activities remained within normal reference ranges throughout the experimental period in all groups, with no statistically significant intergroup differences ($P > 0.05$), indicating absence of hepatocellular toxicity (Table 4). Similarly, serum creatinine and blood urea nitrogen levels did not differ significantly among groups at any time point ($P > 0.05$), suggesting preserved renal function following extract administration. In contrast, total serum protein and albumin concentrations, which were reduced at baseline in infected goats, showed significant improvement in the closantel and high-dose extract groups by day 28 ($P < 0.05$). The increase was more pronounced in the closantel group. The albumin-to-globulin ratio improved correspondingly, indicating partial restoration of protein metabolism following parasite suppression.

Table 4
Serum biochemical parameters (mean $\pm$ SE) in goats following administration of aqueous *S.chirata* extract and closantel

Parameter	Days	Control group	Positive control group	T1	T2	T3
AST(U/L)	0	57.97 $\pm$ 1.51	55.97 $\pm$ 1.20	55.25 $\pm$ 1.37	56.45 $\pm$ 1.05	54.93 $\pm$ 0.94
	7	58.27 $\pm$ 1.46	54.93 $\pm$ 1.01	53.73 $\pm$ 1.29	55.42 $\pm$ 1.06	54.78 $\pm$ 1.09
	14	60.13 $\pm$ 1.60	54.80 $\pm$ 0.85	54.18 $\pm$ 1.40	53.60 $\pm$ 1.01	55.43 $\pm$ 1.38
	21	53.45 $\pm$ 3.90	56.20 $\pm$ 1.45	54.53 $\pm$ 1.16	54.05 $\pm$ 0.82	55.30 $\pm$ 1.26
	28	53.67 $\pm$ 1.18	54.58 $\pm$ 1.48	55.38 $\pm$ 1.24	56.43 $\pm$ 1.22	54.15 $\pm$ 1.50
	Mean $\pm$ SEM	56.70 $\pm$ 1.93	55.30 $\pm$ 1.20	54.62 $\pm$ 1.29	55.19 $\pm$ 1.03	54.92 $\pm$ 1.23
ALT(U/L)	0	17.93 $\pm$ 1.19	18.05 $\pm$ 1.15	18.72 $\pm$ 1.17	18.47 $\pm$ 0.59	18.58 $\pm$ 0.89
	7	18.05 $\pm$ 1.20	19.67 $\pm$ 1.22	18.92 $\pm$ 1.45	18.50 $\pm$ 1.19	16.13 $\pm$ 0.84
	14	19.08 $\pm$ 1.38	20.08 $\pm$ 1.22	17.90 $\pm$ 1.20	19.52 $\pm$ 0.93	16.38 $\pm$ 1.28
	21	18.17 $\pm$ 0.84	18.42 $\pm$ 1.83	16.42 $\pm$ 0.91	17.97 $\pm$ 0.75	17.95 $\pm$ 1.06
	28	18.00 $\pm$ 1.24	14.70 $\pm$ 1.96	16.98 $\pm$ 1.24	18.15 $\pm$ 0.83	18.02 $\pm$ 1.27
	Mean $\pm$ SEM	18.25 $\pm$ 1.17	18.18 $\pm$ 1.48	17.79 $\pm$ 1.19	18.52 $\pm$ 0.86	17.41 $\pm$ 1.07
BUN(mg/dl)	0	24.13 $\pm$ 1.50	21.85 $\pm$ 0.96	21.48 $\pm$ 0.98	17.17 $\pm$ 1.47	20.18 $\pm$ 0.94
	7	23.96 $\pm$ 1.54	21.10 $\pm$ 1.64	20.48 $\pm$ 0.56	19.51 $\pm$ 1.07	21.13 $\pm$ 0.70
	14	23.92 $\pm$ 0.95	24.27 $\pm$ 0.67	19.62 $\pm$ 1.09	20.21 $\pm$ 1.72	18.59 $\pm$ 0.93
	21	20.46 $\pm$ 1.09	18.38 $\pm$ 0.81	21.88 $\pm$ 0.97	19.39 $\pm$ 1.07	20.25 $\pm$ 0.87
	28	21.89 $\pm$ 1.27	21.57 $\pm$ 1.22	19.85 $\pm$ 1.51	20.17 $\pm$ 1.12	19.37 $\pm$ 1.04

a, b, c Mean bearing different superscripts in a row showed a statistical difference at P < 0.05

