Gastrointestinal parasites of indigenous pigs (*Sus domesticus*) in south-central Nepal

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**Abstract**
**Background:** Intestinal parasites have a significant impact on productivity of pigs. Additionally, presence of zoonotic parasites in pig faeces used as fertilizer and ingestion of raw or undercooked pork products originated from parasite-infested pigs pose a risk to human health.

**Objectives:** The aim of the study was to estimate the prevalence and diversity of gastrointestinal (GI) parasites in indigenous pigs (*Sus domesticus*) maintained under traditional rearing system in Nepal.

**Methods:** Fresh faecal samples (*n* = 100) were collected from the pigs of varying age and sex maintained in 18 small-scale farms in south-central Nepal. Samples were processed using various standard methods and examined for parasite eggs, cysts or oocysts.

**Results:** Prevalence of GI parasites in indigenous pigs was 91%, comprising of 14 different genera of protozoans and helminths. Male pigs generally had a higher (97.5%) prevalence of GI parasites than females (87%). While 90% of the suckling and weaner piglets were positive for the GI parasites, all growers and 85% the adult pigs were infected with the parasites. *Entamoeba* spp. were the primary protozoans in all age groups. *Strongyloides* sp. was more prevalent helminths in suckling and weaner piglets, whereas *Ascarid* spp. were higher in both growers and adults. Triplet infection was higher (33.3%) in suckling and weaner piglets, while quadruplet and pentuplet infections were higher (*p* < .05) among growers (46.7%) and adults (30%), respectively.

**Conclusions:** The indigenous pigs harbour a higher prevalence and greater diversity of GI parasites. GI parasitism varies by sex and age of the pigs.

**Keywords**
*Balantidium*, Chwanche, gastrointestinal parasites, Nepal, swine, zoonosis
1 | INTRODUCTION

Pigs are small, adaptable, rapidly growing and multiparous livestock species reared globally for their meat value. Their manure can also be used to produce biogas and as a soil fertilizer. For a long time, pig husbandry practices were restricted to very few ethnic communities in Nepal due to religious constraints and misconceptions of pork meat (Nidup et al., 2010). However, with increased urbanization, and cross-cultural experiences, people’s perception regarding pig rearing and pork consumption has changed in recent years. That might be why the annual demand of pork in Nepal was reported to increase by 10% (Thapa, 2018), and the pork was in the 4th position of all the meat consumed across the country (Pant, 2017).

The Nepalese pig industry is relatively small, as represented by its number 13,55,659 in the first 8 months of the fiscal year 2018/2019 (GoN, 2019). The native or indigenous pig breeds of rural Nepal are Chwanche, Hurrah, Bampudke, Pakhribas Black and Dharane Kalo Bangur, and others (Anonymous, Unknown). It is usually common in Nepal to raise the indigenous pigs under traditional farm management (Paudel et al., 2014). Their feed mainly includes kitchen waste, garbage, roots, green forages and locally available grains like rice-bran, maize, husks, and others (Nidup et al. 2010). In contrast, exotic breeds of pigs have been imported in Nepal since 1957 AD to upgrade the native pigs via crossbreeding. They include Tamworth, Saddleback, Faulen, Landrace, Hampshire, Duroc and The Large White (Yorkshire White; Anonymous, Unknown) and are raised primarily by urban and commercial farmers with special care and feeds (Paudel et al., 2014). Whatever the farming breed and management practices adopted, the pork industry is believed to play a substantial role in meeting the food security and boosting the economy of Nepalese farmers.

While pig farming in Nepal supports the sustainable livelihood of farmers, it is still facing many challenges regarding productivity, profitability and sustainability. Some of the existing challenges are lack of sufficient meat-processing factories and clean slaughterhouses, high feeding cost, poor market linkage, lack of adequate breeding farms, presence of primitive breeds (genetic threats), primitive model of farming practices and parasitic diseases (Gatenby & Chemjong, 1992; Paudel et al., 2014; Nidup et al., 2010). Among parasitic diseases, the gastrointestinal (GI) parasites are responsible for a substantial loss on the efficiency of pig production by competing directly for nutrients required for optimum growth and reproduction or by causing tissue injuries (lesions), leading to condemnation of organs during meat inspection, poor feed conversion, diarrhoea and dehydration or even death of the animals.

