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Infection levels of gastrointestinal parasites in sheep and goats in Papua New Guinea

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Abstract

Gastrointestinal parasites of livestock cause diseases of important socio-economic concern worldwide. The present study investigated the prevalence of gastrointestinal parasites in sheep and goats in lowland and highland regions of Papua New Guinea (PNG). Faecal samples were collected from a total of 165 small ruminants (110 sheep and 55 goats) from February to April 2011. Analysis by a modified McMaster technique revealed that 128 animals (72% of sheep and 89% of goats) were infected with one or more species of gastrointestinal parasites. The gastrointestinal parasites found and their prevalences in sheep (S) and in goats (G) were as follows: strongyle 67.3% (S), 85.5% (G); *Eimeria* 17.3% (S), 16.4% (G); *Strongyloides*, 8.2% (S), 23.6% (G); *Fasciola*, 5.5% (S), 18.2% (G); *Trichuris*, 1.8% (S), 3.6% (G); and *Nematodirus*, 1.8% (S), 3.6% (G). Two additional genera were found in goats: *Moniezia* (9.1%) and *Dictocaulus* (3.6%). This is the first study to quantitatively examine the prevalence of gastrointestinal parasites in goats in PNG. The high rates of parasitism observed in the present study are likely to be associated with poor farming management practices, including lack of pasture recovery time, lack of parasite control measures and poor-quality feed.

Introduction

Parasitism is recognized as a major threat to the production of small ruminants in both small-scale and large-scale farms. Gastrointestinal (GI) parasites cause high mortality, reduce production and lead to a significant overall economic loss (Al-Quaisy *et al.*, 1987; McLeod, 1995; Simpson, 2000). GI parasites are highly prevalent in sheep and goats in humid subtropical and tropical areas of the world (Yadav & Tandon, 1989; Banks *et al.*, 1990; Barger *et al.*, 1994; Dorny *et al.*, 1995; Cheah & Rajamanickam, 1997; Regassa *et al.*, 2006; Nwosu *et al.*, 2007; Gadahi *et al.*, 2009; Abebe *et al.*, 2011; Dagnachew *et al.*, 2011).

There are approximately 15,000 sheep and 20,000 goats in Papua New Guinea (PNG) (Quartermain, 2002). Animals are raised by institutions for breeding or for nutritional research purposes and by smallholder farmers for subsistence meat production. There are no sheep and goats native to PNG. Tropical sheep from South-East Asia were introduced by colonial administrators and missionaries in the late 19th century and this sheep population is known as PNG Priangan. In the 1980s, temperate Corriedale and Perendale sheep from New Zealand were brought to the cooler highlands of PNG. These temperate sheep breeds were crossed with the PNG Priangan sheep to produce crossbreds known as Highlands Halfbred (Quartermain, 2002). PNG Priangan sheep are mainly raised in areas of lower altitude, whereas Highlands Halfbred sheep are raised at higher altitudes. A variety of dairy goats, which are now referred to as PNG genotype, were introduced during the early colonial period (Quartermain, 2002).

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Distribution and productivity of small ruminants in PNG are hindered mainly by poor health, nutrition and management (Quartermain, 2004). GI parasites are expected to be widespread in PNG due to its humid tropical climate. In some parts of PNG, previous surveys, which were conducted mostly in government stations, identified a diversity of internal parasite species in small ruminants (Varghese & Yayabu, 1985; Owen, 1988, 1989, 1998; also reviewed by Quartermain, 2004). However, there is insufficient information on the epidemiology of the GI parasites infecting sheep and goats in PNG. Such information is essential for understanding the economic impact these parasites can have on farmers and to support decision-making regarding the treatment and prevention of parasitic diseases in these animals. The present study, therefore, was conducted to obtain data on the prevalence and infection levels of gastrointestinal parasites in sheep and goats on several farms in PNG.

Materials and methods

Study sites

The study was conducted from February to April 2011 in two broad agro-climatic zones, the highlands (specific study sites: Tambul, Baisu, Menifo and Ungai-Bena) and lowlands (specific study site: Labu) in the central region of mainland PNG (fig. 1).

