314 (2025) 106445

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Helminth infections in alpacas (*Vicugna pacos*), husbandry and worm control practices in South American Camelids in Italy

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ARTICLE INFO

Keywords:
Alpacas
Epidemiology
Fecal egg count
Gastrointestinal parasites
Management
Questionnaire
Egg output

ABSTRACT

The recent global expansion of alpaca breeding, including in Italy, has driven growing interest in this species, making further research necessary to support their health and management. Gastrointestinal helminths are among the main health concerns, causing severe disease that affects welfare and productivity. In Europe, data on helminth infections in South American Camelids (SACs) are still limited. This study aimed to assess the prevalence, distribution, and risk factors for helminth infections in alpacas in Italy, and evaluate the husbandry and worm control practices through a structured questionnaire and coprological analyses. Individual fecal samples were collected from 1296 alpacas and analysed by the Mini-FLOTAC, Baermann, and sedimentation techniques. Gastrointestinal strongyle (GIS) type eggs were the most frequently detected helminths (54.0 %), followed by *Nematodirus* spp. (21.2 %), *Trichuris* spp. (12.6 %), *Nematodirus battus* (7.6 %), *Capillaria* spp. (6.7 %), *Moniezia* spp. (3.2 %), *Dicrocoelium dendriticum* (2.5 %), *Strongyloides* spp. (0.5 %), and *Dictyocaulus* spp. (0.2 %). Alpacas < 2 years were at higher risk of infection for all helminth groups. Breeding in central, southern, and insular area was significantly associated with almost all helminth infections. The warm season was significantly associated with GIS, *Nematodirus* spp., and *Trichuris* spp. infections. Alpacas with a BCS < 3 had a higher risk for *Trichuris* spp. and *Capillaria* spp. infections. Questionnaire responses ($n = 104$) revealed great attention to dung removal and parasitological monitoring. This study provides the first data on helminth infections in alpacas in Italy, showing wide species diversity. The use of fenbendazole and ivermectin was widespread, raising concerns about potential anthelmintic resistance.

1. Introduction

Alpacas (*Vicugna pacos*) and llamas (*Lama pacos*) are domesticated South American Camelid (SAC) species, with Peru and Bolivia raising the world's largest population of alpacas (90 % of the world's population) and llamas (64 % of the world's population), respectively (Miranda-de la Lama and Villarroel, 2023). These camelids play a key role in the socio-economic development of the Andean countries, where they are bred for their fibre and meat, as well as for exporting animals of high genetic quality (Vilá and Arzamendia, 2022; Miranda-de la Lama and Villarroel, 2023). Over the past 40 years, the breeding of these camelids has gained popularity beyond South America, expanding also to North America, Oceania, and Europe (Miranda-de la Lama and Villarroel, 2023). In Italy, alpacas were first introduced in 1997 (Morgante et al., 2001), and since then their breeding has gradually increased, currently reaching 902 registered farms; however, the total number of alpacas raised in the countryside is still unknown (Vetinfo, 2025).

The global increase in the alpaca population has resulted in a

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https://doi.org/10.1016/j.tvjl.2025.106445
Received 18 June 2025; Received in revised form 16 September 2025; Accepted 16 September 2025
Available online 17 September 2025

continuous expansion in scientific research on these animals over the years, focusing mainly on camelid health. Endoparasites are regarded as a common cause of disease, with sanitary and economic implications worldwide (Cañal and Beltrame, 2022). Alpacas can be parasitized by several gastrointestinal nematode (GIN), cestode, and trematode species, most of which are generalist parasites, infecting both camelids and ruminants. SAC-specific GIN, such as *Camelostrongylus mentulatus*, *Graphinema aucheniae* and *Spiculopteragia peruviana* located in the third-compartment (C-3), *Lamanema chavezi* and *Nematodirus lamae* in the small intestine, and *Trichuris tenuis* in the large intestine have been described, mainly occurring in South America (Ballweber, 2009; Fowler, 2010).

The epidemiological scenario of helminths of SAC has been well investigated over the past 50 years in South American countries, of which Peru accounts for about 80 % of global research, followed by Ecuador (12.0 %), Chile, and Bolivia (4.0 %, each) (Cañal and Beltrame, 2022). In Europe, data on camelid endoparasites are available from Switzerland (Hertzberg and Kohler, 2006), Austria (Lambacher et al., 2016), Germany (Kultscher et al., 2019), Poland (Szopieray et al., 2024; Pilarczyk et al., 2025), and some reports from the United Kingdom (Tait et al., 2002). In contrast, in Italy only a recent study on *Toxoplasma gondii* and *Neospora caninum* infections in SAC is available (Castaldo et al., 2025), while information on the distribution and prevalence of helminth infections in alpacas is scarce, except for a report on a limited number of farms and animals from a restricted area of central Italy (Ortu and Perrucci, 2022).

Therefore, this study aimed to (*i*) investigate the epidemiological scenario of helminths in alpacas in Italy, (*ii*) assess the risk factors potentially associated with the main helminth infections, and (*iii*) carry out a questionnaire survey on husbandry and worm control practices in SAC in Italy.

2. Material and methods

2.1. Study animals and sampling

The study was conducted from August 2022 to January 2025 on 1296 alpacas kept at 88 sampling sites, located in 13 Italian regions. Based on temperature and rainfall data, sampling sites were grouped into two Italian areas: "Northern Area" (mean temperature 15.9 °C and mean rainfall 1186.9 mm), and "Central/Southern/Insular Area" (mean temperature 19.9 °C and mean rainfall 849.9 mm) (ISPRA, 2025). The sampling period was recorded and categorized into two main seasons: "cold" (21 September – 20 March) or "warm" (21 March – 20 September). For each alpaca, data regarding animal identification number, breed, sex, age, and body condition score (BCS) were recorded. All the animals were classified into four age-classes: crias ($\leq$ 6 months), weaners (> 6 months - < 12 months), tuis ($\geq$ 1 year - < 2 years), and adults ($\geq$ 2 years) (Love, 2017). Body condition score was determined using the specific alpaca and llama chart applying a scale of 1–5 with half scores (Van Saun, 2013). To facilitate the statistical analysis, in the present study, animals were grouped into two categories: "poor" (BCS < 3), and "good" (BCS $\geq$ 3).

