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▣ BRIEF COMMUNICATION

Distribution of Gastrointestinal Parasitic Infection in Domestic Pigs in the Republic of Korea: Nationwide Survey from 2020-2021

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Abstract: This study aimed to examine the distribution of gastrointestinal parasitic infections in domestic pigs in the Republic of Korea. From May 2020 to October 2021, 364 pig fecal samples were collected from 75 farms in 7 Provinces and microscopically examined. A total of 170 (46.7%) pigs were infected with at least one of the following parasites: *Balantioides coli*, strongyles, *Ascaris suum*, *Trichuris suis*, and coccidia. By parasite species, *B. coli*, strongyles, *A. suum*, *T. suis*, and coccidia oocysts or eggs were detected in 144 (39.6%), 24 (6.6%), 14 (3.8%), 4 (1.1%), and 1 (0.3%) samples, respectively. One hundred fifty-four, 15, and 1 cases showed single, double, and triple infections, respectively. Of the swine fecal samples from 75 farms, 69 specimens (92.0%) were infected with 1 or more parasites. All surveyed farms across the country exhibited a positive rate of over 30%, among which the highest positive rate was 65.0% in Chungcheongnam-do, and Jeollabuk-do was followed by 61.9%. Winter showed a statistically lower prevalence than other seasons. This study showed that gastrointestinal parasites are prevalent in pigs in Korea, although the diversity of parasites is low.

Key words: Gastrointestinal parasites, pig, prevalence, stool examination, protozoans, nematodes

Gastrointestinal parasitic infections play an important role in the transmission of diseases affecting the pig farming industry, causing losses of profitability and productivity. Common parasites found in pigs are *Entamoeba* spp., *Giardia duodenalis*, *Ascaris suum*, *Trichuris suis*, *Eimeria* spp., *Isospora* spp., *Cryptosporidium* spp., *Balantioides coli* (synonym *Balantidium coli*), and strongyles [1-7]. The following gastrointestinal parasites have been identified via microscopic and polymerase chain reaction (PCR) examinations in domestic pigs: *Ascaris*, *Blastocystis*, strongyles, *Entamoeba*, *Balantioides*, *Trichuris*, *Eimeria*, *Isospora*, *Giardia*, and others [2,6-8]. Some parasitic infections are asymptomatic but are often associated with gastroenteritis, resulting in diarrhea, anemia, intestinal obstruction, poor growth, and delayed development [9]. Moreover, some zoonotic parasites are a serious public health concern [6,10].

The Republic of Korea (Korea) is among the top 10 pork-consuming countries, and pig breeding is one of the most important livestock industries. According to the KOrean Statistical Information Service (KOSIS), the number of pigs raised on domestic farms was approximately 7-8 million and the number of farms was approximately 6,000 in Korea in 2011. The number of farm pigs has increased to 11 million by 2021, but the number of farms has not increased significantly compared to the past. This result suggests that pig breeding system has become more intensive and industrialized [11]. An intensive breeding system has some advantages, especially in reducing breeding-related economic costs; however, it makes animals susceptible to disease outbreaks and transmission.

There was an earlier report on swine gastrointestinal parasitic infection in Korea published in 1975 [7]. Since then, the breeding system, including the farm environment, vaccination and medication systems, and disinfection, has significantly improved [1,7]. However, current status of swine gastrointestinal parasitic infection across the country are scarce; previous studies have investigated only a limitedly confined regions, and the most recent study was conducted a decade ago. Recent studies have investigated gastrointestinal parasites, including *Giardia* and *Blastocystis* using PCR; however, PCR-based diagnosis cannot reveal the distribution of various gastrointestinal parasitic infections [2,8]. There is a substantial gap between

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the reported data and current infection status. This study aimed to investigate the distribution of gastrointestinal parasitic infections in domestic pigs in Korea.