Parameter	Days	Control group	Positive control group	T1	T2	T3
	Mean ± SEM	22.87 ± 1.27^c	21.43 ± 1.06^{bc}	20.66 ± 1.02^{ab}	19.29 ± 1.29^a	19.90 ± 0.90^{ab}
Creatinine(mg/dl)	0	1.48 ± 0.03	1.54 ± 0.05	1.43 ± 0.09	1.50 ± 0.07	1.53 ± 0.08
	7	1.49 ± 0.02	1.52 ± 0.03	1.53 ± 0.09	1.55 ± 0.05	1.47 ± 0.08
	14	1.45 ± 0.03	1.61 ± 0.03	1.36 ± 0.08	1.45 ± 0.07	1.48 ± 0.08
	21	1.51 ± 0.06	1.56 ± 0.04	1.49 ± 0.08	1.49 ± 0.07	1.51 ± 0.06
	28	1.54 ± 0.04	1.37 ± 0.09	1.45 ± 0.08	1.52 ± 0.07	1.38 ± 0.05
	Mean ± SEM	1.49 ± 0.04	1.52 ± 0.05	1.45 ± 0.08	1.50 ± 0.07	1.47 ± 0.07
TSP(gm/dl)	0	5.65 ± 0.23	5.47 ± 0.08	5.55 ± 0.08	5.68 ± 0.06	5.32 ± 0.12
	7	5.57 ± 0.22	5.48 ± 0.12	5.42 ± 0.06	5.48 ± 0.07	5.45 ± 0.08
	14	5.30 ± 0.10	5.63 ± 0.14	5.30 ± 0.06	5.48 ± 0.09	5.55 ± 0.09
	21	5.22 ± 0.09	5.67 ± 0.07	5.27 ± 0.08	5.32 ± 0.07	5.57 ± 0.08
	28	5.17 ± 0.08	6.00 ± 0.12	5.20 ± 0.06	5.18 ± 0.05	5.60 ± 0.07
	Mean ± SEM	5.38 ± 0.14^a	5.65 ± 0.11^b	5.35 ± 0.07^a	5.43 ± 0.07^a	5.50 ± 0.09^{ab}
Albumin(gm/dl)	0	3.48 ± 0.14	3.18 ± 0.09	3.27 ± 0.07	3.23 ± 0.09	3.15 ± 0.08
	7	3.42 ± 0.14	3.22 ± 0.10	3.22 ± 0.08	3.20 ± 0.05	3.23 ± 0.12
	14	3.05 ± 0.06	3.48 ± 0.14	3.10 ± 0.04	3.27 ± 0.05	3.30 ± 0.10
	21	3.03 ± 0.08	3.58 ± 0.05	3.13 ± 0.06	3.12 ± 0.06	3.32 ± 0.08
	28	3.02 ± 0.06	3.88 ± 0.14	3.08 ± 0.05	3.05 ± 0.02	3.38 ± 0.09
a, b, c Mean bearing different superscripts in a row showed a statistical difference at P < 0.05						

Parameter	Days	Control group	Positive control group	T1	T2	T3
	Mean $\pm$ SEM	3.20 $\pm$ 0.10 ^a	3.47 $\pm$ 0.10 ^b	3.16 $\pm$ 0.06 ^a	3.17 $\pm$ 0.05 ^a	3.28 $\pm$ 0.09 ^a
Globulin(gm/dl)	0	2.17 $\pm$ 0.11	2.30 $\pm$ 0.09	2.28 $\pm$ 0.09	2.45 $\pm$ 0.09	2.17 $\pm$ 0.06
	7	2.18 $\pm$ 0.12	2.27 $\pm$ 0.07	2.20 $\pm$ 0.06	2.27 $\pm$ 0.07	2.22 $\pm$ 0.08
	14	2.25 $\pm$ 0.07	2.15 $\pm$ 0.07	2.20 $\pm$ 0.07	2.22 $\pm$ 0.06	2.27 $\pm$ 0.05
	21	2.20 $\pm$ 0.09	2.15 $\pm$ 0.08	2.13 $\pm$ 0.06	2.20 $\pm$ 0.07	2.25 $\pm$ 0.05
	28	2.13 $\pm$ 0.05	2.08 $\pm$ 0.07	2.10 $\pm$ 0.04	2.13 $\pm$ 0.07	2.22 $\pm$ 0.07
	Mean $\pm$ SEM	2.19 $\pm$ 0.09	2.19 $\pm$ 0.08	2.18 $\pm$ 0.06	2.25 $\pm$ 0.07	2.23 $\pm$ 0.06
A:G ratio	0	1.62 $\pm$ 0.06	1.39 $\pm$ 0.09	1.45 $\pm$ 0.07	1.34 $\pm$ 0.08	1.46 $\pm$ 0.05
	7	1.60 $\pm$ 0.07	1.48 $\pm$ 0.07	1.47 $\pm$ 0.07	1.44 $\pm$ 0.04	1.47 $\pm$ 0.10
	14	1.36 $\pm$ 0.04	1.63 $\pm$ 0.09	1.42 $\pm$ 0.05	1.48 $\pm$ 0.03	1.46 $\pm$ 0.06
	21	1.39 $\pm$ 0.08	1.68 $\pm$ 0.07	1.48 $\pm$ 0.06	1.42 $\pm$ 0.06	1.48 $\pm$ 0.05
	28	1.42 $\pm$ 0.04	1.88 $\pm$ 0.10	1.47 $\pm$ 0.03	1.44 $\pm$ 0.06	1.54 $\pm$ 0.08
	Mean $\pm$ SEM	1.48 $\pm$ 0.06 ^a	1.61 $\pm$ 0.08 ^b	1.46 $\pm$ 0.06 ^a	1.42 $\pm$ 0.05 ^a	1.48 $\pm$ 0.07 ^a
a, b, c Mean bearing different superscripts in a row showed a statistical difference at P < 0.05						

3.6 Antioxidant status

Baseline antioxidant parameters suggested compromised redox balance in infected goats. By day 28, ferric reducing antioxidant power (FRAP) values increased significantly in both the closantel and 500 mg/kg extract groups (P < 0.05 compared to control), indicating enhanced systemic antioxidant capacity (Table 5). Superoxide dismutase and catalase activities showed modest increases in the high-dose extract group; however, changes did not reach statistical significance in all comparisons. The untreated control group showed no improvement in antioxidant status over time. These findings suggest that the higher dose of *S. chirata* extract may exert adjunct antioxidant effects in addition to partial anthelmintic activity.