During routine clinical examination, veterinary practitioners were involved in opportunistic fecal sampling, either directly from the rectum of each animal, or alternatively from fresh deposits on the ground in case of crias. Samples were transferred into plastic containers, labelled, stored at 4 °C, and delivered to the Department of Veterinary Medicine and Animal Production of the University of Naples "Federico II" for coprological analyses. All procedures were performed for diagnostic purposes during a routine health check, and for this reason, the study did not require ethical approval according to European Directive 2010/63/EU. Written informed consent was obtained from the owners of the animals included in the study.

2.2. Coprological analysis

Individual Fecal Egg Counts (FECs) were performed within 24–48 h, using the Mini-FLOTAC technique with a detection limit of five eggs per gram (EPG). The flotation medium used was saturated $ZnSO_4$ solution (specific gravity 1.350) (Cringoli et al., 2017). Using the optical microscope (Leica-DM-750, Wetzlar, Germany), based on morphological and morphometric features, each egg was identified as belonging to gastrointestinal strongyle (GIS) type eggs, *Lamanema chavezi, Nematodirus battus, Nematodirus* spp. (i.e., all other *Nematodirus* species except *N. battus*), *Strongyloides* spp., *Capillaria* spp., *Trichuris* spp., *Moniezia* spp., and *Dicrocoelium dendriticum* (Fowler et al., 2010).

Based on the FEC result, GIS egg shedding levels for each age-class were grouped into four levels: 1–100 EPG, 101–200 EPG, 201–300 EPG, and > 300 EPG. Since standardized egg shedding categories for alpacas are not available, this classification was defined by the authors in order to provide a clearer overview of egg output.

Furthermore, for each fecal sample, a qualitative sedimentation technique was performed for the detection of trematode eggs, and the content was examined under a stereomicroscope (Leica-MS5, Wetzlar, Germany) (Hutchinson, 2009).

In case of samples positive for GIS type eggs by Mini-FLOTAC, pooled fecal cultures (maximum of four animals) were set up. Approximately 40 g of feces were homogenized with water and vermiculite and incubated at 25–27 °C for seven to ten days to obtain infective third-stage larvae - L3. At the end of the incubation period, L3 were recovered by the Baermann technique (Kultscher et al., 2019) and differentiated microscopically at the genus level based on morphological criteria (van Wyk et al., 2013). Additionally, the Baermann technique was also used for the detection of *Dictyocaulus* spp. first-stage larvae (L1) from fresh feces (Hutchinson et al., 2009).

2.3. Questionnaire survey

Based on similar studies in Germany (Neubert et al., 2021) and the UK (French et al., 2021), a questionnaire survey was developed and voluntarily filled by SAC owners using an online programme, Microsoft Forms® (Microsoft Corporation, Redmond, WA, USA). The structured questionnaire (Supplementary file) comprised 89 questions, including 61 closed-ended multiple-choice questions, 15 yes/no questions, and 13 open questions where respondents provided descriptive information or a number. Most of the close-ended questions included an additional "other" category to allow respondents to provide an alternative answer if none of the given options applied. The questions were assigned to a section, for a total of four key areas: (*i*) animals owner data (e.g., farming experience, education level and main occupation), (*ii*) farm veterinarian's data, (*iii*) farm structure and husbandry practices (e.g., primary use of animals, country of animal origin, feed management, herd size, type of stable, access to pasture, co-grazing with ruminants, facilities cleaning practices), (*iv*) animal health management and deworming practices (e.g., vaccination, timing and frequency of treatment against endoparasites, drug used, dosage, coprological diagnosis for endoparasites, knowledge of anthelmintic resistance phenomena, management of newly introduced animals, diseases and clinical signs occurring on the farm).

2.4. Data analysis

All collected data were entered into a Microsoft Excel® spreadsheet, edited, coded and then summarized by descriptive statistics like mean and proportion (e.g., prevalence). The Wald method was used to calculate the 95 % Confidence Interval (CI) of the prevalence. For each helminthic taxon with a prevalence higher than 5 %, a univariable approach (Pearson Chi squared test) was initially performed to assess the association of each encountered parasite with the considered risk factors (area, season, BCS, and physiological-category). The factor 'physiological-category' was purposively created for the statistical analysis, dividing the animals into five categories with different physiological characteristics potentially influencing parasite burden: the three juvenile age-classes, plus adult females and adult males. If more than one factor resulted in significance, a multivariable logistic regression model was used to assess the association of the potential risk factors with the parasitic taxa. Finally, the model fitness was assessed by the Hosmer–Lemeshow goodness-of-fit test (Dohoo et al., 2009). Differences in egg output among subgroups were assessed through a non-parametric approach, using the Mann-Whitney *U* test or the Kruskal-Wallis test, considering the same factors. For the data analysis the software IBM SPSS Statistics 29.0 was used, and a *p*-value < 0.05 was regarded as statistically significant.

3. Results

3.1. Study animals and sampling

Out of 1296 alpacas included in the study, 57.6 % (747/1296) were females, and 42.4 % (549/1296) were males. Regarding the age-classes, 9.2 % (119/1296) were crias, 10.1 % (131/1296) weaners, 15.0 % (195/1296) tuis, and 65.7 % (851/1296) adults (i.e., 323 adult males, and 528 adult females). The mean age of animals ± standard deviation was 4.2 ± 3.9 years (range: 1 month – 23 years). Almost all the alpacas belonged to the Huacaya breed (97.7 % - 1266/1296), with only a small percentage belonging to the Suri breed (2.3 % - 30/1296). Among all animals, 80.4 % (1042/1296) showed a good BCS, whereas 19.6 % (254/1296) had a poor BCS.

Of the 88 sites sampled, 64.8 % (57/88) were classified as farms, 23.9 % (21/88) as private gardens where animals were kept as companion animals, 10.2 % (9/88) as zoological gardens, and 1.3 % (1/88) as sanctuaries. With regards to the location, 64.8 % (57/88) of the sampling sites belonged to the "Northern Area", including a total of 762 animals (58.8 %), whereas 23.9 % (21/88), 7.9 % (7/88), and 3.4 % (3/88) were located in the central, southern, and insular areas, respectively. Accordingly, 35.2 % (31/88) of the sampling sites belonged to the "Central/Southern/Insular Area", with a total of 534 (41.2 %) alpacas (Fig. 1).