From May 2020 to October 2021, we collected 364 pig fecal samples from 75 farms in 7 Korean provinces (Gyeonggi-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, and Gyeongsangnam-do). Seven slaughterhouses and pig farms were randomly selected. In each farm, 5 pigs were selected randomly, and consequently, the average number of samples per farm and the standard deviation were 4.68 and 0.64, respectively. There was no intended bias in the sampling numbers according to the provinces since the samples were randomly collected. When samples came from the same farm but in different seasons, the farms were counted as different farms. To avoid cross-contamination, stool samples were collected by dissecting the intestines at the slaughterhouse. All samples were transported to the College of Veterinary Medicine, Chungbuk National University, Cheongju, Korea as soon as possible, maintained at 4˚C, and examined by light microscopy with a fecal flotation technique using fully saturated sodium nitrate (specific gravity 1.33) [12].

Our fecal examination showed that 170 (46.7%) of the 364 swine samples were infected with at least 1 gastrointestinal parasite, including *B. coli*, strongyles, *A. suum*, *T. suis*, and coccidia (Table 1). At the farm level, 92.0% (69/75) of the farms included pigs infected with at least 1 parasite. At the parasite species level, *B. coli*, strongyles, *A. suum*, *T. suis*, and coccidia were detected in 144 (39.6%), 24 (6.6%), 14 (3.8%), 4 (1.1%), and 1 (0.3%) samples, respectively (Table 1; Fig. 1). Of these, 154, 15, and 1 samples were infected with single, double, and triple parasites, respectively (Table 2).

Regarding the geographical distribution, the highest prevalence was 65.0% (26/40) in Chungcheongnam-do, followed by 61.9% (13/21) in Jeollabuk-do. The lowest prevalence was 37.0% (27/73) in Gyeongsangbuk-do ($P<0.001$, Fisher's exact test). No further analysis was performed due to regional bias in sample size. The highest peak of the season was observed in spring (64.8%; 35/54), followed by autumn (45.9%, 50/109), summer (44.6%, 70/157), and winter (34.1%, 15/44) ($P=0.017$, chi-square test) (Fig. 2; Supplementary Table S1).

A major finding of this study was that *Balantidoies coli* infection was most common, ranging from 23.1% to 61.9%. *B. coli* is a large pathogenic ciliated protozoan that infects both humans and pigs [6]. Few studies have assessed *B. coli* infection

Table 1. Regional prevalence of gastrointestinal parasites in domestic pigs in Korea

Provinces (No. of samples)	Parasites identified (%, CI**)					Total* (%, CI)	
	B. coli	Strongyles	*A. suum*	*T. suis*	Coccidia	Co-infection counted separately****	Co-infection counted integratedly****
Gyeonggi-do ($n=75$)	33 (44.0, 32.8-55.2)	10 (13.3, 5.6-21.0)	4 (5.3, 0.3-10.4)	4 (5.3, 0.3-10.4)	1 (1.3, 0-3.9)	52 (69.3, 58.9-79.8)	43 (57.3, 46.1-68.5)
Chungcheongbuk-do ($n=4$)	2 (50.0, 1.0-99.0)	0	0	0	0	2 (50.0, 1.0-99.0)	2 (50.0, 1.0-99.0)
Chungcheongnam-do ($n=40$)	22 (55.0, 39.6-70.4)	1 (2.5, 0-7.3)	4 (10.0, 0.7-19.3)	0	0	27 (67.5, 53.0-82.0)	26 (65.0, 50.2-79.8)
Gyeongsangbuk-do ($n=73$)	22 (30.1, 19.6-40.7)	8 (11.0, 3.8-18.1)	2 (2.7, 0-6.5)	0	0	32 (43.8, 32.5-55.2)	27 (37.0, 25.9-48.1)
Gyeongsangnam-do ($n=122$)	41 (33.6, 25.2-42.0)	3 (2.5, 0-5.2)	4 (3.3, 0.1-6.4)	0	0	48 (39.3, 30.7-48.0)	47 (38.5, 29.9-47.2)
Jeollabuk-do ($n=21$)	13 (61.9, 41.1-82.7)	0	0	0	0	13 (61.9, 41.1-82.7)	13 (61.9, 41.1-82.7)
Jeollanam-do ($n=16$)	8 (50.0, 25.5-74.5)	1 (6.3, 0-18.1)	0	0	0	9 (56.3, 31.9-80.6)	8 (50.0, 25.5-74.5)
Not available*** ($n=13$)	3 (23.1, 0.2-46.0)	1 (7.7, 0-22.2)	0	0	0	4 (30.8, 5.7-55.9)	4 (30.8, 5.7-55.9)
Total ($n=364$)	144 (39.6, 34.5-44.6)	24 (6.6, 4.0-9.1)	14 (3.9, 1.9-5.8)	4 (1.1, 0.0-2.2)	1 (0.3, 0-0.8)	187 (51.4, 46.2-56.5)	170 (46.7, 41.6-51.8)

*$P<0.05$ by Fisher's exact test.
**CI, 95% confidence intervals.
***Not available, samples without information on the sampling provinces.
****When the samples were infected by multiple parasites, each parasite was calculated as a single case or same case.

