Research paper

The endoparasitism challenge in developing countries as goat raising develops from smallholder to commercial production systems: A study from Laos


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ABSTRACT

Progressing economic development in Southeast Asia has increased regional demand for goat meat, leading to expanding production by smallholders and recently, development of commercial farms. In Laos, an emerging export market for goats into Vietnam has led to increased goat numbers, with potential increases in risk of disease, particularly endoparasitism. A cross-sectional survey investigated the prevalence of gastrointestinal parasites in indigenous Kambing-Katjang goats on smallholder farms (n = 389) in 8 villages where no anthelmintic treatments were in use, providing comparisons with a case study of imported Boer crossbred goats (n = 45) on a commercial farm where intensive anthelmintic treatments were required to manage mortalities attributable to Haemonchosis. Clinical examinations, collection of faecal samples, and pathological examination on the commercial farm, accompanied collection of information on animal gender, age and body weight, with data analyses performed in Genstat. Faecal samples contained eggs of multiple endoparasitic species, with Strongylus spp. and coccidian oocysts of Eimeria spp. most prevalent. Significant associations between the presence of endoparasites and the farm type (smallholder versus commercial; p < 0.008 and 0.001) were observed, with the odds ratios of the commercial farm having Strongylus spp. and Eimeria spp. of 1.3 (CI = 0.6–2.9) and 4.8 (CI = 2.5–9.1). Mortalities from endoparasitism were only recorded at the commercial farm, with the loss of 24 goats in the final 3 months of the dry season (Feb-April). This study identified a moderate prevalence of multiple endoparasitic species in smallholder goat farms that appeared well-tolerated, whereas in the developing commercial system, endoparasites posed significant risks to enterprise viability, even with use of anthelmintics. Further studies on endoparasite control are required if commercial tropical goat meat production is to prove sustainable and assist in addressing regional food security, plus provide a pathway to improve the livelihoods of Lao goat smallholders seeking to expand and intensify their enterprises.

1. Introduction

Goats are increasingly important for subsistence food production with over 90% of the global goat population found in developing countries (Glimp, 1995; FAO, 2005; World Bank, 2013). As goats produce several livestock products with lower inputs than cattle and buffalo, smallholder goat farmers in developing countries, particularly in Asia and Africa, have increasingly been recruited to goat raising, with goats described as an ‘entry point’ on the ‘pathway from poverty’. Goats are considered more easily managed than cattle, especially by resource poor farmers, including women. Goat raising offers households nutritional benefits as meat protein for hunger alleviation, enhanced livelihoods from animal trading income, more effective utilisation of family labour, and increased livelihood stability and resilience in rural communities due to more self-reliance (FAO, 2005; World Bank, 2013). Further, goats provide nutrients for soil fertility as manure fertiliser for croplands, plus reproduce quickly and are in considerable demand in many countries, particularly where Islamic festivals occur. In Southeast Asia, goats have been of increasing importance, particularly in countries with large Islamic populations, including Indonesia, Malaysia, and parts of the Philippines and Thailand. However, in recent years, increasing demand for consumption of goat meat in Vietnam and China has created opportunities for increasing production in the Lao People’s Democratic Republic (Laos, henceforth). Currently, the government of...
Laos is attempting to obtain an average meat supply for local consumption of 60 kg/capita/year, plus increase meat exports to a value of USD50 million by 2020 (FAO, 2005).

In Laos, goat production is traditionally extensive with low inputs, and subsequently low outputs (Kounnavongsa et al., 2010). Four major goat management systems have been described, including: free range; semi-free range; semi-rotational grazing; and permanent grazing with or without tethering. Free range is the most commonly observed system, although semi-free range can be found in areas where cropping predominates (Kounnavongsa et al., 2010; Phengvichith and Preston, 2011). In most systems, goats are herded back to the village and kept in small hutches overnight for protection, although housing is only considered beneficial if it is kept clean (Phengsavanh, 2003). The system used by an individual farmer will depend upon feed and labour availability plus local community agreements, particularly related to cropping and use of common grazing areas (Kounnavongsa et al., 2010; Phengvichith and Preston, 2011).