The majority of samples (61.4 % - 796/1296) were collected during the warm season, followed by the cold season (38.6 % - 500/1296).

3.2. Coprological analysis

In total, 66.3 % (859/1296, 95 % CI 63.71 – 68.85) of the alpacas tested positive for helminths in single or mixed infections, and GIS type eggs were the most frequently detected, being observed in 54.0 % (700/1296, 95 % CI 51.30 – 56.73) of the animals. A detailed parasitological assessment is presented in Table 1 and Fig. 2.

Regarding the GIS egg shedding levels, 46.0 % (596/1296) of the alpacas had a negative FEC, whereas 45.1 % (585/1296) of the animals had FEC between 1 and 100 EPG, 4.3 % (56/1296) ranged from 101 to 200 EPG, 1.2 % (16/1296) showed values between 201 and 300 EPG, and 3.3 % (43/1296) of the animals had a FEC > 300 EPG. Details of GIS egg shedding levels by age-class are shown in Fig. 3.

Table 1
Prevalence and mean EPG of helminths in study alpacas in Italy ($n = 1296$).

Helminth	Positive animals		EPG	
	(%, *n*)	95 % CI	Mean	Min. – Max.
Gastrointestinal strongyle type eggs	54.0 % (700)	51.30 – 56.73	84.4	5 – 3315
Nematodirus spp.	21.2 % (275)	18.99 – 23.45	18.6	5 – 200
Trichuris spp.	12.6 % (163)	10.77 – 14.38	16.6	5 – 110
Nematodirus battus	7.6 % (99)	6.19 – 9.09	17.7	5 – 365
Capillaria spp.	6.7 % (87)	5.35 – 8.08	8.6	5 – 45
Moniezia spp.	3.2 % (42)	2.28 – 4.20	n.a.	n.a.
Dicrocoelium dendriticum	2.5 % (33)	1.69 – 3.40	7.6	5 – 45
Strongyloides spp.	0.5 % (7)	0.14 – 0.94	7.9	5 – 20
Dictyocaulus spp. (larvae)	0.2 % (2)	0 – 0.37	n.a.	n.a.

EPG: eggs per gram; CI: confidence interval; n.a: not applicable.

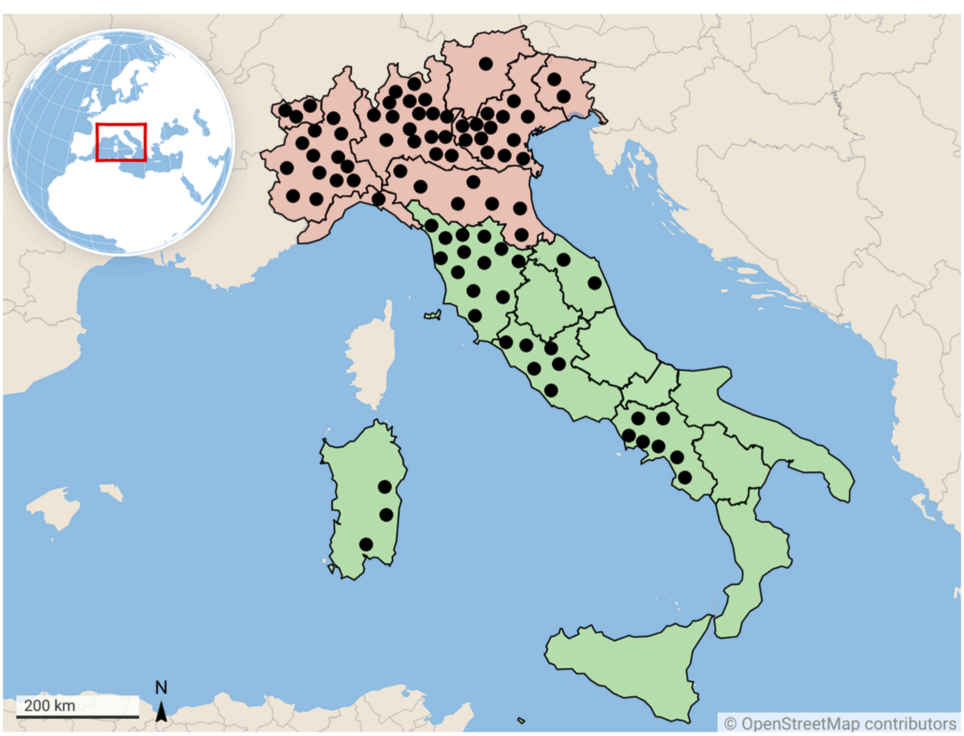

Fig. 1. Sampling sites (circles) distributed across Northern Area (red) and Central/Southern/Insular Area (green).