The prevalence of enteric parasites in pigs is widely reported across the globe. Some protozoan parasites, such as Entamoeba spp. (Matsubayashi et al., 2014, 2015), Giardia (Armson et al., 2009; Laber et al., 2002), Eimeria (Henry & Tokach, 1995; Jones et al., 1985), Cystoisospora (Chae et al., 1998; Johnson et al., 2008), Cryptosporidium (Argenzio et al., 1990, 1997), Balantidium coli (Laber et al., 2002; Sangioni et al., 2017) and helminth parasites such as Fasciola sp. (Capucchio et al., 2009; Horchner & Dalchow, 1972), Trichuris sp. (Batte et al., 1977; Laber et al., 2002), hookworm (Seguel & Gottdenker, 2017; Steenhard et al., 2000), strongyles (Patra et al., 2013; Sarashina & Taniyama, 1986), Strongyloides spp. (Giese et al., 1973; Laber et al., 2002), Ascarid spp. (Midttun et al., 2018; Ondrejková et al., 2012) are found to be associated with severe morbidity and mortality in pigs. Ascaris suum, Strongyloides, Trichuris suis and Strongyle have previously been reported from pigs in Nepal (Baskota & Shrestha, 2019; Sah, 2018). However, these reports included very few parasites and have not elaborated on how they could occur in pigs. Therefore, the objective of the study was to determine the prevalence and diversity of GI parasites of domestic pigs in Nepal. The resulting data on GI parasites in the pigs may aid in establishing effective and sustainable interventions to improve pig’s health and the pig industries in Nepal.

FIGURE 1 | Map of the study area showing the locations of sample collection
2 | MATERIALS AND METHODS

2.1 | Study area

The study was conducted from June to September 2019 in Shaktikhor area of Kalika Municipality (251–1,003 m above sea level, a.s.l.) in the Chitwan district of Nepal (Figure 1). The area lies in the southcentral part of Nepal and is approximately 182 km away from the capital city Kathmandu. The region experiences a tropical to subtropical climate with an annual mean temperature of 29.3°C in summer and 9.4°C in winter. The average yearly precipitation in the area is 199 mm (Adhikari et al., 2020). The indigenous/ethnic people living in the study area prefer traditional small-scale pig rearing. Most of the household rears two to ten locally available indigenous breed Sus domesticus (“Chwanche” in the Nepali language; Figure 2) under scavenging management (Pant, 2017) at the backyard of their house (Associate Professor Dr. Nirajan Bhattarai, Department of Animal Breeding and Biotechnology, Faculty of Animal Science, Veterinary Science and Fisheries, Agriculture and Forestry University, Rampur, Chitwan, Nepal: personal communications). Pigs were categorized into suckling and weaner (piglets <4 months), growers (4–8 months), and adults (>8 months) groups as previously described (Sharma et al., 2020). The inclusion criteria of the survey farms were accessibility of the farms and voluntary participation of the pig farmers.

2.2 | Sample collection

Approximately 10 g of fresh faecal samples were non-invasively collected from 100 pigs (one sample per animal) of different ages and sexes owned by 18 smallholder farmers. Briefly, the top layer of the stool that has not touched the ground immediately after defecation was collected with gloved hands. Utmost care was taken to avoid contamination of the samples. The samples were then placed into 20 ml screw-cap sterile vials containing 2.5% weight/volume (w/v) potassium dichromate. To avoid duplicating the samples, the sampled pigs were marked with identifiers. The samples were immediately transported to the Animal Research Laboratory (ARL) of the Nepal Academy of Science and Technology (NAST) for analysis. Upon receipt at the ARL, the samples were stored at 4°C until further processing.