The altitudes of the study sites are 0 m for Labu, 1600–1608 m for Menifo and Ungai-Bena, 1730 m for Baisu and 2320 m for Tambul, with mean annual temperatures of 26°C, 20.1°C, 20.1°C, 18.3°C and 14.7°C, respectively (Bourke, 2010). The mean annual rainfall for Labu is above 4000 mm and between 2000 and 3500 mm for Ungai-Bena, Baisu and Tambul (Quartermain, 2004). Menifo is drier than most of the PNG highlands and receives a mean annual rainfall of 1000–1500 mm (Quartermain, 2004).

The study sites were further characterized by a questionnaire survey, in which 20 farm managers and smallholder farmers were interviewed. It consisted of questions regarding general farm management practices, feeding systems and herd health programmes.

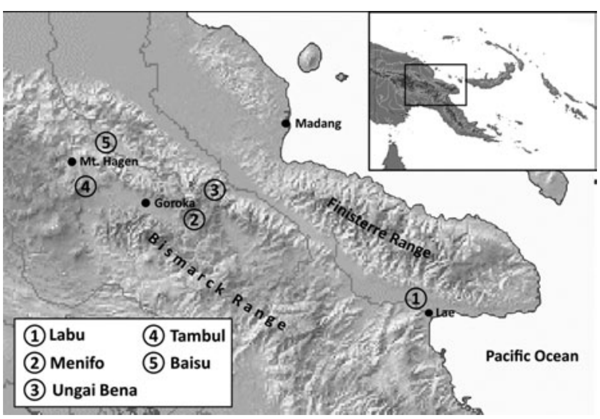

Fig. 1. Topographical map of Papua New Guinea (PNG) showing the study sites.

Farm management

The flocks from the three institutional farms (Labu, Baisu and Tambul) were kept together in fenced areas (approximately 20–60 ha), grazed pasture at a high stocking rate at daytime and were kept in houses with wooden, slatted floors at night. At the time of sample collection, the total numbers of sheep and goats in Labu, Baisu and Tambul were 125, 70 and 143, respectively. The subsistence farmers kept few animals (usually fewer than 15) which grazed free range or were tethered and housed at night on slatted floors or on the ground underneath the farmer's house.

Feeding system

Most animals grazed on native grasses and shrubs. Smallholder farmers also fed their animals with starchy vegetables (mostly sweet potatoes). The interviewed farmers also indicated that there were shortages of feed. The animals drank from troughs (sourced from water supply or rainwater tanks), rainwater run-off water or ponds.

Herd health program

The floors of the resting houses were not swept. The animals were penned on dirty floor, ground or on bare concrete floors. The smallholder farmers did not shear their sheep and explained that they did not have the resources for it. Most farm managers reported that the most common signs of illness in their animals were diarrhoea and coughing, followed by itching and hair loss. Most smallholder farmers did not know about causes of diseases in their sheep and goats or the use of anthelmintic drugs for treatment of nematode infections. For instance, a man in Ungai-Bena reported the death of his entire flock ($n = 25$) and noticed nematode worms in the gut of a dead sheep. The three large institutional flocks were drenched with benzimidazole (Panacur) nominally at bimonthly intervals. At the time of sampling animals had been drenched 2 months previously in Labu and 4 months previously in Baisu and Tambul.

Collection and examination of faecal samples

A total of 110 faecal samples from sheep and 55 faecal samples from goats were obtained from the rectum of randomly selected animals between 07.30 and 09.00 h and kept at 4°C until taken to the laboratory for analysis. Each sample was examined visually for consistency, mucus and macroscopic parasites. Two grams of each faecal sample were examined using a modified McMaster technique (Whitlock, 1948). Parasites were identified morphologically to genus, or in the case of strongyles, to group level (Soulsby, 1965). Parasite egg load was expressed as eggs per gram faeces (EPG). The volume of the flotation fluid used in the examinations was 50 ml and the fluid volume examined in the counting chamber was 0.3 ml. Since EPG is calculated using equation 1, the minimum EPG count in our analyses was 83 eggs/g and occurred when only one egg was observed in the counting chamber.