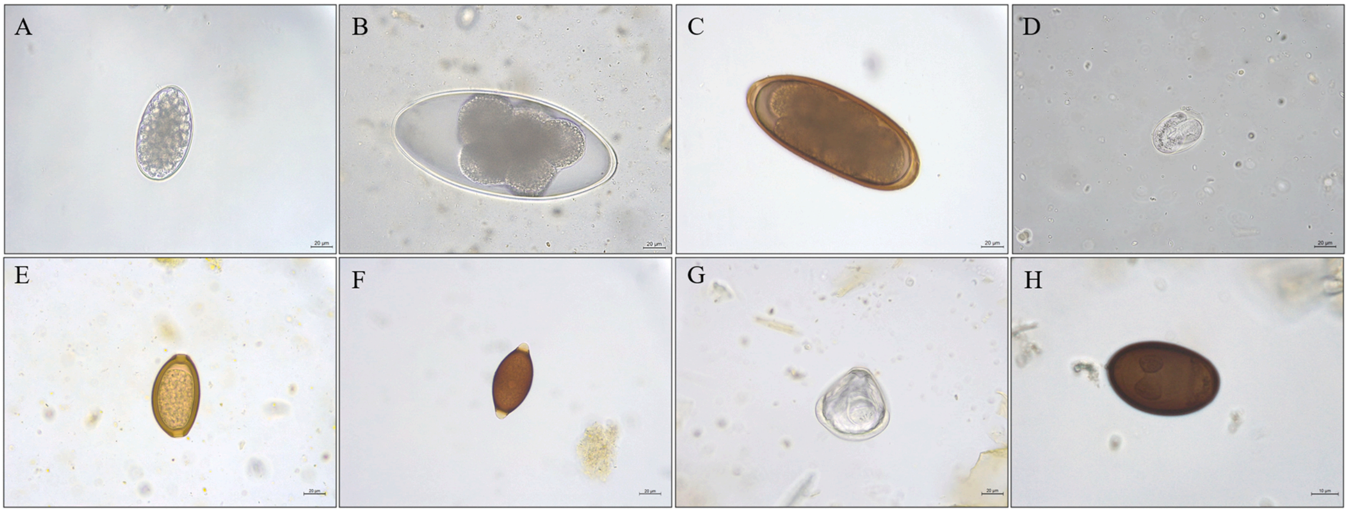

Fig. 2. Helminth eggs detected in the study: strongyle type egg (A), *Nematodirus* spp. (B), *Nematodirus battus* (C), *Strongyloides* spp. (D), *Capillaria* spp. (E), *Trichuris* spp. (F), *Moniezia* spp. (G), *Dicrocoelium dendriticum* (H). All images were captured at 40 × magnification, except *D. dendriticum* egg at 100 × .

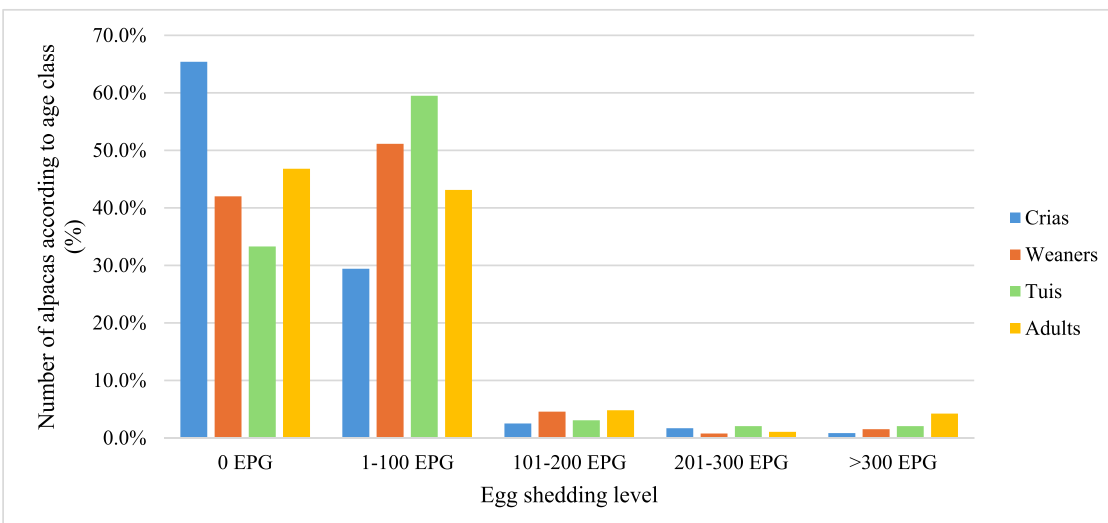

Fig. 3. Strongyle egg shedding levels of alpacas by age-class.

At the farm level, GIS type eggs were confirmed as the most commonly detected helminths with a prevalence of 83.0 % (73/88, 95 % CI 75.10–90.81), followed by *Trichuris* spp. in 54.5 % (48/88, 95 % CI 44.14–64.95), *Nematodirus* spp. in 53.4 % (47/88, 95 % CI 42.99–63.83), *Capillaria* spp. in 37.5 % (33/88, 95 % CI 27.38–47.62), *N. battus* in 34.1 % (30/88, 95 % CI 24.19–43.99), *Moniezia* spp. in 18.2 % (16/88, 95 % CI 10.12–26.24), *D. dendriticum* in 15.9 % (14/88, 95 % CI 8.27–23.55), *Strongyloides* spp. in 6.8 % (6/88, 95 % CI 1.55–12.08) and *Dictyocaulus* spp. in 2.3 % (2/88, 95 % CI 0–5.39) of the farms.

Single infections were diagnosed in 56.5 % (485/859, 95 % CI 53.15 – 59.78) of the infected alpacas, while the rest of the infected animals (43.5 %; 374/859, 95 % CI 40.22 – 46.85) had mixed infections. In detail, 28.2 % (242/859, 95 % CI 25.16 – 31.18), 11.2 % (96/859, 95 % CI 9.07 – 13.28), 3.6 % (31/859, 95 % CI 2.36 – 4.86), 0.5 % (4/859, 95 % CI 0.01 – 0.92), and 0.1 % (1/859, 95 % CI 0 – 0.34) of the alpacas were parasitized by two, three, four, five, and seven helminths, respectively. The most common association detected was a GIS type and *Nematodirus* spp. eggs (Table S1).

A total of 2741 larvae were identified by fecal cultures, revealing the presence of third-stage larvae of *Trichostrongylus* spp. (61.5 %), *Ostertagia* spp. (12.3 %), *Cooperia* spp. (11.3 %), *Haemonchus contortus* (10.3 %), *Bunostomum* spp. (2.0 %), *Oesophagostomum* spp. (1.5 %), and *Chabertia* spp. (1.1 %).

3.3. Questionnaire survey

A total of 104 questionnaires were collected during the survey. The average SAC farming experience of respondents was 10 years (minimum 1, maximum 27 years). The majority of respondents had a secondary grade level of education (52.9 %, 55/104), followed by a university degree (29.8 %, 31/104), and a master's or PhD (1.9 %, 2/104 each), while the remaining (10.6 %, 11/104) had lower qualifications. Among the interviewees, 14.4 % (15/104) stated that keeping of SAC was their main occupation, while 86.5 % (90/104) declared that they were engaged in different working areas and kept SAC as a secondary activity. Most respondents managed small herds (≤ 20 animals) (85.6 %, 89/104), and animals were kept mainly as companion animals (48.1 %, 50/104) and/or for fibre production (36.5 %, 38/104). Among the owners, 69.2 % (72/104) declared to keep Italian SAC (born at the same farm or purchased from other Italian farms), while 25.0 % (26/104) also purchased animals from other European countries (i.e., Austria, Belgium, France, Germany, the Netherlands, Switzerland, and the United Kingdom) or Oceania (i.e., Australia and New Zealand), South America (i.e., Chile, and Peru) and North America (i.e., the USA), whereas 5.8 % (6/104) of the owners purchased exclusively animals from foreign countries.