2.3 | Sample processing and analysis

Each stool sample was processed using multiple methods: direct wet mount, sedimentation, saturated salt (45% w/v NaCl) flotation and acid-fast techniques (Adhikari et al., 2021; Adhikari et al., 2020; Ghimire & Bhattarai, 2019). Samples positive for Eimeria sp. or Cystoisospora sp. were proceeded for the sporulation assays (Adhikari et al., 2020; Chhabra & Mafukidze, 1992). Samples were then examined for parasitic bodies such as cysts, trophozoites, oocysts and ova under a B-383PLi light microscope (OPTIKA Microscopes) at 100×, 400× and 1,000× magnifications. Images of the parasites/parasitic bodies were taken by a camera (SXView 2.2.0.172 Beta (Nov 6, 2014)) attached to the microscope. The micrometry of parasites was calculated using ImageJ 1.51k (National Institute of Health). Identification of the parasites was made as previously described (Chhabra & Mafukidze, 1992; Soulsby, 2012; Widisuputri et al., 2020).

2.4 | Parasite severity

Parasite severity was measured by quantifying the number of eggs of nematodes and oocysts of Eimeria and Cystoisospora released per gram of faeces (epg/opg) by applying the McMaster technique (Adhikari & Ghimire, 2021; Soulsby, 2012). We used the 2 Cell McMaster Counting Slide (Hawksley and Sons Ltd.) following the manufacturer’s recommendations. Briefly, three grams each of coccidian and nematode-positive stool samples were weighed and

**FIGURE 2** Pigs in different conditions. (a) An adult female pig with piglets in soil. (b) An adult female pig in wet soil inside a pen. (c) Pigs in the wood-built pen. (d) A grower feeding on cattle and buffalo dung.
filtered through a tea strainer into a 50 ml beaker using 43 ml of floatation fluid made up of 45% NaCl. Then, 0.15 ml of the filtrate was placed into each depth of the McMaster slide using a pipette, and the slide was examined using a 100× total magnification under a compound microscope. All oocysts or eggs in both chambers were counted, and their sum was multiplied by 100. Finally, the resulting product was divided by 2 to calculate the epg or opg.

2.5 | Data analysis

Data were expressed as a number of parasite positive samples (frequency) and prevalence in terms of percentage using the Microsoft Excel 2016 for Windows (Microsoft Corporation). The GraphPad Prism Software Windows v5.00 (GraphPad Software, Inc.) was used to perform statistical analysis of the data. The chi-square ($\chi^2$) test was used to compare the differences in the prevalence of GI parasites by sex and age of the pigs. For all analyses, $p < .05$ (at 95% confidence interval) was considered statistically significant.

3 | RESULTS

A total of 91 faecal samples (91%) had one or more GI parasites. Protozoan parasites were highly (89%) prevalent in the pigs than the helminths (75%; Table 1). Regarding protozoa, B. coli, Cryptosporidium sp., Entamoeba coli, Entamoeba spp., Eimeria neodebliecki, E. debliecki, E. suis, E. perminuta, E. porci, E. polita, E. scabra, Giardia sp., Iodamoeba butschlii, and Cystoisospora sp. were detected in the samples (see Table 1; Figures 3 and 4; Table S1). In contrast, helminths identified included Ascarid spp., Fasciola spp., hookworm, strongyle, Strongyloides sp. and Trichuris spp. The three morphotypes of eggs of Ascarid spp. (corticated oval, corticated round and decorticated smooth) were also detected. Similarly, ova of different Trichuris spp. (long and thin form and short and broad form; size: 56–77 $\mu$m × 24–30 $\mu$m) were recorded. Due to the lack of faecal culture and identification of third-stage larvae for a complete diagnosis, we considered “strongylid” for the strongyle-type eggs of Oesophagostomum, Hysteroglymus, Globocephalus and Trichostrongylus (Adhikari et al., 2020; Gatenby & Chemjong, 1992; Ghimire & Bhattarai, 2019). Strongylid eggs were of four types depending on size (70–135 $\mu$m × 34–77 $\mu$m) and shape (oval to rectangular; see Table 1; Figure 3).

Regarding age-wise distribution, we found a 90% prevalence of enteric parasites in suckling and weaner piglets, 100% in growers and 85% in adult pigs (Table 1). Entamoeba spp. were primary protozoa in all three age groups. Regarding helminths, Strongyloides sp. was higher in suckling and weaner piglets, whereas Ascarid spp. were higher in both growers and adult pigs.