$$\text{EPG} = \text{eggs counted} \times \frac{\text{total volume (ml)}}{[\text{examined volume (ml)} \times \text{weight of faeces (g)}]} \quad (1)$$

Data analysis

Prevalence was calculated as the percentage of positive samples in the total number of samples examined. Apart from the overall prevalence (i.e. the infection with any GI parasite) in each flock, prevalence was also calculated for each parasite type, stratified by animal species and breed, study site, agro-ecological zone and farm management type. Differences in prevalence among groups were compared by Fisher's exact test (FET) (for two groups) or chi-squared analysis (for more than two groups).

EPG counts were transformed to their decadic logarithms to obtain a normal distribution of values prior to statistical testing for significant differences between animal species and breeds, study sites, agro-ecological zones and farm management systems. Differences between/among groups were compared by *t*-tests or one-way analysis of variance (ANOVA); followed by a *post hoc* Tukey's HSD test. Statistical analyses were performed using GraphPad Prism version 4 (GraphPad Inc., California, USA).

Results

From the total of 165 small ruminants examined, 128 (78%) were found to be infected with one or more types of GI parasites. A mixed infection with two or more types of GI parasites was found in 39% (50/128) of the infected animals: 33% (26/79) of sheep and 49% (24/49) of goats (not significantly different by FET, $P = 0.09$).

Table 1 shows prevalence and mean EPG counts over all sampling sites, stratified by the type of host animal (sheep or goat) and the type of parasite. The overall prevalence of GI parasite infection was significantly higher (FET; $P = 0.017$) in goats (89%, 49/55) than in sheep (72%, 79/110). Specifically, prevalence of strongyle (FET; $P = 0.0002$), *Strongyloides* (FET; $P = 0.013$) and *Fasciola* (FET; $P = 0.013$) were significantly higher in goats than in sheep. In addition, the mean EPG counts for strongyle were significantly higher in goats than in sheep ($t = 2.48$, $P = 0.014$).

Table 2 summarizes prevalence and mean EPG data grouped by study site. There were no statistically significant differences in the prevalence but there were several significant differences in the EPG counts for different GI parasite types across the study sites.

Strongyle and *Strongyloides* parasites were found in both sheep and goats in all study sites. The mean EPG counts for goats infected with *Strongyloides* in Tambul were significantly higher than the ones in Labu (ANOVA: $F = 3.91$, $P = 0.05$, Tukey's test: $P < 0.05$). *Eimeria* was found in sheep from four study sites (Labu, Ungai-Bena, Tambul and Menifo) and in goats from three sites (Labu, Ungai-Bena and Baisu). In sheep, the mean EPG count for *Eimeria* in Labu was significantly lower than in Menifo (ANOVA: $F = 3.41$, $P = 0.045$; Tukey's test: $P < 0.05$).

No significant differences were observed for the other genera of GI parasites. *Fasciola* was found in sheep from three study sites (Labu, Ungai-Bena and Tambul) and in goats from three study sites (Labu, Ungai-Bena and Baisu). *Trichuris* occurred in sheep from two study sites (Ungai-Bena and Menifo) and in goats only from Labu. *Nematodirus* was found in sheep from two sites (Baisu and Tambul) and in goats only from Baisu. *Moniezia* was only found in goats from three study sites (Labu, Ungai-Bena and Baisu). *Dictyocaulus* was only found in goats from Labu.

There was also a trend for goats to be more heavily infected than sheep in all areas. In Labu, mean EPG for strongyle ($t = 2.47$, $P = 0.021$) and *Eimeria* ($t = 3.95$, $P = 0.004$) were higher in goats than in sheep. In Ungai-Bena, the prevalence for *Strongyloides* was higher in goats than in sheep (FET: $P = 0.037$) and mean EPG for strongyle in goats was higher than in sheep ($t = 3.03$; $P = 0.006$).