Typically, Lao goat herds consist of 3–10 animals (Kounnavongsa et al., 2010; Phengvichith and Preston, 2011), although there are some recent examples of developing herds with as many as 200 animals raised on semi and fully commercial farms. Approximately 215,600 goats were recorded in Laos in the 2011 agricultural census (Steering Committee for Lao Census of Agriculture, 2012). This data is likely to be underestimated the actual numbers of goat currently as the Lao goat is widely considered to have been increasing rapidly due to recent expanding regional demand for goat meat, particularly from Vietnam, with estimates that between 2000 – 3000 goats per month are being exported (Phengsavanh and Hoang, pers. comm.).

Increasing demand for consumption of goat meat in Laos and neighbouring Vietnam and China, is providing opportunities for smallholder farmers to increase productivity and has led to the development of semi to full commercial production systems to capitalise on the growth in this emerging livestock sector, particularly if biosecure transboundary trade can be enhanced (Stur et al., 2006; Windsor, 2011; Nampanya et al., 2015). However, introducing goats and expanding small goat herds where smallholders and potential commercial operators have limited experience of small ruminants, can be exceedingly challenging. In recent years, many international development agencies have promoted smallholder goat-raising programs with distribution of goats to untrained farmers, often accompanied by severe mortality and morbidity problems (Windsor et al., 2017). Unfortunately, these incidents have generally been poorly investigated, as numerous goat-raising programs have been established without adequate veterinary advice and in countries such as Laos where veterinary services are poor and knowledge of goat diseases is low or non-existent. Where investigations have occurred, these have mostly been performed by non-veterinarians, with spurious conclusions and interventions, including that animals have died from bloat and diarrhoea of undetermined aetiology, and animals being treated with antibiotics without regard to food safety and antimicrobial residue issues. Recent observations suggest that the main constraints to raising goats in Laos include high mortality rates of kids, with disease issues including internal parasitism, Contagious Ecthyma (Orf virus), pasteurellosis and other infectious and metabolic diseases, plus potential risk of endemic foot-and-mouth disease (FMD) and incursion of Pestes des Petits Ruminants (PPR) from neighbouring countries to the north (Windsor et al., 2017).

Further, lack of reliable feeding systems with seasonal deficiencies in both quantity and quality of nutrition are issues requiring attention. Improving goat production in Laos requires systematic caprine studies to provide the evidence-basis for the practical approaches that can assist smallholder goat farmers improve their husbandry and health practices for increasing goat productivity. For this reason, a cross-sectional study was undertaken aiming at estimating the likely prevalence and risk association of internal parasites in goats on smallholder farms compared to a commercial farm in Laos, plus determine baseline live weights of various age categories for future benchmarking following likely interventions to improve the efficiency of Lao goat production systems.

2. Materials and methods

2.1. Study site, farmer and goat selection

This cross-sectional survey was conducted between February 2015 and May 2017, involving 4 lowland and 4 upland villages with 66 smallholder farms, and one commercial farm (n = 67; Table 1). We defined goat smallholder farmers as those farmers with less than 20 goats where their goats are free or semi-free grazing extensively on the common grassland, forest and paddy fields in the dry seasons, with limited inputs, and where reproduction and management interventions including supplementary feeding (such as salt and minerals), anthelmintics and vaccinations, are rarely provided. Four smallholder villages and the commercial farm were located in the lowland Xathany district of Vientiane Capital (VTE) and an additional 4 smallholder villages were located in Pakse district in upland Lung Prabang Province (LPB). The selection of each smallholder site for investigation was based on discussions with senior veterinarians and district officials to establish the following selection criteria: (1) there is a presence of goats (> 50 heads) in the village; (2) ethnicity and language acceptability; and (3) year round vehicular access.