The animals had access to pasture in 85.6 % (89/104) of the sampling sites, and grazing was permanent (all year) in 69.7 % (62/89) of the cases. Rotational grazing was practised in 43.8 % (39/89) of the farms. Almost half (49.0 %, 51/104) of the respondents also farmed ruminants, of which 39.2 % (20/51) stated that SAC shared environments with ruminants. Dung removal from the pasture was performed in 73.0 % (65/89) of the sampling sites, with a daily (38.5 %, 25/65), weekly (32.3 %, 21/65), monthly (18.5 %, 12/65), or lower (10.8 %, 7/65) frequency. The higher frequency (daily or weekly) was more common in small (80.4 %, 37/46) and medium (15.2 %, 7/46) herds, rather than in larger ones (4.3 %, 2/46). Dung was removed in all farms provided with paddocks (100.0 %, 33/33), while cleaning of the stables was performed in 96.1 % (74/77) of the farms (Table S2).

Regarding sanitary management practices, 91.3 % (95/104) of the owners vaccinated their animals against infectious diseases (i.e., *Clostridium perfringens* in 98.9 %, *Clostridium tetani* in 23.2 %, Bluetongue virus in 2.1 %). Parasitological analyses (individual coprology) were performed by 85.6 % (89/104) of the respondents. Regarding anthelmintic treatment, the majority of the interviewees dewormed SAC (86.5 %, 90/104), and most of them based the treatment decision on the results of coprological analysis (68.9 %, 62/90), while the remaining respondents dewormed following a strategic program (i.e., parasite life cycle, weather conditions, farm management practices) (31.1 %, 28/90), and/or veterinary recommendation (7.8 %, 7/90) and clinical signs (i.e., poorly formed stools, diarrhoea, weight loss, anaemia, emaciation) (6.6 %, 6/90) The majority of the owners that dewormed regardless coprological diagnosis, treated once (46.4 %, 13/28) or twice (42.9 %, 12/28) a year. Respondents indicated a preference for the months of April (30.0 %, 27/90) and October (44.4 %, 40/90) to deworm animals. Benzimidazoles were the most frequently administered drugs (75.5 %), followed by macrocyclic lactones (62.2 %) (**Fig. 4**). Regarding anthelmintic dosages used for SAC, most respondents (22.2 %, 20/90) administered a dose that was twice the usual dose for sheep and the main route of administration was oral (84.4 %). A total of 51.0 % (53/104) of the owners declared to keep newly introduced animals in quarantine; drenching of new arrivals was performed on 54.8 % (57/104) of the farms. No cases of anthelmintic resistance on their farms were reported; however, among farmers who performed FEC before deworming (68.9 %, 62/90), 58.1 % (36/62) used post-treatment FEC reduction to assess treatment efficacy. Among diseases/clinical signs of the gastrointestinal system occurring on the farm, 28.8 % (30/104) indicated the occurrence of diseases, with endoparasites being the most frequently reported (53.3 %, 16/30) (Table S3).

3.4. Risk factors analysis

Significant differences were observed between the two areas, with the Central/Southern/Insular Area showing a higher prevalence and mean EPG for GIS ($p < 0.001$), *Nematodirus* spp. ($p < 0.001$), *Trichuris* spp. ($p < 0.001$) and *Capillaria* spp. ($p < 0.001$). Seasonal variation was also significant, with the warm season being associated with higher infection rates and EPG for GIS ($p < 0.001$), *Nematodirus* spp. ($p < 0.05$), and *Trichuris* spp. ($p < 0.05$). Animals with poor BCS exhibited significantly increased egg output for GIS ($p < 0.05$), and prevalence for *Nematodirus* spp. ($p < 0.05$), *Trichuris* spp. ($p < 0.01$) and *Capillaria* spp. ($p < 0.01$). The physiological-category showed significant differences ($p < 0.001$), with tuis being associated with GIS, *Capillaria* spp. and *Trichuris* spp. infections while weaners were associated with *Nematodirus* spp. and *N. battus* (Table 2, Table 3). Logistic regression analysis (Table 4) revealed that the risk of infection was significantly higher in the Central/Southern/Insular Area for GIS and *Nematodirus* spp. ($p < 0.001$), *Trichuris* spp. ($p < 0.05$) and *Capillaria* spp. ($p < 0.01$). The likelihood of *Trichuris* spp. and *Capillaria* spp. infection was higher ($p < 0.01$) for alpacas with poor BCS compared to those with a good BCS. Lastly, physiological-category was regarded as a risk factor for all parasitic taxa ($p < 0.001$).

4. Discussion

This survey provided the first large-scale epidemiological data on the prevalence of helminths in alpacas in Italy and associated risk factors for the infection. Moreover, to the best of the authors' knowledge, this study used for the first time the Mini-FLOTAC technique for the detection of helminths in alpacas, following its previous recommendation in llamas (Paras et al., 2018) and camels (Mohammedsalih et al., 2025).

The wide biodiversity of helminths herein found confirms that helminths are widespread in Italian alpacas. The overall helminth prevalence (66.3 %) is similar to that of a previous report on a limited number of animals (i.e., 157 alpacas kept on three farms) in central Italy (68.1 % - Ortu and Perrucci, 2022).