Table 1. GI parasite prevalence and eggs/g (EPG) counts stratified by GI parasite type for the total number of faecal samples collected in the present study. *N* is the total number of faecal samples. The total prevalence refers to the fraction of animals infected with one or more GI parasite types. EPG counts are given as means ± SD. Where no SD value is given on the mean EPG count, there was only a single or few positive observations with the same values, so that SD could not be calculated. Values with the superscript (*) are significantly different between sheep and goats by either Fisher's exact test (FET) or *t*-test.

	Goat ($N = 55$)		Sheep ($N = 110$)	
Parasite	Prevalence (%)	EPG	Prevalence (%)	EPG
Strongyle	85.5*	745 ± 622*	67.3*	762 ± 1264*
Strongyloides	23.6*	277 ± 437	8.2*	323 ± 377
Eimeria	16.4	203 ± 103	17.3	633 ± 1467
Fasciola	18.2*	257 ± 275	5.5*	125 ± 46
Trichuris	3.6	125 ± 59	1.8	111 ± 48
Moniezia	9.1	116 ± 46	0	0
Dictyocaulus	3.6	83	0	0
Nematodirus	3.6	249 ± 117	1.8	111 ± 48
Total	89*	927 ± 821	72*	909 ± 1795

Table 2. GI parasite prevalence and eggs/g (EPG) counts for GI parasite type and study site. N_G and N_S are the total numbers of faecal samples collected at each study site for goats and sheep, respectively. P (%) is the prevalence in per cent. EPG counts are given as means ± SD. Where no SD value is given on the mean EPG count, there was only a single or few positive observations with the same EPG values, so that SD could not be calculated.

	Labu (N_G = 14, N_S = 27)		Ungai-Bena (N_G = 15, N_S = 16)		Baisu (N_G = 22, N_S = 19)		Tambul (N_G = 4, N_S = 29)		Menifo (N_G = 0, N_S = 19)	
	P (%)	EPG	P (%)	EPG	P (%)	EPG	P (%)	EPG	P (%)	EPG
Goat										
Strongyle	71.4	813 ± 603	93.3	810 ± 582	90.9	706 ± 713	75	478 ± 212	No data	
Strongyloides	21.4	83[1]	40	210 ± 170	9.1	83	50	960 ± 996[1]		
Eimeria	21.4	221 ± 95	20	249 ± 143	13.6	138 ± 48	0	0		
Fasciola	35.7	199 ± 216	20	470 ± 374	9.1	83	0	0		
Trichuris	14.3	125 ± 59	0	0	0	0	0	0		
Moniezia	14.3	83	6.7	166	9.1	125 ± 59	0	0		
Dictyocaulus	14.3	83	0	0	0	0	0	0		
Nematodirus	0	0	0	0	9.1	249 ± 117	0	0		
Sheep										
Strongyle	66.7	406 ± 570	68.8	445 ± 677	78.9	603 ± 389	69.0	1216 ± 1585	52.6	1087 ± 2303
Strongyloides	3.7	1246	6.3	83	5.3	83	17.2	266 ± 180	5.3	166
Eimeria	25.9	95 ± 31[1]	25	374 ± 220	0	0	6.9	125 ± 59	31.6	1605 ± 2453[1]
Fasciola	11.1	166	6.25	83	0	0	6.9	83	0	0
Trichuris	0	0	12.5	83	0	0	0	0	5.3	166
Moniezia	0	0	0	0	0	0	0	0	0	0
Dictyocaulus	0	0	0	0	0	0	0	0	0	0
Nematodirus	0	0	0	0	5.3	83	6.9	125 ± 59	0	0

[1] Values are significantly different by ANOVA/Tukey's HSD testing.

Table 3 shows the prevalence and mean EPG counts for GI parasites with respect to sheep breed, agro-ecology and farm management systems. For comparisons of agro-ecology and farm management systems, the data for sheep and goats were combined. No statistically significant differences were found in either prevalence or mean EPG counts for each parasite type between the two agro-ecological zones, with the exception for *Eimeria* and

Table 3. GI parasite prevalence and mean eggs/g (EPG) counts stratified for sheep breed, agro-ecology and farm management. *N* is the number of animals examined and prevalence (%) is the observed percentage of animals infested with one or more GI parasite types. EPG counts are given as mean ± SD. Where no SD value is given for the mean EPG count, there was only a single or few positive observations with the same EPG values, so that SD could not be calculated.