In each village, 5–10 goat farmers were selected for participation, based on the list of the farmers with goats in the village provided by village chief. A sample size of 434 goats 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; Dohoo et al., 2010). The selection of animals at the smallholder farms was dependent on the number and availability of animals per farmer, although no more than 6 samples were taken from the sampled herd, with gender and age considered. From detailed discussions with the goat owners it was considered highly unlikely that any of these goats had previously been treated with anthelmintics. Most (if not all) goats were free-grazed during the day and housed overnight.

The commercial farm was selected on the basis of proximity to the National University of Laos (NUOL) campus for agricultural studies (at Nabong near Vientiane) and willingness to be involved in applied research on goat health and production. Approximately 20% of the herd (consisting of about 220 goats) was randomly selected, with gender and age also considered. All animals in this herd were Boer-crossbred goats imported from Thailand and their progeny, although more detailed information on their genetic basis was unknown. These animals were also housed overnight and provided with a range of feed supplements, with grazing during the day in a silvopastoral system where goats had access to weeds growing beneath a Eucalyptus tree plantation. The use of anthelmintics, particularly ivermectin (1cc per 30 kg bodyweight) and mebendazole (13–15 mg/bodyweight or 1 tablet of 500 mg per 30 kg bodyweight), administered at doses widely considered as therapeutic in this species (sometimes twice the recommended dose rate for sheep as advised by the manufacturer), was instituted at commencement of the operation in 2015. The farm operator administered anthelmintic treatments to his herd two to four times per year (rotating between ivermectin and mebendazole) with further treatments with
levamisole (5 mg per Kg bodyweight) for animals that were suspected to have severe parasitic burdens (as determined by oculary examination for conjunctival pallor indicative of anaemia). Due to problems of low feed availability in grazing areas contributing to endoparasitism, mortalities attributable mainly to Haemonchosis were observed in the dry seasons. Improved management practices have recently been introduced to address these issues, including establishing forage plantations, more frequent rotational grazing, and a more strategic parasite control program with continual monitoring of the clinical health of all animals and regular faecal counting to assess endoparasite burdens.

2.2. Data collection, faecal sample collection and analysis

At faecal sampling, descriptive data obtained included: owner, village and district names, and animal details including gender, age and live weight were recorded on the data collection sheets. Information on mortalities suspected as due to gastrointestinal parasites and occurring in the 3 months prior to the sample collection, was also obtained. Due to temporary malfunction of the weight scale, only weight from the commercial farm in the lowland was available.

2.2.1. Faecal sample collection

Faecal samples were collected directly from the rectum by hand using latex gloves and placed in zip-lock plastic bags, and labelled with an identification number. Unless samples could be analysed within 24 h, 0.5 ml of 3% formalin was added to preserve the samples during prolonged transport to the laboratory, requiring addition of formalin to preserve the samples.

2.2.2. Faecal egg count

The faecal egg count (FEC) concentration was determined using a modified McMaster’s egg counting technique (JA Whitlock & Co., Australia) as described in the literature (Hansen and Perry, 1994; Rast et al., 2013). The number and morphology of faecal parasite eggs were recorded and quantitative estimates of egg numbers per gram of faeces obtained.

Samples of the 100 faeces collected from the two villages of Senoudom and Hartviengkham of VTE, were submitted for larval co-culture to determine morphological identification of Strongyles spp. eggs observed in the FEC, using a modification of the technique as previously described (Roberts and O’Sullivan, 1950). Two pooled samples were made for each village and the samples incubated at 26–28 °C for 7 days. Third stage larvae were harvested at the end of the incubation period, fixed with Lugol’s iodine solution and examined under a light microscope. Identification to the genus level was achieved using the key system described (Van Wyk and Mayhew, 2013). Coproculture for samples from LPB could not be performed due the prolonged transport to the laboratory, requiring addition of formalin to preserve the samples.

