

The prevalence of intestinal parasite infections in goats from smallholder farms in Northern Thailand

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Summary

The present study determined the prevalence of gastrointestinal (GI) parasites in small ruminants kept in smallholder farms in Phitsanulok, Northern Thailand. A total of 885 goats from 31 smallholder farms were selected randomly between May 2019 to January 2020. Fecal samples were collected to estimate fecal egg counts and oocysts counts using the modified McMaster technique. Furthermore, pooled fecal samples from each of the farms were cultured in order to differentiate third-stage larvae of nematode. Examination of fecal samples revealed that 885 were positive for one or more parasites, giving an overall prevalence of 87.2 %, of which 38.6 % were infected with one and 48.6 % with multiple parasite. *Strongyles* and *Eimeria* oocysts were the most prevalent. *Haemonchus contortus* and *Strongyloides papillosus* were the predominant species based on the percentage of larvae in fecal cultures. Tapeworm eggs were encountered in 14.2 % of all samples. No significant difference in gastrointestinal parasite prevalence was associated with sex of the host. Infection was significantly ($P = 0.009$) highest in poor body conditioned goats (72.0 %) as compared to moderate (48.9 %) and good body conditioned (50.0 %) goats. This report on prevalence of GI parasites of small ruminants in smallholder farms in Northern Thailand reveals a high endoparasitic infections that appeared well-adapted to environmental conditions. Further studies on endoparasite control are required to establish the impact of parasitism on productive performance, including monitoring control parasite programs are needed for better health and productivity.

Keywords: gastrointestinal parasites; prevalence; smallholders; goats

Introduction

The production of small ruminants is an attractive agricultural enterprise for Thai smallholder farmers because of lower inputs and high reproductive rate compared with cattle and buffalo, and their ability to thrive on native pasture that is unsuitable for crop production (Jittapalapong *et al.*, 2012; Windsor *et al.*, 2018). Sheep and goats are becoming increasingly important in Southeast Asia, particularly in regions with large Islamic populations such as In-

onesia, Malaysia, and parts of the Philippines. (Windsor *et al.*, 2018). Moreover, in recent years, demand for goat meat from Thailand and neighboring regions is increasing, particularly from Vietnam and Laos. This provides opportunities for smallholder farmers to increase productivity. In Thailand, goat production is traditionally extensive with low inputs, and subsequently low outputs. Five major small ruminant management systems have been described, including: tethering, free range, semi-free range, intensive, semi-rotational grazing and livestock-tree crop integrat-

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ed systems (Pralomkarn & Boonsanit, 2012). Free range is the most popular system typically practiced by small farmholders and consist of 10 – 60 animals per herd. It allows sheep and goats to browse alongside road verges, empty paddy fields, ample uncultivated areas and used public lands. In most systems, sheep and goats are herded back to the shelter in the evening and kept in small hutches overnight for protection.

An effective herd health program to maintain the health of livestock and prevent the occurrence of disease is necessary for rearing animals. Veterinary services are poor and knowledge about goat diseases is low or non-existent. An effective health management is only provided in commercial and governmental goat farms. Where investigations have occurred, these have mostly been performed by non-veterinarians, and animals being treated with antibiotics without regard to food safety and antimicrobial residue issues. Several investigations regarding health problems in goat have been conducted in Thailand for many years. Gastrointestinal parasite (GI) burdens are frequently associated with grazing management. Therefore, animals that graze communal pastures, are often at higher risk of exposure.

However, helminthic and protozoal infections have been reported among goats in Thailand (Worasing *et al.*, 2011; Jittapalpong *et al.*, 2012). It has also been found that GI parasitism among ruminants occurred all year round in tropical climates such as Thailand, with higher infection intensities during the rainy season (Jittapal-

pong *et al.*, 2012). Temperature and humidity are primary factors involved in the development and survival of parasite eggs, larvae, cysts, and oocysts in the environment.

To date, the importance of caprine GI parasitic infections has not been investigated in detail in lower Northern Thailand. But, a comprehensive understanding of endoparasitism is crucial for the sustainable control of parasites that interact with hosts in a specific climate, management system and production environment. Improving goat production in Thailand requires prevalence studies to provide the evidence-basis for the practical approaches that can assist smallholder goat farmers to improve their husbandry and health practices for increasing goat productivity. The specific objectives of this investigation were to estimate the prevalence of GI parasitism of goats on smallholder farms reared under traditional production systems.