Among helminths, GIS type eggs were the most common parasites

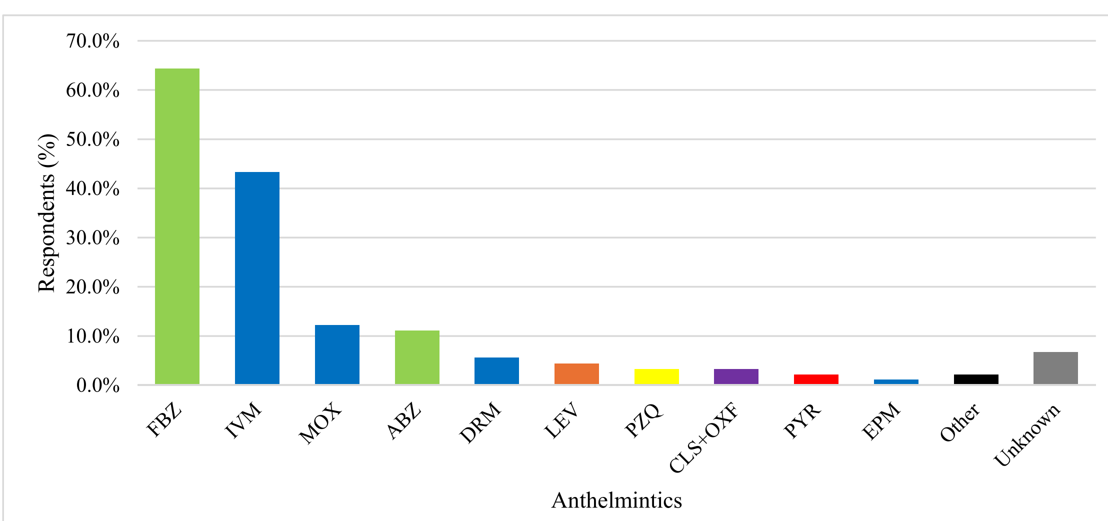

Fig. 4. Anthelmintics used in South American Camelids in Italy. Respondents could use more than one drug. FBZ: fenbendazole; IVM: ivermectin; MOX: moxidectin; ABZ: albendazole; DRM: doramectin; LEV: levamisole; PZQ: praziquantel; CLS: closantel; OXF: oxfendazole; PYR: pyrantel; EPM: eprinomectin.

Table 2
Prevalence and abundance (mean output) of gastrointestinal strongyle type eggs, *Nematodirus* spp., and *Nematodirus battus* in the subgroups identified by the considered individual factors (area, season, BCS, and physiological-category). Differences in mean egg output among subgroups are highlighted by different superscript letters when statistically significant ($p < 0.05$). Significant differences are reported in bold.

Factor	Variable		Gastrointestinal strongyle type eggs				*Nematodirus* spp.				*Nematodirus battus*			
		Tested alpacas (*n*)	Positive (%, *n*)	*p*-value	Mean output (EPG)	*p*-value	Positive (%, *n*)	*p*-value	Mean output (EPG)	*p*-value	Positive (%, *n*)	*p*-value	Mean output (EPG)	*p*-value
Area	**Northern**	762	46.6 % (355)	**< 0.001**	13.8	**< 0.001**	16.4 % (125)	**< 0.001**	1.8	**< 0.001**	11.5 % (88)	**< 0.001**	2.1	**< 0.001**
	Central/ Southern/ Insular	534	64.6 % (345)		91.0		28.1 % (150)		6.9		2.1 % (11)		0.3	
Season	**Cold**	500	44.6 % (223)	**< 0.001**	11.5	**< 0.001**	18.4 % (92)	**0.049**	1.7	**< 0.01**	8.6 % (43)	> 0.05	1.0	> 0.05
	Warm	796	59.9 % (477)		67.0		23.0 % (183)		5.4		7.0 % (56)		1.6	
BCS	**Poor**	254	58.7 % (149)	> 0.05	64.3	**0.043**	26.0 % (66)	**0.038**	4,7	**0.030**	9.8 % (25)	> 0.05	1.2	> 0.05
	Good	1042	52.9 % (551)		41.1		20.1 % (209)		3,7		7.1 % (74)		1.4	
Physiological-category	**Crias**	119	34.5 % (41)	**< 0.001**	19.0^{a}	**< 0.001**	30.3 % (36)	**< 0.001**	6.5^{a}	**< 0.001**	7.6 % (9)	**< 0.001**	0.5^{a}	**< 0.001**
	Weaners	131	58.0 % (76)		$25.7^{b,c}$		38.9 % (51)		10.0^{a}		20.6 % (27)		6.9^{b}	
	Tuis	195	66.7 % (130)		37.9^{c}		33.3 % (65)		6.4^{a}		9.7 % (19)		1.5^{a}	
	Adult males	323	51.4 % (166)		$28.0^{a,b}$		16.1 % (52)		2.2^{b}		5.3 % (17)		0.5^{a}	
	Adult females	528	54.4 % (287)		$70.2^{b,c}$		13.4 % (71)		2.0^{b}		5.1 % (27)		0.6^{a}	

EPG: eggs per gram.

Table 3
Prevalence and abundance (mean output) of *Trichuris* spp. and *Capillaria* spp. in the subgroups identified by the considered individual factors (area, season, BCS, and physiological-category). Differences in mean egg output among subgroups are highlighted by different superscript letters when statistically significant ($p < 0.05$). Significant differences are reported in bold.

Factor	Variable		*Trichuris* spp.				*Capillaria* spp.			
		Tested alpacas (*n*)	Positive (%, *n*)	*p*-value	Mean output (EPG)	*p*-value	Positive (%, *n*)	*p*-value	Mean output (EPG)	*p*-value
Area	**Northern**	762	9.7 % (74)	**< 0.001**	1.4	**< 0.001**	5.1 % (39)	**< 0.01**	0.4	**< 0.01**
	Central/ Southern/ Insular	534	16.7 % (89)		3.1		9.0 % (48)		0.9	
Season	**Cold**	500	10.0 % (50)	**0.027**	1.5	**0.025**	7.0 % (35)	> 0.05	0.5	> 0.05
	Warm	796	14.2 % (113)		2.4		6.5 % (52)		0.6	
BCS	**Poor**	254	18.1 % (46)	**< 0.01**	4.3	**< 0.01**	10.6 % (27)	**< 0.01**	0.8	**< 0.01**
	Good	1042	11.2 % (117)		1.5		5.8 % (60)		0.5	
Physiological-category	**Crias**	119	12.6 % (15)	**< 0.001**	2.2^{a}	**< 0.001**	2.5 % (3)	**< 0.001**	0.1^{a}	**< 0.001**
	Weaners	131	25.2 % (33)		4.7^{b}		6.9 % (9)		0.5^{a}	
	Tuis	195	29.7 % (58)		6.6^{b}		18.5 % (36)		1.7^{b}	
	Adult males	323	6.2 % (20)		0.6^{a}		5.3 % (17)		0.4^{a}	
	Adult females	528	7.0 % (37)		0.6^{a}		4.2 % (22)		0.4^{a}	

EPG: eggs per gram.

Table 4
Results of the logistic regression model for different parasitic taxa. Significant differences are reported in bold.