2.3. Data management and analysis

The survey data was transcribed into a Microsoft Excel spreadsheet, with descriptive analysis performed using frequency tables and univariable logistic regression and generalised linear mixed models performed in the Genstat to determine the association between the binary outcome variable of FEC result (positive/negative) with two explanatory variables. Locations (lowland versus upland), farm type (smallholder versus semi-commercial farm), sex (male versus female) and age classification (4 age cohort groups: < 6 months old, 6–12 months old, 12–24 months old and > 24 months old), were defined as fixed variables in the model, whereas animal identification was a random variable to account for clustering (Dohoo et al., 2010). From the likelihood ratio chi-square analysis, the odds ratios of significant explanatory variables were examined to determine the extent as well as positive or negative association with the presence of infection. A p-value of < 0.05 was used to indicate significant differences. Odd ratios and their 95% confidence interval (CI) were determined in Microsoft Excel spreadsheet as described (Dohoo et al., 2010).

Due to limited information on live weights of Kambing-Katjang goats, predicted means of live weights of goats was determined only for smallholder farms, using restricted maximum likelihood (REML) in the Genstat 14th statistical program. Village, farm type, age classification, sex, Strongyles spp. presence (0 and 1), were defined as fixed variables in the model, whereas animal identification was a random variable. A p-value of < 0.05 was used to indicate significant differences. Post-hoc testing was conducted by comparing the prediction means of the interest age classification.

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Table 2
Summary of descriptive analysis of goat parasite prevalence survey by location and farm type classification.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Location</th>
<th>Farm type</th>
<th>Total/Grand mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lowland</td>
<td>Upland</td>
<td>Smallholder</td>
</tr>
<tr>
<td>No. Faceal samples (Females)</td>
<td>227 (143)</td>
<td>207(163)</td>
<td>389(306)</td>
</tr>
<tr>
<td>Mean age (yrs)</td>
<td>1.8( ± 1.4)</td>
<td>1.7( ± 1.3)</td>
<td>1.8( ± 1.4)</td>
</tr>
<tr>
<td>Weight (Kg)*</td>
<td>35.9( ± 21.5)</td>
<td></td>
<td>35.9( ± 21.5)</td>
</tr>
<tr>
<td>No. Samples positive for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 4 or more parasitic egg species</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- 3 parasitic egg species</td>
<td>127</td>
<td>127</td>
<td>254</td>
</tr>
<tr>
<td>No Sample positive for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Strongyles sp.</td>
<td>181</td>
<td>176</td>
<td>322</td>
</tr>
<tr>
<td>- Coccidiosis sp.</td>
<td>164</td>
<td>150</td>
<td>296</td>
</tr>
<tr>
<td>- Moniezia sp.</td>
<td>15</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>- Trichuris sp.</td>
<td>27</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>- Others (Capillaria sp., Strongylidae sp.)</td>
<td>8</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Mean eggs per gram (EPG)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Strongyles sp.</td>
<td>297( ± 385)</td>
<td>662( ± 817)</td>
<td>504( ± 673)</td>
</tr>
<tr>
<td>- Coccidiosis sp.</td>
<td>884( ± 290)</td>
<td>1193( ± 2683)</td>
<td>1140( ± 2968)</td>
</tr>
<tr>
<td>- Moniezia sp.</td>
<td>36( ± 293)</td>
<td>70( ± 466)</td>
<td>53( ± 404)</td>
</tr>
<tr>
<td>- Trichuris sp.</td>
<td>13( ± 58)</td>
<td>4( ± 20)</td>
<td>4( ± 19)</td>
</tr>
<tr>
<td>- Others (Capillaria sp., Strongylidae sp.)</td>
<td>1( ± 7)</td>
<td>6( ± 44)</td>
<td>3( ± 32)</td>
</tr>
</tbody>
</table>

Mean ± standard deviation.
* Due to temporary malfunction of the weight scale, only weight from the commercial farm in the lowland was available.
3. Results

3.1. Descriptive data summary

Number of samples, mean weights, and presence of parasites were tabulated (Table 2). The faecal egg examination identified eggs of multiple nematodes, one cestode and one protozoan species, including Strongyloides spp., Trichuris spp., Capillaria sp., Moniezia sp., and coccidian species (presumably one or more Eimeria spp.) Of 434 samples, the FEC revealed the presence of multiple parasitic eggs with 321 samples (73%) having more than two parasitic egg species, mostly Strongyloides spp. and Eimeria spp.