The overall prevalence of GI parasites was higher in male pigs (95.7%) than the females (87%), without statistical significance.

### Table 1: Age-wise prevalence of gastrointestinal parasites in domestic pigs of south-central Nepal

| Parasites                  | Sucklings and weaners | Growers | Adults | Overall | $p$-values |
|---------------------------|-----------------------|---------|--------|---------|------------|
| Entamoeba spp.            | 17 (56.7)             | 19 (63.3) | 25 (62.5) | 61 (61) | ns         |
| Eimeria spp.              | 16 (53.3)             | 17 (56.7) | 14 (35)  | 47 (47) | $p < .05$  |
| Balantidium coli          | 4 (13.3)              | 9 (30)   | 15 (37.5) | 28 (28) | $p < .05$  |
| Cystoisospora sp.         | 7 (23.3)              | 6 (20)   | 8 (20)  | 21 (21) | ns         |
| Entamoeba coli            | 1 (3.3)               | 5 (16.7) | 5 (12.5) | 11 (11) | $p < .05$  |
| Cryptosporidium sp.       | 5 (16.7)              | 3 (10)   | 2 (5)   | 10 (10) | $p < .05$  |
| Iodoamoeba butschlii      | 0 (0)                 | 2 (6.7)  | 6 (15)  | 8 (8)   | $p < .05$  |
| Giardia sp.               | 4 (13.3)              | 1 (3.3)  | 2 (5)   | 7 (7)   | $p < .05$  |
| Total                     | 26 (86.7)             | 29 (96.7) | 34 (85) | 89 (89) | $p < .05$  |

Note: Sucklings and weaners ($n = 30$), Growers ($n = 30$), Adults: ($n = 40$). Total numbers of samples = 100. Values in brackets indicate the % prevalence. $p$-Values were assessed by comparing the prevalence rates of individual parasite among three age-groups using Chi-square tests. Abbreviation: ns, not significant.
The prevalence of enteric parasites (protozoans and helminths combined) among suckling and weaner piglets was higher in females than males. Growers had a similar prevalence of the parasites in both sexes, while the prevalence was higher in males among adult pigs (Table 2). Regarding polyparasitism, triplet infection (33.3%) was higher among the suckling and weaner piglets, while quadruplet and pentuplet infections were higher among the growers (46.7%) and adults (30%), respectively. However, among all positive samples with polyparasitism, quadruplet infection (30%) was the highest, and septuplet infection (4%) was the lowest (Table 1) (Table S2). Of seven Cystoisospora and Eimeria positive samples, most samples (10%) were from adults, whereas 6.7% samples were from growers. These parasites were found in only one sample of sucklings and weaners
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Age- and sex-wise distribution of polyparasitism in those pigs was statistically significant ($p < .05$; Table 2).

The range of opg of faeces for *Eimeria* spp. was highest (400–6,200) in suckling and weaner piglets, whereas opg for *Cystoisospora* sp. was highest in the growers (100–2,400). On the other hand, the epg count of *Ascarid* spp. (100–7,800), hookworm (100–1,600), *Strongyloides* sp. (100–2,200) and *Trichuris* spp. (100–1,500) was higher in adult pigs, and that of the strongyle (100–4,200) was higher in the growers (Table S4).

4 | DISCUSSION

The present study investigated the prevalence and diversity of GI parasites in indigenous pigs of Nepal. Our findings of 91% overall prevalence of GI parasites in the pigs are in concordance with the findings from Burkina Faso and Uganda (91%; Nissen et al., 2010; Tamboura et al., 2006), but slightly lower than that of the reports from Indonesia (100%; Widisuputri et al., 2020), Bangladesh (96.4%; Dey et al., 2014),...
Brazil (93.1%; Barbosa et al., 2015). In contrast, our result was higher than the reports from Kenya (83%-84.2%; Kagira et al., 2012; Obonyo et al., 2013), Tanzania (83%; Nonga & Paulo, 2015), South Africa (79.2%; Nwafor et al., 2019) and Korea (73.5%; Ismail et al., 2010). The difference in the prevalence of parasites in these studies can be attributed to many factors such as age, sex and breeds of the pigs and their immune system, the diversity in the climate or sampling season, landscapes of sampling sites and husbandry practices, variation in sample size and the laboratory techniques for faecal analysis.