Material and Methods

Study area and farm selection

A cross-sectional study was conducted from May 2019 to January 2020 in Phitsanulok, lower northern Thailand. (16.78°North, 100.20°East). Five districts; Muaeng, Bangragarm, Phompiram, Wadbote and Bangkatum in Phitsanulok province were selected for this research (Fig. 1). These districts are located at an altitude of 44 m above sea level. These areas are characterised by



Fig. 1. Five districts which were investigated for parasitic infections in small ruminants.

Table 1. Descriptive statistics (number and percentage of positive samples and mean, SD, Min, and Max) of fecal egg/oocyte counts in goats of 31 Smallholder Farms in Thailand.

Variables	Examined	Positive [n (%)]	Mean	SD	Min – Max
Gastrointestinal strongyles	885	680 (76.8%)	799.0	1348.6	0 – 13333
<i>Trichuris</i> spp.	885	4 (0.5%)	0.2	3.4	0.58
<i>Nematodirus</i> spp.	885	8 (0.9%)	0.6	7.1	0 – 104
<i>Dicrocoelium dendriticum</i>	885	1 (0.1%)	1.5	1.5	0 – 1368
<i>Eimeria</i> spp.	885	445 (50.3%)	427.6	118.1	0 – 96285
<i>Moniezia</i> spp.	885	132 (14.2%)	69.5	20.0	0 – 15786
Others (<i>Strongyloides</i> spp.)	885	6 (0.7%)	0.6	0.3	0 – 246

a tropical continental climate by hot season (mid-February to mid-June), rainy season (mid-June to mid-October) and winter season (mid-October to mid-February), respectively. The average monthly temperature ranges from 18.7°C in January to 37.2°C in April and the monthly precipitation between 3.9 and 247.6 mm. It has mixed weather with a daily average relative humidity ranging from 62 to 81 % (Thai Meteorological Department, 2019). In total, goats from 31 smallholder farms were included.

In this research, goats were kept in the free-range environment. These animals grazed during the day and were housed overnight without feed supplements being provided. The selection of animals at the smallholder farms was dependent on the number and availability of animals per farmer, although not more than 8 samples were taken from the sampled herd, with gender and species considered. All goats in this study were crossbreeds of Boer and Anglo. Sampled animals were not treated with anthelmintics within the last 3 months.

The use of anthelmintics, particularly ivermectin (10 mg/30 kg bodyweight) and mebendazole (13 – 15 mg/kg bodyweight or 1 tablet of 500 mg/30 kg bodyweight), administered at doses widely considered as therapeutic in these species. The farmer administered anthelmintic treatments to his herd two to four times per year (rotating between ivermectin and mebendazole) with further treatments with levamisole (5 mg/kg bodyweight) for animals that were

suspected to have severe parasitic infections (as determined by ocular examination for conjunctival pallor indicative of anaemia).

Collection and fecal sampling

At each farm, at least 90 % of the individuals older than 3 months before the sample collection were sampled. A total of 885 goats raised on 31 different farms were taken. A sample size was determined within the expected prevalence of disease in the population of 0.01 and 95 % confidence and population size of >10,000 (Fosgate, 2009). Fecal samples were collected per-rectum using plastic gloves, put into fecal pots, labelled and kept cool before transportation to the laboratory and then stored at 4°C in the refrigerator until analysis to avoid hatching of the eggs. Body Condition Scoring. Body condition scores (BCS) were determined by physically feeling the level of muscling and fat deposition over and around the vertebrae in the loin region. This was categorised on a scale of 1 – 5, according to Friedrichs (1993), where a score of 1 indicates thin and emacia- ted goats, while a score of 5 indicates obese goats.

Parasitological measurements

The intensities of nematodes and coccidial infections were categorized by mean eggs per gram of feces (EPG) and oocysts per gram of feces (OPG), respectively. Fecal egg counts (FEC) and

Table 2. Third-stage strongylid larvae identified in coprocultures of goats (expressed as mean percentage).