The level of egg count numbers differed, with the mean EPG for Strongyloides spp. and Eimeria spp. of 297 (± 385) and 884 (± 2950) in lowland goats, respectively. Coproculture revealed the nematode population consisted of an average of 47% Haemonchus sp., 29% Trichostrongylus sp., 15% Strongyloides sp., 5% Oesophagostomum sp. and 5% Teladorsagia sp.

3.2. Prevalence of goat endoparasites and related risk factors

Variables investigated and logistic regression results are tabulated (Table 3). There were no significant associations between the presence of parasites and location (lowland vs upland), sex (male vs female) and age classification, although a significant association of the farm type (smallholder versus commercial) with explanatory variables with Strongyloides spp. and Eimeria spp., was observed (p < 0.001 and 0.008). The odds ratios of the commercial farm having Strongyloides spp. and Eimeria spp. were 1.3 (95% CI = 0.6–2.9) and 4.8 (95% CI = 2.5–9.0) compared to the observed smallholder farms. Further, the age classification variable was significantly associated with the present of Moniezia sp., with odd ratios of goats aged in the 6–<12 months cohort groups being 2.4 and 6.84 (95% CI = 1.0–5.6 and 1.9–24.9) respectively, compared to the <6months aged cohort group.

Mortalities associated with suspected endoparasitism were recorded on the commercial farm. A total of 24 goats died in the 3 months prior to the end of the dry season (Feb – Apr 2017), including 15 kids, 2 weaners and 7 adults. Necropsies performed on these animals confirmed the presence of anaemia and hypoproteinaemia, with variable burdens of Haemonchus contortus located in the abomasum. Moniezia sp., were also present in the intestinal tract of most animals. Low fat reserves suggested that a number of these animals may have had anemia from low feed availability and there were also several cases of pregnancy toxemia in late gestation does. None of the smallholder farmers had farm performance records (not unexpected in Laos, particularly considering they only have 5–10 goats). Although occasional losses may have occurred on these farms, queries on the likelihood of major disease outbreaks associated with endoparasitism suggested this had not occurred and two previous necropsies conducted on smallholder goats in LPB to examine for the presence of intestinal parasites, revealed that neither animal had endoparasitism, nor was there a history of anthelmintic therapy.

3.3. Statistical analysis of goat live weights

There were significant differences in predicted mean weights of smallholder goats between age classification categories (p < 0.001) as tabulated (Table 4). The predicted mean weights was 15.3 (± 2.5) kg in the <6months aged classification, and 37.5 (± 2.6) kg in the >24months aged classification.

4. Discussion

To investigate the potential constraints to improving goat productivity in Laos, faecal samples of goats from smallholder farms in the northern upland and central lowland areas plus a nearby commercial enterprise, were examined for gastrointestinal parasites, with baseline live weights of 4 age cohorts of the upland goats determined. As the selection process for all sites and collection of faecal samples was necessarily based on convenience selection and farmer and animal selection process for all sites and collection of faecal samples was necessary, caution is advised on extrapolation of these findings. However, the data is a useful confirmation of concerns that the low to moderate burdens of internal parasitism (mean EPG for Strongyloides spp. of less than 1000) in smallholder goats is of potential importance to goat health and production in Laos as gastrointestinal parasite control programs are necessary where production systems are intensified in response to an increasing demand for goat meat in local and regional markets.

A previous study identified moderate to high prevalence of Strongyloides spp. nematodes in Lao goats, with Trichostrongylus spp. found in the faeces of 13 out of 14 goats surveyed (93%) with the mean FEC of 1728 per gram of faeces (Otake et al., 2014). In that study, coproculture of these goats showed from most to least common: Haemonchus sp.;
Predicted mean weights of live smallholder goats by age classification categories.