One of the reasons for the higher prevalence of GI parasites in this study could be due to the poor rearing condition of the pigs. Many farmers in the study area were unaware of effective pig-rearing and farm management practices. In Nepal, pig farmers usually do not pay much attention to the indigenous breeds compared with the crossbreds (Gatenby & Chemjong, 1992). The sampled indigenous pigs were fed inadequately and untimely and kept in wood-built and untidy pens with the porous floor (Figure 2). These components generate higher moisture and attract mechanical vectors such as flies in the pens that may have contributed to the acquisition of diverse parasites.

The methodological variation could be another potential contributor to the higher prevalence of enteric parasites in the study. We have applied multiple techniques for faecal analysis, including direct wet mount, flotation, sedimentation, acid-fast staining and sporulation, which might have cumulatively contributed to higher detection rates of the enteric parasites. More importantly, pigs themselves are the natural reservoir of many GI parasites recorded in this study (Ji et al., 2019; Schuster & Ramírez-Avila, 2008). Indigenous breeds also naturally possess a high GI parasitic rate (Murthy et al., 2016), possibly contributing to a high prevalence rate in the faecal samples studied.

We found the highest parasitic prevalence (100%) in growers and the lowest (85%) in adult pigs. Similar results were also reported from Tanzania (Nonga & Paulo, 2015) and India (Sharma et al., 2020). The higher prevalence of enteric parasites in the growers might be due to their higher exposure to the outside environment. After completing the weaning period, they need to search for food themselves; thus, they forage on grasses in the open fields and get exposed to various parasites. On the other hand, the lower prevalence of GI parasites in adult pigs could be due to the enhanced resistance and susceptibility to reinfec tion governed by an increased immunological memory (Brake, 2003).

The findings of a higher prevalence of GI parasites in males lie in agreement with other published reports (Dey et al., 2014; Sharma et al., 2020; Sowemimo et al., 2012). The lower GI parasitism in females in our study could be due to deworming practice performed by few farmers (field observation) for adult pregnant pigs in pre-farrowing condition (2 weeks before farrowing). Additionally, testosterone hormone, which acts as an immunosuppressant (Salvador et al., 1996), could have contributed to the higher prevalence of GI parasites in male pigs. However, further study is required to test this hypothesis.

Regarding the diversity of parasites, Entamoeba spp. had the highest prevalence rate (61%). This rate was lower than the findings from Indonesia (99%; Widisuputri et al., 2020), Kenya (87%) (Kagira et al., 2012), but higher than that reported from China (55.4%; Ji et al., 2019), United Kingdom (52.4%; Jacob et al., 2016) and Brazil (18.6%-44.3%; Barbosa et al., 2015). Various amoeba species have been previously reported in pigs, such as E. suis, E. histolytica and E. polecki (Ji et al., 2019; Mendoza-Gómez et al., 2015). In addition to the pathogenic species, non-pathogenic amoeba like E. coli and I. butschlii were also reported in the current study. Compared with the studies from Spain (44%; Bornay-Llinares et al., 2006) and Colombia (40%; Mendoza-Gómez et al., 2015), we found a lower prevalence of E. coli (11%) in the pigs, but higher than the results from Nigeria (2%; Ejinaka & Onyali, 2020). Similarly, the prevalence of I. butschlii (8%) was lower than the findings from Colombia (7.5%-57%; Mendoza-Gómez et al., 2015) and Italy (25%; Cacciò et al., 2012). These data indicate the global distribution of the amoeba in pigs.