Table 5
Antioxidant status indicators (Catalase, SOD, and FRAP; mean $\pm$ SE) in goats before and after treatment with aqueous *S.chirata* extract and closantel

Parameter	Days	Control group	Positive control group	T1	T2	T3
Catalase (μ M/min/g Hb)	0	47.38 $\pm$ 3.57	35.53 $\pm$ 3.28	51.18 $\pm$ 5.73	37.65 $\pm$ 3.79	34.69 $\pm$ 3.51
	28	41.03 $\pm$ 3.90	46.95 $\pm$ 3.57	45.69 $\pm$ 4.25	42.30 $\pm$ 4.76	42.72 $\pm$ 5.73
	Mean $\pm$ SEM	44.21 $\pm$ 3.74	41.24 $\pm$ 3.43	48.44 $\pm$ 4.99	39.98 $\pm$ 4.28	38.71 $\pm$ 4.62
SOD (U/g Hb)	0	3066.67 $\pm$ 688.32	2000.00 $\pm$ 647.04	3000.00 $\pm$ 764.20	2366.67 $\pm$ 468.80	1733.33 $\pm$ 388.73
	28	2300.00 $\pm$ 690.41	2433.33 $\pm$ 340.26	2566.67 $\pm$ 380.93	2600.00 $\pm$ 450.19	2033.33 $\pm$ 660.13
	Mean $\pm$ SEM	2683.34 $\pm$ 689.37	2216.67 $\pm$ 493.65	2783.34 $\pm$ 572.57	2483.34 $\pm$ 459.50	1883.33 $\pm$ 524.43
FRAP (μ mol/l)	0	114.29 $\pm$ 27.23	77.89 $\pm$ 8.19	222.79 $\pm$ 30.12	188.78 $\pm$ 13.40	127.89 $\pm$ 22.84
	28	105.44 $\pm$ 19.28	168.03 $\pm$ 24.39	210.54 $\pm$ 28.80	230.27 $\pm$ 26.43	189.46 $\pm$ 5.64
	Mean $\pm$ SEM	109.87 $\pm$ 23.26^a	122.96 $\pm$ 16.29^a	216.67 $\pm$ 29.46^b	209.53 $\pm$ 19.92^b	158.68 $\pm$ 14.24^{ab}
a, b, Mean bearing different superscripts in a row showed a statistical difference at P < 0.05						

4 Discussion

Gastrointestinal nematode infections, particularly those caused by *H.contortus*, remain a major constraint to small ruminant productivity in tropical and subtropical regions. The present study provides field-based evidence evaluating the in vivo efficacy and physiological impact of aqueous *S.chirata* extract against molecularly confirmed *H.contortus* infection in goats. By integrating ITS-2 rDNA-based species confirmation, WAAVP-compliant faecal egg count reduction testing, and multidimensional host response profiling, this investigation addresses key methodological gaps in previous phyto-therapeutic studies.

4.1 Anthelmintic efficacy of *S.chirata*

Closantel achieved complete suppression of egg shedding by day 14, confirming retained susceptibility of the local *H. contortus* population to salicylanilides. Closantel acts primarily by uncoupling oxidative phosphorylation in parasite mitochondria, leading to energy depletion and parasite death (Westers et al. 2016). The absence of reduced efficacy suggests that resistance to this compound has not yet emerged in the study population, although continued surveillance remains essential given widespread reports of multidrug resistance in *H. contortus* globally (Kaplan 2004; Kotze and Prichard 2016). In contrast, the aqueous extract of *S. chirata* demonstrated moderate, dose-dependent in vivo activity, with a maximum

faecal egg count reduction of 60.65% at 500 mg/kg by day 28. While this efficacy does not meet $\geq 95\%$ threshold required for classification as an effective standalone anthelmintic under WAAVP guidelines (Coles et al. 1992; Wood et al. 1995), the reduction was statistically significant and biologically meaningful. Importantly, egg shedding continued to decline progressively over time in the high-dose group, suggesting a sustained but submaximal antiparasitic effect.

The moderate efficacy observed may be attributable to the pharmacodynamic properties of secoiridoid glycosides such as amarogentin and swertiamarin, which have been reported to exert antiparasitic activity through interference with metabolic and neuromuscular pathways (Aleem and Kabir 2018). However, aqueous extraction may limit concentration and bioavailability of lipophilic bioactive constituents, potentially explaining the incomplete suppression of egg output. Moreover, plant-derived compounds often act through multi-target, sublethal mechanisms rather than rapid parasitocidal activity, which may reduce worm fecundity without complete elimination. Such mechanisms could contribute to gradual reductions in egg shedding observed in the present study. From a resistance-management perspective, partial efficacy does not preclude utility. Phyto-therapeutics with moderate activity may reduce parasite burden and fecundity, thereby lowering pasture contamination and selection pressure on synthetic anthelmintics. When integrated into rotational or combination control programs, such agents may contribute to resistance mitigation strategies rather than replacing conventional drugs outright.