<table>
<thead>
<tr>
<th>Age classification categories</th>
<th>&lt; 6 months</th>
<th>6–&lt;12 months</th>
<th>12–24 months</th>
<th>&gt; 24 months</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>15.3 a</td>
<td>26.4 b</td>
<td>37.4 c</td>
<td>37.5 c</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Standard error</td>
<td>± 2.5</td>
<td>± 2.2</td>
<td>± 2.4</td>
<td>± 2.6</td>
<td></td>
</tr>
</tbody>
</table>

Predicted mean ± standard errors. Letters (a, b, and c) indicate a significant difference between the means within the age classification categories.

**Trichostrongylus spp.** and **Oesophagostomum spp.**, with necropsy on an adult goat identifying *Trichuris spp.* (Otake et al., 2014). Another report found a range of endoparasites including the nematodes *Strongyloides papillosus*, *Cooperia* spp., and *Bunostomum* spp., plus other parasites including *Eimeria* spp., *Moniezia* spp., *Paramphistomum* spp., and *Eurytrema* spp. in Laos (Sani et al., 2004). As well as causing morbidity and mortality in goats, nematodes are a potential public health issue with *Oesophagostomum* spp. and *Haemonchus* spp. reported as zoonotic (Otake et al., 2014).

Necropsy observations on goat mortalities at the commercial farm indicated the major cause of death was anaemia due to *Haemonchus contortus* with low feed availability in the dry season predisposing to inanition and pregnancy toxaeemia. The *Moniezia* spp. infestations may have also been of relevance to losses of some of the kids. Although there was no record of losses by the smallholder farmers and no major outbreaks of disease were reported, it is considered unlikely that there would have been no losses associated with gastrointestinal parasites on any of the 66 smallholder goat farms. High mortality rates of kids had been observed in Laos by others with one report of losses of up to 50% prior to weaning (Keonouchanh and Xaypha, 2006). Clinical signs described in kid mortality, may include diarrhoea, inappetence, subcutaneous oedema, anaemia, general ill-thrift, chronic weight loss, and mortality (Fox, 2012). A more recent study reports an annual loss per household of 2 animals from an average herd size of 10 (range: 1–8), with a third of 34 interviewed farmers reporting as having no deaths (Windsor et al., 2017). Further studies on goat mortalities in Laos are advised.

Our study showed that there was no significant association between the presence of parasites and location (lowland versus upland) although a significant association of the farm type (smallholder vs commercial) was identified with the explanatory variables of *Strongylus* spp. and *Eimeria* spp., likely reflecting (as confirmed in interviews) that only the commercial farm was using routine anthelmintic parasite control. In this study, all grazing goats were herded back to housing pens for overnight protection. As housing is only considered beneficial if it is kept clean (Phengsavanh, 2003) poor hygiene management may be a contributory factor to the presence of *Strongylus* spp. and *Eimeria* spp. burdens on both the smallholder and commercial farms, although a major risk factor for endoparasitism on the latter farm was undoubtedly the low levels of available forage in the mid to late dry seasons, an issue now undergoing amelioration through forage plantation. Further parasitological and epidemiological studies are required to more accurately quantify the association of parasitism and disease in Lao goats and enhance the development of more efficacious parasite control management programs.

Internal parasitism of goats is an important global issue and can become severe, particularly where there is poor nutrition, or other factors leading to high levels of exposure to infective larva, including intensification leading to grazing rather than browsing by goats, and unhygienic housing conditions. Both of these risk factors are common in developing countries such as Laos. Further, anthelmintic treatments are commonly used for managing internal parasites of ruminants including goats in many parts of the world, despite lack of registration of most of these products for goats. However, anthelmintics are rarely used and not widely available for use in goats in smallholder systems in Laos (Keonouchanh and Xaypha, 2006; Kounnavongsa et al., 2010).