Larval genus	Total (%)
<i>Haemonchus contortus</i>	55.84
<i>Strongyloides papillosus</i>	20.53
<i>Teladorsagia</i>	5.80
<i>Bunostomum trigoncephalum</i>	5.00
<i>Charbertia ovina</i>	4.18
<i>Nematodirus</i> spp.	3.46
<i>Trichostrongylus</i> spp.	3.07
<i>Cooperia oncophora</i>	0.92
<i>Cooperia curticei</i>	0.85

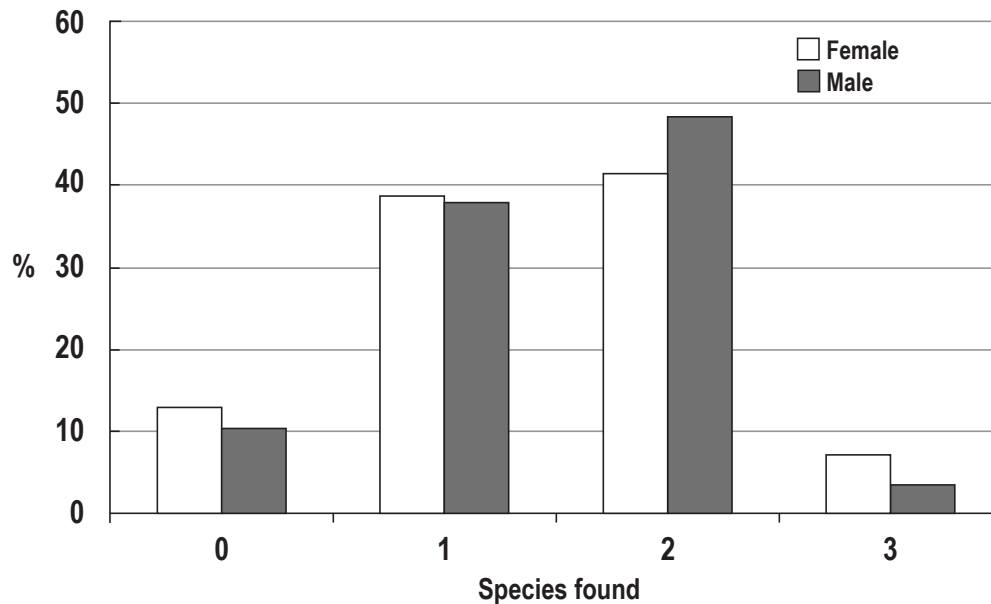


Fig. 2. Distribution of the number of different helminth species found in male and female goats in Northern Thailand.

fecal oocyst counts (FOC) were done using a modified McMaster method (MAFF, 1986) with 60 ml of saturated NaCl solution as the flotation fluid (specific gravity = 1.2) and 4 g of feces to determine EPG and *Eimeria* OPG. For *Moniezia* spp., individual animals were classified as infected if at least one tapeworm egg was identified in a sample. For further identification of nematode species, third-stage larvae (L_3) were cultured with pooled feces (10 – 20 g) of each flock (only for farms with >10 individual samples). L_3 were recovered from the coprocultures by applying the Baermann technique (MAFF, 1986). The first 100 randomly selected L_3 of each sample were identified to the generic level *Teladorsagia*, *Trichostrongylus*, *Chabertia*, *Haemonchus*, *Nematodirus*, *Bunostomum* and *Cooperia* by microscopy (MAFF, 1986). On the basis of the counted L_3 , the percentage of larval type was calculated when less than 100 L_3 were isolated from the sample. A pooled sample of each farm was used to detect the eggs of liver flukes applying the sedimentation test using 5 – 10 g of feces and larvae of lungworms applying the Baermann test using approximately 4 g of feces (MAFF, 1986).

Statistical analysis

All descriptive and analytical statistics were performed using the R-package. For the epidemiological studies, results of the FEC were used to calculate prevalence rates. The prevalence (p) of animals harbouring each parasite was calculated as $p = d/n$, where d is the number of animals diagnosed as having a given parasite at that point in time and n = number of animals at risk (examined) at that point in time (Thrusfield, 2005).