4.2 Haematological recovery and parasitic load suppression

Haemonchosis is characterized by chronic blood loss due to the hematophagous feeding behavior of adult worms, resulting in anemia and reduced oxygen-carrying capacity (Urquhart et al. 1996). Significant improvement in haemoglobin concentration, packed cell volume, and erythrocyte counts in the closantel group reflects effective parasite elimination and restoration of hematological homeostasis. Notably, the high-dose *S. chirata* group also demonstrated progressive improvement in erythrocytic parameters, consistent with partial suppression of parasite burden and reduced blood loss. The decline in eosinophil counts following high-dose treatment further supports reduced helminth-associated antigenic stimulation. Eosinophilia is a hallmark of helminth infections and reflects Th2-mediated immune activation (Aziz and Mahmoud 2021). The observed modulation of eosinophil levels suggests that phyto-therapeutic intervention may attenuate parasite-driven immune responses, potentially reducing chronic inflammatory burden. These findings indicate that even submaximal reductions in egg shedding may translate into measurable physiological benefits for the host, reinforcing the importance of evaluating host response parameters alongside parasitological endpoints.

4.3 Biochemical profile and safety assessment

Safety evaluation is critical in the development of plant-based therapeutics. Serum AST, ALT, creatinine, and blood urea nitrogen values remained within physiological limits across all treatment groups, indicating absence of hepatocellular or renal toxicity at the administered doses. These findings are consistent with previous reports describing favorable safety profiles of *S. chirata* extracts (Sinha et al. 2023). Improvement in total serum protein and albumin concentrations in the high-dose group likely reflects restoration of abomasal integrity and reduced protein loss associated with parasite suppression. Hypoproteinemia in haemonchosis results from both blood loss and plasma protein leakage through damaged mucosa (Baker et al. 2003). The

observed biochemical recovery therefore supports a biologically relevant therapeutic effect beyond mere statistical reduction in egg counts.

4.4 Oxidative stress modulation and adjunct therapeutic potential

Helminth infections are associated with increased generation of reactive oxygen species and oxidative tissue damage (Halliwell and Gutteridge 1999; Alam et al. 2020). The significant increase in ferric reducing antioxidant power (FRAP) in the high-dose *S. chirata* group suggests enhancement of systemic antioxidant capacity. This effect may be attributed to phenolic compounds such as mangiferin and related secoiridoids, which possess documented free radical scavenging properties (Du et al. 2018). The dual observation of parasite suppression and improved redox status suggests that *S. chirata* may exert complementary antiparasitic and antioxidant effects. Such combined activity may improve resilience of infected animals, particularly under field conditions where nutritional and environmental stressors coexist. The capacity to modulate oxidative balance could represent a valuable adjunct mechanism supporting recovery during chronic parasitism.

4.5 Translational implications for integrated parasite management

Given the accelerating global spread of anthelmintic resistance in *H. contortus* (Kaplan 2004; Kotze and Prichard 2016), reliance on single-modality chemotherapeutic control is increasingly unsustainable. The present findings support the concept that plant-derived agents with moderate efficacy and favorable safety profiles may contribute to integrated parasite management frameworks. Rather than serving as replacements for synthetic anthelmintics, phyto-therapeutics such as *S. chirata* may function as adjunct interventions that reduce parasite fecundity, improve host resilience, and potentially delay resistance development by lowering drug-selection pressure. Future investigations should focus on phytochemical standardization, pharmacokinetic characterization, repeated-dose regimens, and evaluation of synergistic combinations with conventional anthelmintics. Controlled infection models and larger sample sizes would further clarify efficacy thresholds and mechanistic pathways.

5 Conclusions

This study demonstrates that aqueous *S. chirata* extract exerts moderate, dose-dependent *in vivo* activity against molecularly confirmed *H. contortus* infection in goats under natural field conditions. Although efficacy did not meet WAAVP criteria for standalone anthelmintic classification, the highest dose significantly reduced egg shedding and improved hematological and antioxidant status without evidence of toxicity. These findings highlight the potential of *S. chirata* as a safe complementary phyto-therapeutic within integrated parasite management strategies aimed at mitigating anthelmintic resistance. Further research on phytochemical standardization, optimized dosing regimens, and combination approaches is warranted to enhance translational applicability in small ruminant production systems.

Declarations

Acknowledgements

The authors wish to place on record their deep sense of gratitude to the Hon'ble Vice Chancellor of Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUAT), Meerut, for the visionary leadership, constant encouragement, and for providing the requisite infrastructural and research facilities that were instrumental in the successful execution and completion of this study.

Contribution statement for authorship credit

Ramakant: Concept development, accurate labeling, transportation, sample processing, data compilation, and conducting experimental trials. Arbind Singh: Manuscript writing and editing. Vikash Jaiswal: Sequence analysis, submission, and phylogenetic analysis. Prem Sagar Maurya: Sample processing, research methodology, and imaging. Ayush Pal: Assistance in manuscript writing. T. K. Sarkar: Resource management and review. Devesh Kumar Yadav: Statistical analysis. Amit Kumar Verma: Final editing and compilation.

Data Availability Declaration

Manuscript has no associated data

Ethical Approval The experimental protocol was reviewed and approved by the Institutional Animal Ethics Committee of SVPUAT (IAEC/SVPUAT/2022/125 dated 3 December 2022) and was carried out in accordance with CPCSEA guidelines for the care and use of experimental animals.

Consent for publication: All authors provided their consent for the publication.

Conflicts of Interest: The authors declare that there are no conflicts of interest among them.