		Parasitic taxa	Gastrointestinal strongyle type eggs		*Nematodirus* spp.		*Nematodirus battus*		*Trichuris* spp.		*Capillaria* spp.	
	Hosmer–Lemeshow test:		*p*-value= 0165		*p*-value= 0919		*p*-value= 0563		*p*-value= 0685		*p*-value= 0960	
Factor	Variable	freedom degree	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value
Area	**Northern**	Reference										
	Central/ Southern/ Insular	1	1.970	**< 0.001**	1.772	**< 0.001**	0.118	**< 0.001**	1.576	**0.014**	1.962	**< 0.01**
Season	**Cold**	Reference										
	Warm	1	1.628	**< 0.001**	1.226	0.187	1.256	0.313	1.472	**0.049**	0.838	0.472
BCS	**Poor**	1	1.336	0.053	1.281	0.152	1.495	0.126	1.704	**< 0.01**	2.115	**< 0.01**
	Good	Reference										
Physiological-category	**Crias**	Reference										
	Weaners	4	2.798	**< 0.001**	1.509	0.131	3.448	**< 0.01**	2.509	**< 0.01**	3.125	0.095
	Tuis		4.761	**< 0.001**	1.302	0.305	1.125	0.787	3.568	**< 0.001**	11.270	**< 0.001**
	Adult males		2.577	**< 0.001**	0.519	**0.011**	0.521	0.140	0.578	0.138	3.012	0.087
	Adult females		2.559	**< 0.001**	0.382	**< 0.001**	0.516	0.108	0.577	0.096	2.047	0.254

(54.0 %) in this study, as well as in alpacas from different European countries (Hertzberg and Kohler, 2006; Kultscher et al., 2019; Pyziel-Serafin et al., 2022). The low level of GIS egg shedding (mean EPG 84.4) found is in accordance with previous studies in alpacas (Kultscher et al., 2019; Hinney et al., 2024). Unlike other livestock species, there are currently no available guidelines on a FEC-based approach for targeted selective treatment of GIS in alpacas, and the egg shedding categories (i.e., low, medium, and high) have not yet been definitively established. Some authors set up the threshold at FEC ≥ 150 or 200 EPG for treatment of adult animals (Rashid et al., 2018; Kultscher et al., 2019; Hinney et al., 2024). Accordingly, GIS egg shedding levels have been hypothesized for each age-class in this study, and few animals (4.6 %) exhibited FEC > 200 EPG (Fig. 3), corresponding to the threshold for selective therapy. These results highlighted an uneven distribution of egg shedding among animals, as previously observed in camelids (Williamson, 2014). In small ruminants, it has been estimated that around 20–30 % of the animals on a farm may harbour 70–80 % of the parasite population (Charlier et al., 2014). A similar pattern was observed in horses, where 15–30 % of the adult animals shed 80 % of the eggs (80:20 - *Pareto Principle*), while in donkeys 40 % of the individuals shed approximately 80 % of the eggs (80:40 - distribution rule) (Buono et al., 2023). Whether these rules also apply to alpacas is unknown, but a similar scenario could be assumed. Low levels of GIS egg output could be related to the typical behaviour of alpacas to deposit feces in specific common places – latrines - that could minimize the infection pressure and environmental contamination (Kultscher et al., 2019). Additionally, almost all the investigated farms (73.0 %) performed regular and frequent dung removal, strongly contributing to a lower environmental contamination with eggs and/or larvae (Ballweber, 2014). Reports on SAC-specific GIN, such as *N. lamae* and *L. chavezi*, have been documented in Europe (Mitchell et al., 2016; Bauer et al., 2024; Gliga et al., 2024), although no SAC specific-GIN have been detected in this study. This phenomenon could be related to the fact that almost half of the investigated farms (49.0 %) also raised ruminants, increasing the interactions and parasite spread among species (Cebra, 2014). This hypothesis is supported by evidence that spill-over of SAC-specific parasites (e.g., *C. mentulatus*) to ruminants has been demonstrated in domestic (De Ybáñez et al., 2003) and wild ruminants (Rossi and Ferroglio, 2011). At the same time, these results are a cause for concern due to the potential transmission of resistant parasites from small ruminants to camelids, particularly in view of the increasing cases of anthelmintic resistance in both alpacas and llamas documented in last years across Europe (Kultscher et al., 2019; Hinney et al., 2024), Australia (Jabbar et al., 2013; Rashid et al., 2018), and America (Gillespie et al., 2010; Galvan et al., 2012).

Gastrointestinal strongyles infections are strictly correlated with climatic conditions. Indeed, temperature and humidity, which vary depending on the geographic area and season, influence L3 development (Rashid et al., 2019a). Higher prevalence and abundance of GIS infection ($p < 0.001$ - Table 3**,** Table 4) were reported in the Central/Southern/Insular Area, as well as during the warm season ($p < 0.001$ - Table 4). In this study, almost all farms (85.6 %) provided access to pasture for alpacas; however, the extended grazing time during the warm season, because of to longer daylight hours, combined with more suitable weather conditions for L3 development, is likely to increase the risk of infection. Statistical analysis also indicated a higher likelihood of GIS infection in tuis compared to crias ($p < 0.001$ – Table 4). Different management practices of young animals may account for this finding. Indeed, crias often have access to the paddock but not to the pasture until weaning (around 6–8 months). On the contrary, tuis seem to be more susceptible to GIN infection, since this category begins grazing on pasture with a lack of previous exposure to GIN and consequently without the development of specific immunity. In addition, young animals usually suffer the stress associated with weaning and dietary changes, which can impair the development of an effective immune response increasing their susceptibility to parasitic infections (Pilarczyk et al., 2025).