For purposes of analysis, animals with FEC values of gastrointestinal nematode (GIN) were classified into GIN-free, low (<500 EPG), medium (500 – 1000 EPG) and high (>1000 EPG). Similarly, FOC values were classified into *Eimeria*-free, low (<1800 OPG), medium (1800 – 6000 OPG) and high (>6000 OPG) (Lambertz *et al.*, 2018).

Transforming non-normally distributed FEC and FOC data into a normal distribution was achieved using the log transformation [$\log_{10}(\text{EPG}+10)$ and $\log_{10}(\text{OPG}+10)$] prior to the analyses. Results for FEC and FOC were presented as arithmetic means \pm standard deviation.

Table 3. Prevalence of helminth infections (percentage of infected goats) in male and female goats in Northern Thailand.

Parasitic infection	Male			Female			χ^2	P
	Total	+	%	Total	+	%		
<i>Strongyles</i>	29	24	82.8	856	656	76.6	0.591	0.442
<i>Trichuris</i> spp.	29	0	0	856	4	0.5	0.136	0.712
<i>Nematodirus</i> spp.	29	0	0	856	8	0.9	0.274	0.601
<i>Dicrocoelium dendriticum</i>	29	0	0	856	1	0.1	0.034	0.854
<i>Eimeria</i> spp.	29	15	51.7	856	430	50.2	0.025	0.875
<i>Moniezia</i> spp.	29	3	10.3	856	129	15.1	0.494	0.482
Others (<i>Strongyloides</i> spp.)	29	0	0	856	6	0.7	0.205	0.651

Total: total number of examined animals; +: number of infected animals.

The association between independent factors (sex) and continuous dependent variables (EPG, OPG and trematode intensity) was calculated using one way analysis of variance (ANOVA). The association between the independent factors and the prevalence of the χ various parasites were evaluated using Chi-square statistic. The correlations between the occurrences (and intensity) of the parasites was undertaken using the Pearson partial correlation (ρ , r). The difference in parasite loads for host sex and body condition score were tested by ANOVA. Moreover, correlations between variables were determined by Pearson's correlation. In all the analysis, confidence level was held at 95 %, and $P < 0.05$ was set for significance.

Ethical Approval and/or Informed Consent

Approvals for using animals in the current study were obtained from the ethical/IACUC committee at the Naresuan University, Phitsanulok, Thailand (Permit Number: NU-AG620504). The research has been complied with all the relevant national regulations and institutional policies for the care and use of animals.

Results

Characteristics of sampled animals and descriptive data of survey
Number of samples and presence of parasites are shown in Ta-

ble 1. The fecal eggs examination identifies eggs of multiple nematodes, one cestode and protozoan species, including Strongyles, *Trichuris* spp., *Strongyloides* spp., *Moniezia* spp., and coccidian species (presumably one or more *Eimeria* spp.). Out of 885 fecal samples, 772 (87.2) were positive one or more parasites. Strongyles was the most prevalent species (76.8 %), followed by *Eimeria* spp. (48.8 %). and tapeworm (*Moniezia* spp.) (14.2 %). In total, the level of egg count numbers differed, with the mean EPG for Strongyles and OPG for *Eimeria* spp. of 799 ± 1348 and 427.6 ± 118 , respectively.

Third-stage larvae identified in coprocultures were dominated by *Haemonchus contortus* (55.84 %). (Table 2). *Strongyloides papillosus* followed with around 20.53 %. Larvae of *S. papillosus* and *H. contortus* were found in all farms, but the other genera made up only a small proportion of third-stage larvae.

Influence of host sex on prevalence

The total prevalence did not vary between sexes ($P > 0.05$) (Table 3). The number of different helminth species per goat separated by sex is show in Figure 2. In males, 51.7 % (N = 29) had a mixed infection with at least 2 species, while it was 48.5 (N = 856) infemales. Male (48.3 %) infected 2 species more often than females (41.5 %). (Fig. 2).

Male goats had higher prevalence ($P > 0.05$) of strongyles than females. Goats with poor body condition had higher mean EPG

Table 4. Contingency table and odds ratio results for association of explanatory variables with parasites positive for fecal eggs of goats, by parasites.