In terms of coccidia, we found Eimeria, Cystoisospora and Cryptosporidium species in the pigs studied. Our findings of 47% prevalence of Eimeria spp. was lower than the findings from Indonesia (78%; Widisuputri et al., 2020) and Bangladesh (56.4%; Dey et al., 2014) but higher than those reported from Japan (40.3%; Matsubayashi et al., 2009), Kenya (5%-40%; Kagira et al., 2012), India (24.63%; Patra et al., 2019) and China (16.53%; Lai et al., 2011). Notably, the present study firstly reported the seven species of Eimeria in pigs from Nepal, the total known Eimeria species being eight (Chhabra & Mafukidze, 1992; Sharma et al., 2020). Similarly, the prevalence of Cystoisospora sp. (21%) in the current study was lower than that reported from Germany (53.8%; Meyer et al., 1999) and Netherlands (53%; Eysker et al., 1994), but higher than those from Korea (17.3%; Chae et al., 1998), India (12.40%; Patra et al., 2019) and Bangladesh (9.1%; Dey et al., 2014). On the other hand, 10% prevalence of Cryptosporidium sp. in this study was in accordance with a study from India (10.66%; Patra et al., 2019), but lower than those reported from Canada (66.4%; Farzan et al., 2011), Ireland (44.6%; Xiao et al., 2006) and Denmark (40.9%; Petersen et al., 2015), and slightly higher than those from Turkey (8.8%; Uysal et al., 2009) and USA (8.6%; Xiao et al., 1994). Several species of Cryptosporidium such as C. suis, C. muris, C. parvum (animal genotype) and C. scrofarum (C. Pig genotype II), reported in previous studies of pigs (Kváč et al., 2009, 2013; Xiao et al., 2006) suggest the importance of further molecular studies of these parasites in pigs from Nepal.

Giardia sp. was the only flagellate found in 7% of our samples. This rate was similar to the findings from USA (7.4%; Kváč et al., 2009), but lower than that reported from Canada (66.4%; Farzan et al., 2011), the United Kingdom (57.1%; Minetti et al., 2014), Australia (31.1%; Armonson et al., 2009) and Denmark (14%; Petersen et al., 2015), and higher than reported from India (7.63%; Patra et al., 2019) and Turkey (3.7%; Uysal et al., 2009).

Interestingly, B. coli, a common natural parasite of pigs, was reported in 28% of the samples. This rate was lower than the findings from Indonesia (79%; Widisuputri et al., 2020), Brazil (46.4%-71.6%; Barbosa et al., 2015), Korea (64.7%; Ismail et al., 2010), Kenya (64%: Kagira et al., 2012), Colombia (42%; Mendoza-Gómez et al., 2015), Bangladesh (40%; Dey et al., 2014) and India (29.48%; Patra et al., 2019) but higher than those reported from China (22.79%; Lai et al., 2011), Malaysia (22%; Tan et al., 2014) and Nigeria (13%; Bernard et al., 2015).
Regarding helminths, Ascarid spp. were reported in 45% of the examined samples. This prevalence rate was lower than the findings from Netherlands (72.7%; Eijck & Borgsteede, 2005), Botswana (54.55%; Nsoso et al., 2000), Bangladesh (50.9%; Dey et al., 2014) and South Africa (44.5%; Nwafor et al., 2019) and higher than those from Burkina Faso (40%; Tamboura et al., 2006), Uganda (40%; Nissen et al., 2010), Tanzania (37%; Nonga & Paulo, 2015) and India (33.3%; Patra et al., 2019). Strongyle was the second most prevalent nematode. The 32% prevalence report of this parasite was lower than the findings from Uganda (89%; Nissen et al., 2010), Kenya (75%; Obonyo et al., 2013), Tanzania (52%; Nonga & Paulo, 2015) and Brazil (46.6%; Barbosa et al., 2015) but higher than the findings from Ghana (11%; Atawalna et al., 2016) and India (11.10%; Patra et al., 2019). *Trichuris* spp. were recorded in the 30% samples. This rate was lower than the findings from Kenya (78%; Obonyo et al., 2013), South Africa (50.6%; Nwafor et al., 2019) and Netherlands (37.5%; Eijck & Borgsteede, 2005) and higher than the results from India (17.3%–27.84%; Murthy et al., 2016; Patra et al., 2019), Japan (24.8%; Matsubayashi et al., 2009), Indonesia (20%; Widisuputri et al., 2020) and Uganda (17%; Nissen et al., 2010). Similarly, the 23% prevalence rate of *Strongyloides* sp. was lower than the findings from Bangladesh (29.1%; Dey et al., 2014) and Kenya (26.6%; Obonyo et al., 2013) and higher than the results from Burkina Faso (21%; Tamboura et al., 2006), Indonesia (19%; Widisuputri et al., 2020), Tanzania (15%); Nonga & Paulo, 2015) and India (12.74%; Petersen et al., 2015). Hookworm was the least reported nematode, detected in only 20% of the samples. However, the rate was higher than the findings from Nigeria (3.5%-5.9%; Ejinaaka & Omyali, 2020; Sowemimo et al., 2012) and Bangladesh (3.6%; Dey et al., 2014).