	Agro-ecology		Farm management		Sheep breed	
	Highlands $N = 124$	Lowlands $N = 41$	NARI $N = 115$	Smallholder $N = 50$	Priangan $N = 27$	H/Halfbred $N = 83$
Prevalence (%)						
Strongyle	75	68.3	74.8	70	66.7	67.5
Strongyloides	14.5	9.8	12.2	16	3.7	9.6
Eimeria	14.5	24.4	13.1	26	25.9	14.5
Fasciola	6.5*	19.5*	10.4	8	11.1	3.6
Trichuris	2.4	4.9	1.7	6	0	3.6
Moniezia	2.4	4.9	3.5	2	0	0
Dictyocaulus	0	4.9	1.7	0	0	0
Nematodirus	4	0	4.3	0	0	3.6
EPG						
Strongyle	818 ± 1156	551 ± 605	748 ± 942	775 ± 1316	405 ± 570	889 ± 1412
Strongyloides	278 ± 375	374 ± 582	357 ± 491	189 ± 151	1246	208 ± 160
Eimeria	696 ± 1492*	133 ± 80*	133 ± 69*	913 ± 1723*	95 ± 32*	948 ± 1796*
Fasciola	228 ± 283	187 ± 165	152 ± 141	374 ± 362	166	83
Trichuris	111 ± 48	126 ± 59	125 ± 59	111 ± 48	0	111 ± 48
Moniezia	138 ± 48	83	104 ± 42	166	0	0
Dictyocaulus	0	83	83	0	0	0
Nematodirus	166 ± 102	0	166	0	0	111 ± 48

NARI, National Agricultural Research Institute.
H/Halfbred, Highlands Halfbred sheep.
* Values are significantly different by either FET or *t*-test.

Fasciola. The mean EPG for *Eimeria* was higher in the highlands than in the lowlands ($t = 2.1$, $P = 0.045$) and the prevalence of *Fasciola* was higher in the lowlands than highlands (FET, $P = 0.028$). There were no significant differences in prevalence or mean EPG between the institutional and smallholder farm management systems with the exception for *Eimeria*. The mean EPG for *Eimeria* was higher in the smallholder farms than National Agricultural Research Institute (NARI) farms ($t = 3.0$, $P = 0.004$). Similarly, no significant differences were found in both parasite prevalence and mean EPG between sheep breeds, with the exception of *Eimeria* where the mean EPG in the Highlands Halfbred sheep was higher than in Priangan sheep ($t = 2.1$, $P = 0.045$).

Discussion

The present study observed 78% of the examined farm animals in PNG being infected with one or more types of GI parasites. Similar infection rates for both sheep and goats have been reported in other developing countries, such as Ethiopia and Kenya (Maichomo *et al.*, 2004; Regassa *et al.*, 2006). This high parasite prevalence may be attributed to poor farm management, e.g. little pasture rest time, poor nutrition and lack of anthelmintic treatment. At all study sites, mixed-species flocks grazed or browsed on natural forage on the same land for most of the time or were moved to other areas with only short pasture rest times. Studies in Fiji, Tonga and Malaysia found that nematodes have short survival times on pasture and suggested rotational grazing as an effective measure for parasite control (Banks *et al.*, 1990; Barger *et al.*, 1994; Cheah & Rajamanickam, 1997).

Natural pasture and shrubs in PNG are often not very nutritious and may contain anti-nutritive factors such as tannin types, which restrict rather than enhance protein availability to the ruminant (Macfarlane, 2000). Signal grass, for example, may cause hepatic dysfunction in farm animals (Macfarlane, 2000). The low-quality feed may result in subsequent malnutrition which may negatively affect the development of acquired immunity against GI parasites (Kyriazakis & Houdijk, 2006). We did not observe significantly lower GI parasite prevalence at study sites with more frequent anthelminthic treatment.