Effective caprine 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. Pastures should not be grazed intensively, and feed should not be cut and fed from heavily infested areas (Fleming and Patrick, 1996). Further, stock can be provided with a higher plane of nutrition to improve their resistance and resilience to internal parasites, reducing the reliance on anthelmintics (Phengvichith and Preston, 2011) that places goats at risk of exposure to parasite populations that have developed anthelmintic resistance (Fleming and Patrick, 1996). In addition, as anthelmintics are manufactured for registration and use in cattle and sheep populations, the products and recommended dosages may not necessarily be readily extrapolated for use in goats (Sani et al., 2004). As goats have a faster metabolic rate, one study found that the dose rate for albendazole in goats should be increased to 1.5 times the recommended dose for sheep. A similar increase in dose rate appears required for closantel (Sani et al., 2004), although this should be managed carefully as this drug has occasionally been associated with induction of neurotoxicity with symptoms of blindness in goats in Australia due to incorrect estimates of the required dose (Finnie et al., 2011). Our study found that the highest predicted live weight was 37.5 (± 2.6) kg in the > 24 months old cohort of Lao Kambing-Katjang goats. Although other studies have shown that the mature weight of similar goats can reach 40 kg, the average live weights in Laos is lower and previously determined as around 32 and 28 kg for male and female goats, respectively (Phengsavanh, 2003; Kongmanila et al., 2008). It is also possible that internal parasites may be contributing to the low live weights observed in the smallholder goats despite apparent low risk of mortality. It was unclear whether the low live weights in this study was due to genetic factors, the variable prevalence of parasitic infections and nutritional deficiency, an interaction of these factors, or involving other factors yet to be determined. The low live weights observed warrants further investigation, as does the role of nutrition in determining the significance of parasite burdens (Hoste et al., 2005). Specific dietary analysis of the goats in this study was not undertaken. Other studies have reported that goats with higher crude protein and energy concentration in their diets are more likely to have improved resistance (lower faecal egg counts) and resilience (improved growth rates and milk output) to gastrointestinal nematode infections (Hoste et al., 2005; Gray et al., 2012).

This study demonstrates that gastrointestinal nematodes and coccidia are prevalent in a majority of goats in smallholder farms and in a commercial farm in Laos, and that low live weights of goats in the Lao smallholder farming system is likely to be common. Although *Strongyloides* spp., *Moniezia* spp., *Trichuris* spp. and *Capillaria* spp. are typically considered to be of low pathogenicity, the presence of multiple species may have deleterious effects on growth rates and milk production, contributing to poor productivity. There are also reports of interactions between *Trichostrongyle* spp. and coccidian infections, with *Trichostrongyle* spp. prolonging coccidiosis infections, plus coccidiosis associated with increasing *Trichostrongyle* spp. shedding (Valentine et al., 2007). With the mixed infestations found, it is probable that these burdens are contributing to subclinical production losses. Further
understanding of host-pathogen-environment factors relevant to the pathogenesis of caprine endoparasitism in Laos is needed, particularly an assessment of whether parasite populations vary significantly between wet and dry seasons, and the role of nutrition in possible seasonal differences in parasite burdens in Lao goats.

In conclusion, the Lao smallholder local breed goat system does have mixed endoparasite infestations, although in the herds sampled in this study, there did not currently appear to be a major issue with Haemonchosis and anthelmintic dependence was not observed. However, this has the potential to change very quickly when intensification occurs, with potential risk factors including introduction of non-native goats with higher body weights and thus energy demands, higher stocking rates, lower forage availability and grazing not browsing behaviour, plus lower feed availability in the dry season, leading to Haemonchosis and parasitic-related mortalities, and increasing anthelmintic dependency. Improved knowledge on caprine parasitic infections and their control in these environments, plus development of strategies for improving nutritional management are required if smallholder goat production in Laos is to progress and provide sustainable improvements in poverty alleviation and regional food insecurity. This knowledge is considered critical to ensure animal welfare and financial viability concerns are addressed where commercial goat farming is initiated.

Acknowledgements

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