Data Availability:

References

1. Abakar A and Osman A (2004) Haematological and biochemical changes following concurrent infections with coccidia and *Haemonchus contortus* in desert lambs. J Anim Vet Adv 3(10):643–647
2. Aebi H (1984) Catalase in vitro. In: Methods in enzymology (L. Packer, edn.). Academic press, New York 105:121–126
3. Ahmed A, Dar MA, Bhat AA, Jena B, Mishra GK and Tiwari RP (2015) Study on Haemato-Biochemical profile in Goats suffering from Gastrointestinal Parasitism in Jaipur district of Rajasthan. J Livest Sci 6:52–55
4. Alam RT, Hassanen EA and El-Mandrawy SA (2020) *Haemonchus contortus* infection in Sheep and Goats: alterations in haematological, biochemical, immunological, trace element and oxidative stress markers. J Appl Vet Sci 48(1):357 – 64
5. Al-Bayati AM, Jihad LJ and Al-Attar SA (2023) The effects of Gastro-intestinal Parasites on haemato-biochemical parameters of sheep in Kirkuk province Iraq. J App Vet Sci 8(4):62–68

6. Aleem A and Kabir H (2018) Review of *Swertia chirata* as traditional uses to its Phytochemistry and pharmacological activity. JDDT 8(5-s):73–78
7. Amulya G, Sudharani R, Ismail-Shareef M and Gopinath SM (2014) Haemato biochemical changes in sheep suffering from gastrointestinal parasitism. IJFV 10(2):20–22
8. Anumol J, Tresamol PV, Vinodkumar K and Saseendranath MR (2012) Haemato biochemical alterations in goats infected with coccidiosis. IJVASR 8(3):163–165
9. Arora M, Sahni YP, Gautam V and Singh A (2009) Evaluation of in vivo anthelmintic efficacy of *Swertia chirata* (Chirayata) against Gastrointestinal Nematodiasis in Goats. JDRAS 30(1–2):1–8
10. Ashfaq M, Khan SA, Fakhrudin Chahar A and Tanwar RK (2016) Haemato biochemical changes in goats suffering from helminth parasites infestation. Vet Pract 17(1):55–56
11. Awad AH, Ali AM and Hadree DH (2016) Some haematological and biochemical parameters assessments in sheep infection by *Haemonchus contortus*. Tikrit J Pure Sci 21(1):11–15
12. Aziz SJ and Mahmoud OI (2021) Measurement of hematological and biochemical parameters in sheep infected with intestinal protozoa and helminthes. Tikrit J Pure Sci 26(1):8–11
13. Baker RL, Nagda S, Rodriguez-Zas SL, Southey BR, Audho JO, Aduda EO and Thorpe W (2003) Resistance and resilience to gastro-intestinal nematode parasites and relationships with productivity of Red Maasai, Dorper and Red Maasai x Dorper crossbred lambs in the sub-humid tropics. Anim Sci 76:119–136
14. Benzie EFL and Strain JJ (1999) Ferric reducing/antioxidant power assay: Direct measurement of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant and ascorbic acid concentration. Methods Enzymol 299:15–27
15. Bordoloi G, Jas R and Ghosh JD (2012) Changes in the haemato-biochemical pattern due to experimentally induced haemonchosis in Sahabadi sheep. J Parasit Dis 36(1):101–105
16. Bott NJ, Campbell EB, Bevrige I, Chilton NB, Ress D, Hunt PW and Gasser RB (2009) A combined microscopic-molecular method for the diagnosis of strongylid infections in sheep. Int J Parasitol 39:1277–1287
17. Chakravarty and Mukhopadhyaya (1992) Pure herbs and herbal healthcare. Indian J Chem 31:70
18. Coles GC, Bauer C and Borgsteede FHM, Greets S, Klei TR, Taylor MA and Waller PJ (1992) World Association for the Advancement of Veterinary Parasitology (W.A.A.V.P.) methods for the detection of anthelmintic resistance in nematodes of veterinary importance. Vet Parasitol 44(1–2):35–44
19. Dhara KC, Ray N, Kesh SS, Bandopadhyay PK, Batabyal S and Goswami A (2020) Haemato-biochemical profile of black Bengal goat on different gastro intestinal parasitic load. Int J Curr Microbiol Appl Sci 9(4):1601–1610
20. Diogenes PVA, Suassuna ACD, Ahid SMM and Blanco BS (2010) Serum protein electrophoretic profile of goats infected with *Haemonchus contortus*. J Anim Vet Adv 9(11):1603–1606
21. Dixit AK, Das G, Dixit P and Sharma RL (2019) Efficacy of herbal extracts and closantel against fenbendazole-resistant *Haemonchus contortus*. J Helminthol 93: 529–532
22. Du S, Liu H, Lei T, Xie X, Wang H, He X, Tong R and Wang Y (2018) Mangiferin: An effective therapeutic agent against several disorders (Review). Mol Med Rep 18(6):4775–4786