Variables	Infected/ Examined	Prevalence (%)	95% CI	Odds Ratio	P value
Strongyles (%)					
Sex					0.402
Female	656/856	76.6	74.8 – 88.2	1.0	
Male	24/29	82.8	46.7 – 91.3	0.654	
Body Condition Score					0.163
Good	23/30	76.7	43.2 – 87.6	1.0	
Moderate	613/805	76.1	73.5 – 90.3	0.426	
Poor	44/50	88.0	76.3 – 99.7	0.430	
Moniezia spp. (%)					
Sex					0.511
Female	129/856	15.1	10.4 – 21.8	1.0	
Male	3/29	2.3	1.3 – 24.9	0.650	
Body Condition Score					0.828
Good	4/30	13.3	11.1 – 26.5	1.0	
Moderate	119/805	14.8	6.3 – 20.6	0.735	
Poor	9/50	18.0	8.1 – 27.9	0.799	
Eimeria spp. (%)					
Sex					0.895
Female	430/856	50.2	50.2 – 66.2	1.0	
Male	15/29	51.7	14.2 – 66.8	0.895	
Body Condition Score					0.009
good	15/30	50.0 ^b	13.2 – 65.7	1.0	
Moderate	394/805	48.9 ^b	42.4 – 62.3	0.383	
Thin	36/50	72.0 ^a	58.2 – 85.8	0.372	

Values with different letters within a column in each variable differ significantly ($P < 0.05$)

Table 5. Results from a predictive logistic regression model for parasitic infection in goats from Northern Thailand.

Variable	Level	β	SE	Wald	OR	P-Value	95% CI
Sex	Male				1	-	-
	Female	-0.16	0.502	0.102	0.852	0.750	0.319 – 2.278
Body Condition Score	Good				1	-	-
	Moderate	-0.853	0.718	1.412	0.426	0.235	0.104 – 1.740
	Thin	-1.061	0.529	4.023	0.346	0.045	0.123 – 0.976

β : regression coefficient; SE: standard error; OR: odds ratio; CI: 95% confidence interval; *: denotes significance ($P < 0.05$).

and prevalence of strongyles than those with good body condition but the differences were not significant ($P > 0.05$). Similarly, there were no significant ($P > 0.05$) associations between area of origin and prevalence and mean EPG of strongyles.

Risk Factors and infection intensity of gastrointestinal helminths and coccidia

There were no significant associations between the presence of parasites and sex (male vs female), although body condition showed significant difference ($P = 0.009$) on the prevalence of *Eimeria* spp. Highest prevalence of *Eimeria* spp. was observed in poor body conditioned goats (72.0 %) followed by moderate (48.9 %) and good body conditioned (50.053.8 %) goats (Table 4). The results of the predictive logistic regression model indicate that body condition score was influenced by parasite infestation (Table 5) (OR = 0.346; 95% CI = 0.123 to 0.976; $P = 0.045$).

The mean burden of different helminthes was assessed according

to sex, and body condition. The infection level of GIN based on FEC was various and ranged from 0 to 15,786 with a mean value of 802.1 (± 45.5) EPG. Eleven samples had more than 5,000 eggs. As presented in Table 6, 17.2 % of males and 22.8 % of females were GIN-negative. In both sexes, the proportion of samples classified as low (<500 EPG) ranged between 38 – 52 %. While 13.8 % of males and 25.4 % of females were classified as high (>1000 EPG), respectively. In females, 47 % of the samples were classified as low (<1800 OPG) and 2.7 % as medium (1800 – 6000 OPG). Around 48 % of the samples collected from males were *Eimeria*-free, while 37.9 and 13.8 % were classified as low and medium, respectively. Around 1 % of the samples in female were classified as high (>6000 OPG) of *Eimeria*-infections. The mean burden of strongyles was significantly different according to the body condition of animals. Goats with poor body condition has higher mean FEC and prevalence of strongyles than those with good body condition ($P > 0.05$) (Table 6).