Nematodirus spp. was the second most common parasite, detected in 21.2 % of the alpacas in the study. In addition to *N. lamae*, which is a SAC-specific parasite, *N. abnormalis, N. battus, N. filicollis, N. helvetianus,* and *N. spathiger* have been described in both SAC and ruminants (Ballweber, 2009). Among these, the "coffee coloured" eggs of *N. battus* can be easily differentiated (Jansen, 1973), and herein it is reported a prevalence of 7.6 %. The mean EPG for *Nematodirus* spp. (18.6) and *N. battus* (17.7) suggested a low fecundity and egg shedding of this parasite, as previously documented (Cebra, 2014; VanHoy et al., 2022). The prevalence and abundance of these helminths were associated with farm location, area, and animal age-class. Specifically, *Nematodirus* spp. was found with statistically higher prevalence in the Central/Southern/Insular Area, whereas *N. battus* was more prevalent and abundant in the Northern Area (Table 2). This difference could be related to the peculiar hatching behaviour of *N. battus* that needs a prolonged exposure to low temperatures followed by a rise in temperature for L3 to hatch (van Dijk and Morgan, 2008). These parasites are more pathogenic in young animals due to a lack of acquired immunity (VanHoy et al., 2022), and statistical analysis confirmed that young animals were at significantly higher risk of infection compared to adults ($p < 0.001$ – Table 2). Nevertheless, adult animals can harbour the infection, contributing to environmental contamination, although the clinical disease is usually absent (VanHoy et al., 2022).

Trichuris spp. eggs were detected in 12.6 % of the fecal samples. Although *Trichuris* spp. eggs require a high flotation density (Kultscher et al., 2019), whipworms are characterized by low egg shedding, as also proven herein (mean EPG 16.6). In this study, identification at the species level was not possible, however the most frequently reported alpaca species are *T. ovis* and *T. tenuis* (Fowler et al., 2010; Rashid et al., 2019b). Although information on the biology of *T. tenuis* and *T. ovis* is scarce, statistical analysis showed significantly higher prevalence and abundance in the Central/Southern/Insular Area ($p < 0.001$ **-** Table 3), as well as during the warm season ($p < 0.05$ **-** Table 4). These results suggest that climatic factors may affect the whipworm life cycle. Nevertheless, it is well known that *Trichuris* spp. eggs are highly resistant and can survive in the environment, accumulating even after long periods of hot, dry weather or drought conditions (Fowler, 2010). Young animals appeared at high risk of infection ($p < 0.001$ – Table 4), probably due to the confinement in limited areas with higher animal densities, increasing the likelihood of re-infection with larvated eggs. This parasite can cause enteritis, diarrhoea, and weight loss (Fowler, 2010). In this study a significant correlation between poor BCS and whipworm infection was found ($p < 0.01$ – Table 4); however, it is unknown if this is a consequence of the infection or animals with poor BCS are predisposed to higher risks of *Trichuris* spp. infection due to compromised immune responses.

Regarding *Capillaria* spp. a prevalence of 6.7 % was reported herein. Although little is known about this nematode, capillarids are known to shed eggs intermittently, so even heavy infections may result in low egg counts (Cebra, 2014). The capillarid species infecting SAC are not well known; however, the same species of ruminants are also described in SAC (*C. brevipes* and *C. longipes* - Duncson, 2012). The biology of this parasite is not clearly known; however, during the prepatent period (approximately 42 days), disease may occur in camelids (Cebra, 2014). In this study, animals showing poor BCS were significantly associated with *Capillaria* spp. infection ($p < 0.01$ - Table 3, Table 4), suggesting a potential pathogenic role for the parasite. Additionally, tuis showed a significantly higher likelihood to get infected ($p < 0.001$ – Table 4), indicating a possible correlation between infection risk and age.

In this study the low prevalence of *Moniezia* spp. (3.2 %) is in agreement with data reported in alpacas in Europe (Kultscher et al., 2019; Szopieray et al., 2024). Both *M. benedeni* and *M. expansa* were detected, confirming that these species are widespread in Europe and suggesting that co-grazing with ruminants, particularly sheep, may play a role in the spread of infection (Duncanson, 2012).

Dicrocoelium dendriticum was reported herein with a prevalence of 2.5 %, whereas no alpacas positive to *F. hepatica* were detected. These results confirm *D. dendriticum* as the most common liver fluke in SAC in Europe (Klein et al., 2012), as it thrives in a wider range of environments compared to *F. hepatica*, which requires aquatic and humid environments (Ballweber, 2009).

Strongyloides spp. was found herein with a prevalence of 0.5 %, lower than in Poland (Szopieray et al., 2024; Pilarczyk et al., 2025), where *S. papillosus* was presumed to be the species involved.

Lungworm infections caused by *Dictyocaulus* spp. have been described in camelids (Cañal and Beltrame, 2022). In this study a prevalence of 0.2 % was reported, suggesting a scant circulation of lungworms in Italian alpacas, however data on the epidemiology are very limited (Gomez-Puerta et al., 2024).

Questionnaire survey reflects proper management practices by SAC owners, including a high level of education and strict attention to dung removal. The careful approach to parasite control by using coprological diagnosis before deworming animals may have contributed to the moderate prevalences herein detected. However, although dewormers are administered mainly one or two times per year (Table S3), the widespread use of FBZ and IVM raises concerns about the potential spread of anthelmintic resistance.

5. Conclusion

This study provides the first large-scale epidemiological data on helminth infections in alpacas in Italy. The results show that alpacas can harbour different helminth species, with gastrointestinal strongyle type eggs being the most common. Fecal Egg Count for gastrointestinal strongyles indicated a generally low egg shedding and an uneven distribution of egg shedding among alpacas. Helminth infection prevalences varied by area, season, and age-class. Regular Fecal Egg Count monitoring is strongly recommended in order to develop target treatment, limiting anthelmintic resistance although further studies are needed to determine the cut-off value for selective therapy of GIS in alpacas.

Funding sources

The study received partial support from a Grant from the Ministry of Health of the Italian Republic (IZSLT 11/24 RC) and research program regarding the "Parasitological Assistance Program in South American Camelids".

CRediT authorship contribution statement

Rudi Cassini: Writing – review & editing, Formal analysis, Data curation. **Giovanni Sgroi:** Writing – review & editing. **Sara Tonon:** Project administration, Funding acquisition. **Michele Capasso:** Methodology. **Alessia Ciaramelli:** Methodology. **Stefano Scarcelli:** Methodology. **Francesco Buono:** Writing – review & editing, Methodology, Conceptualization. **Elisa Castaldo:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Vincenzo Veneziano:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **Walter Basso:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank the freelance veterinarians and camelid owners who contributed to this research. We gratefully acknowledge Dr. Farwa Humak (PhD student in Parasitology) for her valuable assistance and for revising the English language in this manuscript.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2025.106445.

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