23. Dutta B, Konch K, Rahman T, Upadhyaya N, Pathak DC, Samuli SM, Phangchoo CV and Begum SA (2016) Occurrence and pathology of *Haemonchus contortus* infection in Goats. J Entomol Zool Stud 5 (3):1284-87
24. Faran NK, Khatoon S, Meena A, Kumar J and Kumar V (2024) Biochemical alterations and clinical manifestations of helminth infection in goat. Int J Vet Sci Anim Husb 9(1):318–321
25. Halliwell B and Gutteridge JMC (1999) Free Radicals in Biology and Medicine. 3rd edn. Oxford University Press, Oxford, pp. 1–25
26. Iqbal Z, Lateef M, Khan MN, Jabbar A and Akhtar MS (2006) Anthelmintic activity of *Swertia chirata* against gastrointestinal nematodes of sheep. Fitoterapia 77:463–465
27. Jain S and Sahni YP (2009) Anthelmintic activity of *Swertia chirata* seeds against gastrointestinal endoparasitic infestation in goats. J Vet Pharmacol Ther 8(1–2):56–58
28. Jesse FFA, Bitrus AA, Chung ELT, Peter ID, Lila MA and Salleh A (2019) Severe parasitic gastroenteritis (PGE) in a goat: a veterinary case report and way forward. Thai J Vet Med 49:295–299
29. Kaplan RM (2004) Drug resistance in nematodes of veterinary importance: A status report. Trends Parasitol 477–481
30. Khanal S, Shakya N, Nepal N and Pant D (2014) *Swertia chirata*: The himalayan herb. Int J Appl Sci Biotechnol 2(4):389–392
31. Kochewad SA, Chavan SB, Kumar N, Tayade AS, Dhumal N, Jadhavar P and Reddy KS (2023) Self-sustaining goat farming model for livelihood improvement of small and marginal farmers. Technical Bulletin No.40. ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra India, pp. 1–25
32. Kotze A and Prichard R (2016) Chapter nine-anthelmintic resistance in *Haemonchus contortus*: History, mechanisms and diagnosis. Adv Parasitol 93:397–428
33. Kumar S, Shekhar P, Kumar A, Bhatt S, Singh VK and Das AK (2024) Clinico therapeutic studies on haemonchosis in goats. Indian J Anim Res 58(7):1209–1214
34. Kumsa B and Hagos Y (2020) Antihelmintic medicinal plants used for animals in Ethiopia: A review. J Phytopharmacol 9(4):274–280
35. Lans C, Turner N, Khan T and Brauer G (2007) Ethno veterinary medicines used to treat endoparasites and stomach problems in pigs and pets in British Columbia, Canada. Vet Parasitol 148:325–340
36. Marklund S and Marklund G (1974) Involvement of the superoxide anion radical in the autoxidation of pyrogallol and a convenient assay for superoxide dismutase. Eur J Biochem 47:469–474
37. Moudgil AD, Sharma A, Verma MS, Kumar R, Dogra PK and Moudgil P (2017) Gastrointestinal parasitic infections in Indian Gaddi (goat) breed bucks: clinical, hemato-biochemical, parasitological and chemotherapeutic studies. J Parasit Dis 41(4):1059–1065
38. Ntonifor H, Shei S, Ndaleh N and Mbunkur G (2013) Epidemiological studies of gastrointestinal parasitic infections in ruminants in Jakiri, Bui division, North West region of Cameroon. J Vet Med Anim Health 5(12):344–352
39. Parmar D, Chandra D, Prasad A, Sankar M, Nasir A, Khuswaha B, Khare R and Kaur N (2020) Efficacy of closantel against benzimidazole resistant *Haemonchus contortus* infection in sheep. Indian J Anim Res

40. Phoboo S, Bhowmik PC, Jha PK and Shetty K (2010) Anti-diabetic potential of crude extracts of medicinal plants used as substitutes for *Swertia chirata* using in vitro assays. *BOTOR* 7:48–55
41. Prichard PK, Hennessy DR and Steel JW (1978) Prolonged administration: A new concept for increasing the spectrum of and effectiveness of anthelmintics. *Vet Parasitol* 4:309–315
42. Ramakant Sarkar TK, Verma AK, Maurya PS, Thakur V, Singh A, Rawat S, Chandra G, Maurya PK and Gautam S (2024a). Prevalence of gastrointestinal parasitic infections in goats in Western Uttar Pradesh, India. *Acta Sci Vet Sci* 6(6):17–27
43. Ramakant, Sarkar T K, Verma K, Maurya P S, Jaiswal V, Singh A, Thakur V and Rawat S. 2025. PCR based identification of different strongyle species in goats of western Uttar Pradesh, India. *Indian J Anim Sci* 95(1):13–17
44. Ramakant, Sarkar TK, Verma AK, Maurya PS, Thakur V, Singh A, Jaiswal V, Rawat S, Maurya PK and Gautam S (2024b) In vitro anthelmintic activity of aqueous extracts of seven medicinal plants against *Haemonchus contortus* in goats. *Int J Adv Biochem Res* 8(6):51–58
45. Roberts FHS and Sullivan PJO 1(950) Methods for egg counts and larval cultures for strongyles infesting the gastrointestinal tract of cattle. *Aust J Agric Res* 1:99–102
46. Saraswat and Parihar S (2021) *Swertia chirata*- A wonderful herb. *Indian J Pharm Biol Res* 9(4):10–15
47. Selemón M (2018) Review on control of *Haemonchus contortus* in Sheep and Goat. *J. Vet Med Res* 5(5):1139–1145
48. Singh R, Bagherwal RK, Mehta HK, Choudhary NS, Jayraw AK and Awasthi S (2022) Comparative efficacy of closantel and *Azadirachta indica* against strongyle infection in goats. *Indian J Vet Sci Biotechnol* 18(2):118–120
49. Sinha SK, Pati S and Shahi S (2023) Medicinal value of chiraita: A review. *Eur Chem Bull* 12(1, S):158–162
50. Soulsby EJJ (1982) *Helminths, Arthropods & Protozoa of Domesticated Animals*. 7th edn. ELBS, Bailliere Tindall, London pp. 763–778
51. Tan TK, Panchad C, Lee LV, Ngui R, Sharma SKR and Lim ALY (2014) Co- infection of *Haemonchus contortus* and *Trichostrongylus* spp. among livestock in Malaysia as revealed by amplification and sequence of internal transcribed spacer II DNA region. *BMC Vet Res* 10:38
52. Tripathi BN, Kumar A, Dixit AK, Rai B and Saxena VK (2020) Improvement in goat production for sustainable rural livelihood. In: *Mahatma Gandhi's Vision of Agriculture: Achievements of ICAR*. Published by Dr. S.K. Singh, Project Director, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, Krishi Anusandhan Bhawan I, Pusa, New Delhi 110012. pp. 39–47
53. Urquhart GM, Armour J, Duncan JL, Dunn AM and Jennings FW (1996) *Veterinary Parasitology*, 2nd edn. Blackwell Science Ltd., Oxford, UK
54. Veena M, Puttalakshammam GC, Ananda KJ and Sengupta PP (2020) Morphological and molecular characterization of gastrointestinal nematodes in sheep. *Int J Curr Microbiol App Sci* 9(04):2564–2575