Table 6. Results of the fecal egg (expressed as eggs per gram, EPG) and oocyst (expressed as oocysts per gram, OPG) counts differentiated for the prevalence of gastrointestinal strongylid nematodes (GIN) (classified as negative, low, moderate and high), separated by sex and species (expressed as % within sex or body condition score).

	Sex		Body condition score			Total
	Male	Female	Poor	Moderate	Good	
Gastrointestinal strongylid nematodes (GIN)						
Mean FEC ^c	455.5 \pm 132.8 ^b	810.7 \pm 46.6 ^a	1603.3 \pm 287.2 ^A	751.3 \pm 45.4 ^B	738.5 \pm 202.78 ^B	802.1 \pm 45.4
Negative	17.2	22.8	12.0	23.2	23.3	22.6
Low (< 500 EPG)	51.7	38.3	38.0	38.8	40.0	38.8
Moderate (500 – 1000 EPG)	17.2	13.6	6.0	14.0	16.7	13.7
High (> 1000 EPG)	13.8	25.4	44.0	24.0	20.0	25.0
<i>Eimeria</i> spp.						
Mean FOC ^c	591.1 \pm 245.1	422.0 \pm 121.8	172.8 \pm 118.1	412.8 \pm 124.9	1248.9 \pm 945.8	427.6 \pm 118.1
Negative	48.3	49.5	28.0	50.8	50.0	49.5
Low (< 1800 OPG)	37.9	47.0	72.0	45.2	43.3	46.7
Moderate (1800 – 6000 OPG)	13.8	2.7	0	3.2	3.3	3.1
High (> 6000 OPG)	0	0.8	0	0.7	3.3	0.8

Mean \pm standard error of the mean (SEM)

^{A,B}different uppercase superscripts indicate statistical difference of FEC or FOC between body condition score at $P < 0.05$.

^{a,b}different uppercase superscripts indicate statistical difference of FEC or FOC between sex at $P < 0.05$.

Discussion

The present study shows high prevalence of helminths and *Eimeria* in Phitsanulok province, Thailand with a tropical savanna climate. To our knowledge, few studies have reported data regarding the prevalence of endoparasite infection in this area. Therefore, we conducted this study to determine the most prominent species of endoparasite in goats in one of the biggest villages in the rural sector of Phitsanulok, and to clarify the effect of gender on the prevalence of infection. Moreover, knowing the current situation and prevalence of coccidiosis might be beneficial to set an appropriate control strategy and minimize economic losses.

The current findings revealed that the animals were affected by a wide variety of parasites. The findings are useful in identifying areas for improvement and modification of current helminth control strategies, so as to minimize the impact of GI parasites on productivity. The overall GI parasites prevalence of 87.2 % observed in the present study is, however, higher than the prevalence of GI parasites in goats in Laos (73 %) (Windsor *et al.*, 2018), Bangladesh (74.8 %) (Islam *et al.*, 2017) and another study from Thailand (79 %) (Jittapalapong *et al.*, 2012). This difference may be attributed to different sampling sites, seasons, animal breeds, management and agro-climatic conditions. The data, however, is a useful confirmation of concerns that there is a need to control GI parasites in this region.

The types of parasites found in this study included gastrointestinal nematodes, cestodes, trematodes and protozoa. Our observations were similar to those of some other studies conducted in Asia and abroad, which described strongyle infection as a major problem in small ruminants (Zvinorova *et al.*, 2016; Lambertz *et al.*, 2018; Windsor *et al.*, 2018; Sharma, 2020). The proportions of the nematode genera according to L₃ larvae in the current study in which *H. contortus* was the most prevalent, followed by *Strongyloides* spp. and *Cooperia* spp. In southern Thailand, however, the widely reported GI parasites of small ruminants include strongyles, *Trichuris* spp., *Strongyloides* spp., *Capillaria* spp., *Moniezia* spp., and *Eimeria* spp. (Worasing *et al.*, 2011; Jittapalapong *et al.*, 2012). The range in prevalence of strongyles reported in this study shows that the environmental conditions, particularly in moist conditions are highly suitable for transmission of strongyles. However, the order of prevalence reported by a study in South Africa was *Eimeria* spp., *Trichuris* spp., *S. papillosus*, *Moniezia* spp., and strongyles (Mpofu *et al.*, 2020); while that of a Laos study was Strongyles, *Trichuris* spp., *Strongyloides* spp., *Capillaria* spp., *Moniezia* spp., and *Eimeria* spp. (Windsor *et al.*, 2018). Therefore, it seems obvious that differences in prevalence of worm genera dependent on geographical and climatic factors. Climatic conditions, particularly wet periods, are frequently associated with differences in the prevalence of GI parasitic infections, because free-living infective stages (eggs, larvae and oocysts) survive longer in moist conditions (Waruiru *et al.*, 2000). The rainy season in the study region of the current study is 4 months, which accommodates parasite