Interestingly, *Fasciola* sp. was the only trematode reported in this study. Its prevalence rate (9%) was similar to the findings from Nigeria (9.3%; Bernard et al., 2015), but lower than those reported from Bolivia (27.1%; Mas-Coma et al., 1997) and Chile (20.6%; Apt et al., 1993), and higher than those from Italy (4.37%; Capucchio et al., 2009) and China (1.3%; Boes et al., 2000). Adult pigs possess a greater natural resistance to the infection because the fibrous nature of their liver parenchyma and matured immune response act as mechanical barriers for the migrating metacercaria (Nansen et al., 1972; Ross et al., 1967). However, the newly born pigs can acquire *Fasciola* infections more readily than adults (Nansen et al., 1972). These hosts can also act as a secondary reservoir for this trematode and possess transmission potentiality (Mas-Coma et al., 1997).

We also assessed the polyparasitism of the GI parasites in pigs. The current rate of 85% concurrency and the maximum number of faecal samples with triplet to pentuplet infections indicate dominant polyparasitism and high intensity of endoparasites in the pigs. Multi-parasitism is associated with greater exploitation of the host defense mechanism (Schjørring & Koella, 2003) and may impact negatively (Vaumourin et al., 2015). For example, mixed intestinal infections, including *Cryptosporidium* sp., led to piglet death in Australia (Morgan et al., 1999). Similarly, coccidiosis with any other parasitic or bacterial or viral infections leads to excessive mortality (Worliczek et al., 2007). The parasitic severity measured by epg or opg suggests that pigs were severely infected with various species of *Eimeria*, *Cystoisospora*, *Ascaris*, strongyle, *Strongyloides*, hookworm and *Trichuris*. Thus, the effects of mixed infections by all pathogen communities, rather than a single species, should be evaluated while assessing the severity of infections and the resulting pathologies (Serrano & Millán, 2014; Zhang et al., 2016).

## 5 CONCLUSIONS

The indigenous pigs (*S. domesticus*) maintained under traditional rearing system in Nepal had a higher prevalence (91%) GI parasites (protozoans and helminths). GI parasitism varied by sex and age of the pigs. Our findings suggest that indigenous pigs under traditional management can harbour a wide variety of GI parasites with higher prevalence. Thus, periodic trainings on practices for healthy and sustainable pig husbandry should be conducted targeting rural pig farmers. Additionally, deworming practices could help them to achieve maximum productivity and reduce the risk of transmitting potential pig-borne zoonotic diseases.

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## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

## AUTHOR CONTRIBUTION

Roshan Babu Adhikari: Conceptualization; Formal analysis; Investigation; Writing-original draft. Madhuri Adhikari Dhakal: Writing-review & editing. Santosh Thapa: Validation; Writing-review & editing. Tirth Raj Ghimire: Conceptualization; Formal analysis; Methodology; Project administration; Resources; Supervision; Writing-review & editing.

## ETHICS APPROVAL

The authors have adhered to ethical policies of the journal. We declare that the study was conducted on the faecal samples of naturally infected pigs and no experimental infection of the pigs was performed during the study. The fieldwork was conducted with permission from the Kalika Municipality (Chitwan, Nepal) and the Kalika Municipality Veterinary Services (Chitwan, Nepal) (Permission no. 07/2075/76).

## DATA AVAILABILITY STATEMENT

All data generated or analysed during this study are included in the main text of the manuscript and the Supporting Information files.
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