55. Wangchuk P, Giacomun PR, Pearson MS, Smout MJ and Loukas A (2016) Identification of lead chemotherapeutic agents from medicinal plants against blood flukes and whipworms. *Sci Rep* 6:32101
56. Westers T, Bitton AJ, Menzies P, Leeuwen JV, Poljak Z and Peregrine AS (2016) Efficacy of closantel against ivermectin and fenbendazole-resistant *Haemonchus* spp. in sheep in Ontario, Canada. *Vet parasitol* 228:30–41
57. Wood IB, Amaral NK, Bairden K, Duncan JL, Kassai T, Malone JJB, Pankavich JA, Reinecke RK, Slocombe O, Taylor SM and Vercruysse J (1995) World Association for the Advancement of Veterinary Parasitology (WAAVP) of guidelines for evaluating the efficacy of anthelmintics in ruminants (bovine, ovine, and caprine). *Vet Parasitol* 58(3):181–213
58. Zakir AS, Ahmad G, Anwar M and Rehman S (2021) *Swertia chirata*: A comprehensive review of its abundant medicinal properties. *IJUIM* 5(2):157–160
59. Zvinorova PI, Halimani TE, Muchadeyi FC, Matika O, Riggioe V and Dzama K (2016) Prevalence and risk factors of gastrointestinal parasitic infections in goats in low-input low-output farming systems in Zimbabwe. *Small Rumin Res* 143:75–83