survival in the environment. Also, previous study suggested that the animals became infected during the short rainy season and that high strongyle-type egg counts were consequently detected during the following dry season (Waruiru *et al.*, 2000). In our study, high infections with Strongyles and *Eimeria* species could be explained by the environment in which animals were reared, and also by poor animal management. Sheep and goats were reared in mixed crop-livestock systems, where a few numbers of goats were herded together in the same area during the dry and wet seasons. This results in high rates of parasitic infection due to possibilities of re-infection in contaminated pastures. Furthermore, all grazing goats were herded back to housing pens for overnight protection. Poor hygiene management may be a contributory factor to the presence of Strongyles and *Eimeria* spp. burdens on smallholder farms. Further parasitological and epidemiological studies are required to more accurately quantify the association of parasitism and disease in Thai small ruminants and enhance the development of more efficacious parasite control management programs. In addition, anthelmintic treatments are commonly used for managing internal parasites of small ruminants in many parts of the world (Windsor *et al.*, 2018) including smallholder systems in Thailand, despite lack of registration of most of these products for goats.

The most prevalent nematodes were Strongyles, with *Haemonchus* being the most common one. Previous studies on the epidemiology of gastrointestinal helminths have also reported *Haemonchus* as the most important nematode (Chandrawathani and Nural Aini, 2012; Zvinorova *et al.*, 2016; Windsor *et al.*, 2018). *H. contortus* constitutes a severe problem for ruminant's production, it is the most frequent nematode parasite found both, in temperate and tropical regions (Acevedo-Ramírez *et al.*, 2019). Its higher prevalence could be due to that individual females are capable of producing thousands of eggs per day, which can lead to rapid larval pasture contamination and associated outbreaks of haemonchosis (Roeber *et al.*, 2013). Moreover, the requirement of warm and moist environmental conditions for the free-living stages of *H. contortus* governs the parasite's geographical and seasonal distributions (Besier *et al.*, 2016). *H. contortus* has proven to be remarkably adaptable over a wide range of environments, due to its high biotic potential which allows it to take advantage of short periods which are favourable for the development of its free-living stages, and the survival ability of the relatively vigorous infective third-stage larvae, and specific adaptive mechanisms, such as hypobiosis of the fourth-stage larvae (Besier *et al.*, 2016). There is also ability to develop resistance to anthelmintic drugs of *H. contortus* is great, which poses a problem in terms of control (Kotze & Prichard, 2016).

Infection by trematodes had the lowest prevalence (0.1 %) among examined animals. This finding was closely related to reported in southern Thailand that 0.79 % of goats were infected by *Fasciola* spp (Worasing *et al.*, 2011). In Thailand three species are very common, i.e., *Fasciola* spp., *Paramphistomatidae* spp. and *Eu-*

rytrema spp. (Worasing *et al.*, 2011; Jittapalapong *et al.*, 2012). Fasciolosis has been associated with areas having high rainfall and poorly drained soils (Kanyari *et al.*, 2009). Notable that in the study areas are arid or semiarid province and does not seem to be a favorite geographical location for liver fluke and rumen fluke, this could be linked with lower prevalence of trematode parasites compared to other areas in Thailand.

On the other hand, the only cestodes identified through fecal examination in this study were *Moniezia* spp. The occurrence of this parasite elsewhere in the tropics has been described and is associated with ingestion of oribatid mites infected with cysticercoids of *Moniezia* spp. (Diop *et al.*, 2015).