Strongyles were the most abundant parasites detected in this study. Strongyles, especially *Haemonchus* species, are highly fecund, laying up to 5000 eggs/day where environmental factors are favourable (Gupta *et al.*, 1987). The pre-parasitic stages of *Haemonchus contortus* develop and survive better at mean monthly maximum temperatures $\geq$18.3°C (Gupta *et al.*, 1987). Our study sites have mean maximum annual temperatures ranging from 18.9 to 31.1°C with only little variation throughout the year, due to their proximity to the equator. Additionally, most study sites were very humid, which is likely to sustain the survival of the free-living stages of *H. contortus*, leading to high pasture contamination.

A previous study reported high prevalence (89%) of *Eimeria* in sheep from three locations in PNG (Varghese & Yayabu, 1985) whereas the present study found a lower prevalence (21–36%) in similar areas. This may be due to the different methodologies used for parasite identification. In the present study a simple flotation procedure was used, while in the previous study a centrifugation/flotation method was used which has been reported to be more sensitive for detection of oocytes in faecal samples (Dryden *et al.*, 2005). Notwithstanding, this is the first study to report *Eimeria* in goats in PNG. We found *Eimeria* in goats in all study sites except Tambul, where only four goats were screened, and Menifo, where no goats were screened.

The trematode *Fasciola* was present in sheep and/or goats from Labu, Ungai-Bena, Baisu and Tambul. A previous study in PNG found *Fasciola* in the area of Aiyura and showed that the sheep there are exposed to continual (low-level) pasture contamination leading to chronic fasciolosis at all times (Owen, 1989). In PNG, in all areas where the intermediate snail host, *Lymnaea* species, exists, acute fasciolosis can occur in the wet season, especially in areas where the land is not well drained and the grazing pressure is high (Owen, 1989).

This is the first study reporting the prevalence of *Dictyocaulus* in sheep and goats in PNG. Some studies have found that goats are more susceptible to *Dictyocaulus* than sheep (Sharma, 1994; Berrag & Urquhart, 1996; Alemu *et al.*, 2006). We found *Dictyocaulus* in 14% of goats examined in Labu (lowland). A similar prevalence has been reported in Ethiopia in areas with an altitude $<$1500 m (Alemu *et al.*, 2006).

We found higher overall infection levels in goats compared to sheep. Goats were also infected with a wider spectrum of GI parasites. This contradicts some previous studies that found a lower prevalence in goats (Kanyari *et al.*, 2009; Khan *et al.*, 2010; Abebe *et al.*, 2011), but is in agreement with a number of other studies, which also reported higher parasite prevalence in goats (Regassa *et al.*, 2006; Nwosu *et al.*, 2007; Gadahi *et al.*, 2009; Dagnachew *et al.*, 2011). Hoste *et al.* (2008) suggested that goats do not develop resistance as efficiently as sheep and this may be an explanation for our findings.

The EPG counts for *Eimeria* in PNG Priangan sheep ($N = 27$) were significantly lower than those in the Highlands Halfbred sheep ($N = 83$). It is difficult to ascertain the mechanisms behind this difference, especially as, coincidentally, most PNG Priangan sheep samples were collected in Labu, where anthelminthic drug treatment was conducted more regularly. Nevertheless, previous studies have shown that some indigenous sheep breeds exhibit higher levels of resistance against GI parasites and this might partially explain the present findings (Baker & Gray, 2004). PNG Priangan sheep are native to tropical climates, as they originated from South-East Asia and have been exposed to GI parasites in PNG for over a century. In contrast, Highlands Halfbred sheep, which are crossbreeds of the PNG Priangan sheep and the temperate Corriedale and Perendale breeds, have only a fraction of this resistance and will therefore be more susceptible to infection. More detailed studies on immunology and feeding behaviour of the different sheep breeds are required to elucidate this problem further.

The information collected in this study is an important update on GI parasite presence in sheep and goats in PNG. Future investigations should include longitudinal studies and larger cohorts to further assess parasite epidemiology in the diverse agro-climatic zones in the country. Molecular methods should be used to identify the different species of GI parasites infecting sheep and goats in PNG, thus extending previous studies (Varghese & Yayabu, 1985; Owen, 1988, 1989, 1998).

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