Figures

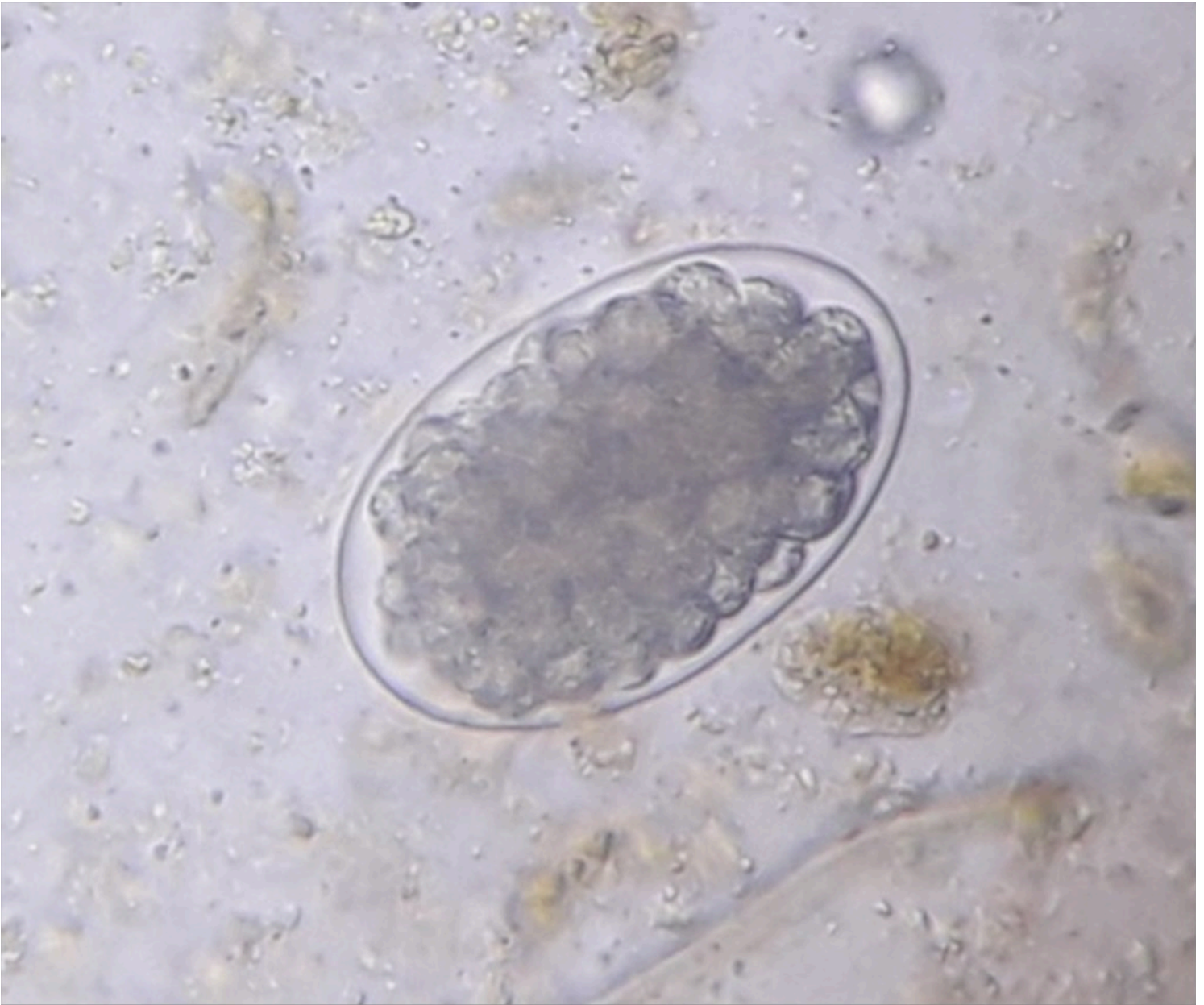


Figure 1

Representative micrograph of strongyle-type egg detected in fecal samples of naturally infected Barbari goats



Figure 2

Agarose gel electrophoresis of ITS-2 PCR amplification products confirming *H. contortus* infection. Lane L: 100bp DNA ladder; L1: negative control; L2: positive control; L3-L8: PCR-positive samples (265bp amplicon)

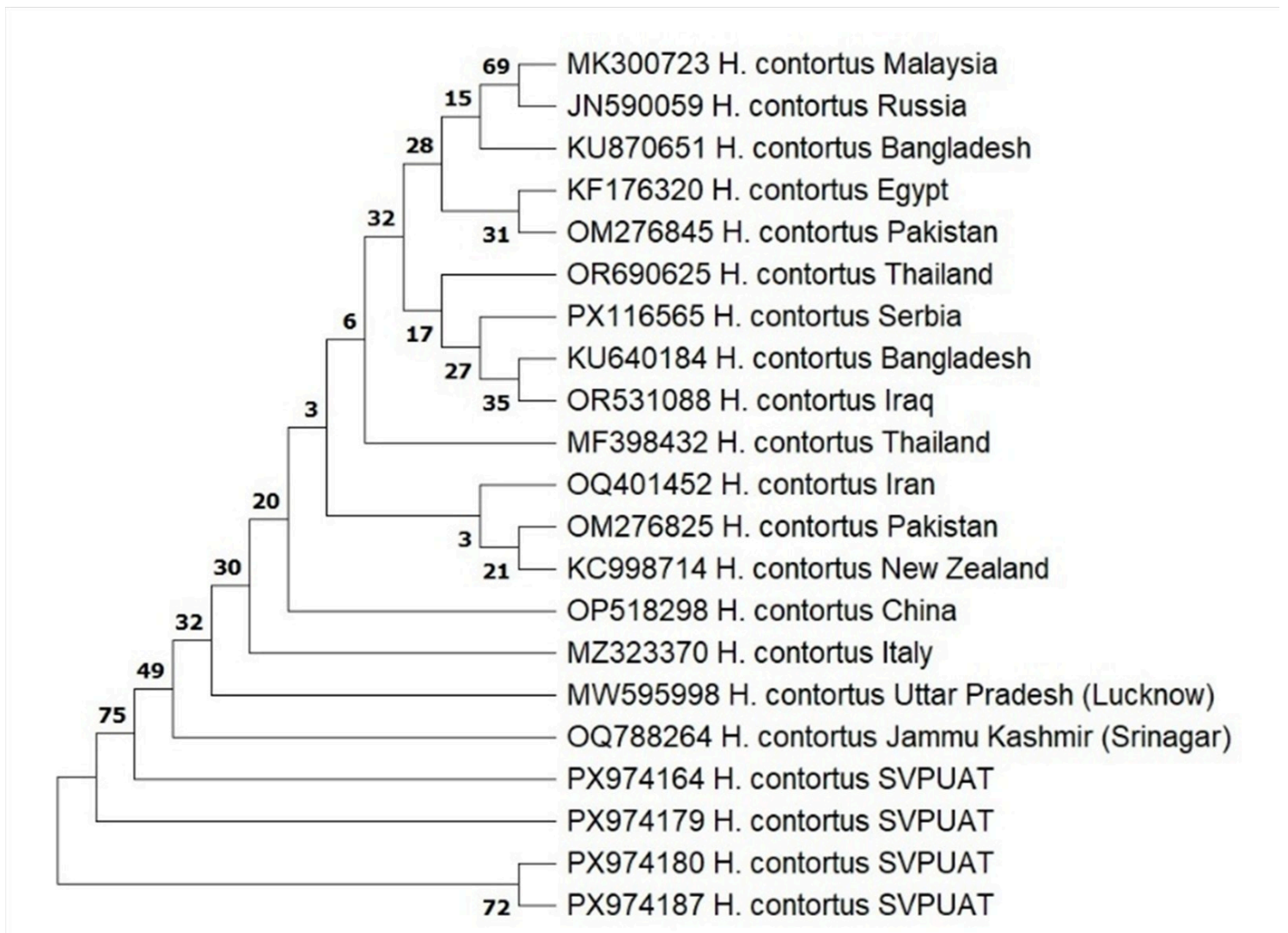


Figure 3

Phylogenetic tree based on ITS-2 rDNA sequences showing genetic clustering of the present *H. contortus* isolates with reference sequences using the neighbor-joining method (1000 bootstrap replicates; MEGA X software)

Supplementary Files

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- [floatimage1.png](#)