The prevalence of *Eimeria* spp. reported in the current study was lower than that reported in Thailand (Jittapalapong *et al.*, 2012) and Laos (Windsor *et al.*, 2018). In the present survey, no clinical signs of coccidiosis were observed in animals. Therefore, there was no significant difference in the prevalence of *Eimeria* infection between males and females. Infection with *Eimeria* is considered to be a risk factor when the infected animals are exposed to any stress condition such as transportation or underfeeding and the associated ailments are likely to perturb the immune system, where *Eimeria* species could propagate intensively in the intestine and result in outbreak (Chartier & Paraud, 2012).

The results of sex-related prevalence of GI parasites revealed that GI parasites infection occurred with similar frequency in males and females, which can be attributed to the fact that both sexes are kept under similar management systems (Windsor *et al.*, 2018; Mpofo *et al.*, 2020). On the contrary, the significant association between host sex and the prevalence of GI parasites was previously reported to occur more often in females higher than male (Islam *et al.*, 2017; Singh *et al.*, 2017). It is interesting to note that females are assumed to be more heavily infected due to stress and low immune status during pregnancy, parturient paresis and lactation periods (Golo *et al.*, 2017).

In this study, the coproculture also showed that the predominant worm species were *H. contortus* and *S. papillosus*, a scenario which has been widely reported in other studies (Futagbi *et al.*, 2015; Singh *et al.*, 2016; Bihagi *et al.*, 2017; Tan *et al.*, 2017; Lambert *et al.*, 2018). Although relatively low level of *strongloides* spp. eggs, *S. papillosus* was predominant species. This is supported by the evidence that the diagnostic tools for infections are mainly limited to fecal analyses with relatively low accuracy and precision (Zanzani *et al.*, 2014). Regarding *Teladorsagia* spp./*Trichostrongylus* spp. and *Bonustomum* previous reports on this country are not available, while prevalences were low in both species. However, the relationship between EPG and worm intensity depends on characteristics of worm communities (intensity and species richness), which are in relation to host susceptibility to infection (Cabaret & Gasnier, 1998). Thus, female *H. contortus* excreted ten times more than *Teladorsagia circumcincta*, and hundred times more than *Trichostrongylus* spp. (Cabaret & Gasnier, 1998). With the multiple infections found, it is probable that these burdens are

contributing to subclinical production losses. Further understanding of host-pathogenic-environmental factors related to endoparasite pathogenesis in small ruminants in Thailand is needed, including an evaluation of whether parasite populations vary significantly with season, age, breed and the role of diet in parasite burdens in Thai small ruminants. Also, effective small ruminants internal parasite control depends on an understanding by farmers and their advisors of the risk factors that contribute to endoparasite transmission, then successful implementation of management strategies that can reduce the impact of parasites (Windsor *et al.*, 2018). The majority of strongyles are harmful to their hosts, causing anaemia, gastroenteritis, and decreased growth rates and mortalities. In the current study, the high intensity of strongyles was associated with poor body condition, showing that the parasite could be affecting the productivity of the animals.

This study was consistent with the findings of Biswas *et al.* (2014) and Admasu & Nurlign (2014), who discovered higher parasite infection in poor body condition animals compared to moderate and good condition hosts. Indeed, malnutrition and other concurrent parasitic infection will result in a weak immune response in the host to the parasites' infective stage (Watson *et al.*, 1994). Meanwhile, Etter *et al.* (1999) discovered increasing parasite fecundity in immunocompromised animals. Infection of small ruminants with coccidia and strongyles leads to gastroenteritis, protein-losing enteropathy, poor weight gain, and loss of body condition (Soulsby, 1982; Idika *et al.*, 2012).

In conclusion, based on findings from this study, natural infections with gastrointestinal parasites in goats in Phitsanulok are common. The infection level of GIN based on FEC was moderate to high and involved infections with multi-species. *H. contortus* and *S. papillosus* were the predominant species. The parasite burden appear to have a significant impact on the body condition of goats. Anthelmintic treatment programs would likely be beneficial, with the stimulation that drug administration should be overseen to ensure utilization of appropriate drug classes and dosages, to minimize the development of drug resistance among parasite populations.

Conflict of Interest

Authors have no potential conflict of interest pertaining this submission to Helminthologia.

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