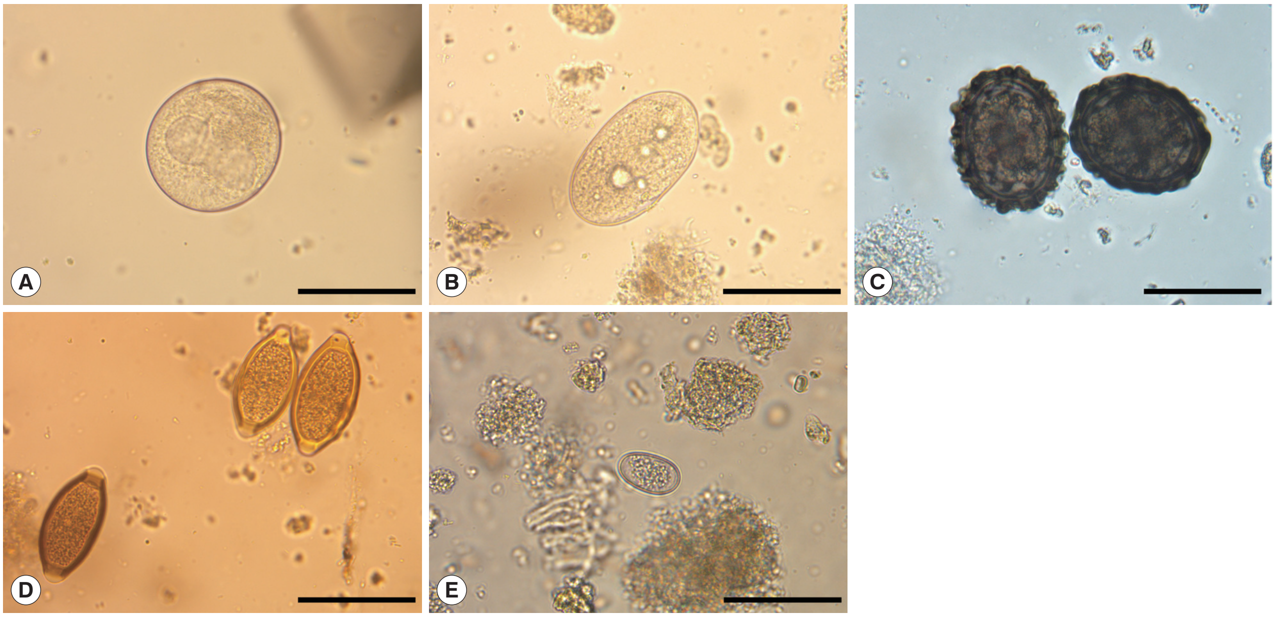

Fig. 1. Eggs and cysts of gastrointestinal parasites in pigs in Korea. (A) *Balantioides coli* cyst. (B) Strongyles egg. (C) *Ascaris suum* eggs. (D) *Trichuris suis* eggs. (E) Oocyst of coccidia. Scale bars = 50 µm.

Table 2. Frequency of single and co-infections with gastrointestinal parasites in domestic pigs in Korea

Variables	Parasites infected	No. of positive samples (%, CI**)
Single infections	*B. coli*	129 (35.4, 30.5-40.4)
	Strongyles	12 (3.3, 1.5-5.1)
	A. suum	10 (2.8, 1.1-4.4)
	T. suis	3 (0.8, 0-1.8)
Double infections	*B. coli* + Strongyles	10 (2.8, 1.1-4.4)
	B. coli + *A. suum*	2 (0.6, 0-1.3)
	B. coli + *T. suis*	1 (0.3, 0-0.8)
	B. coli + Coccidia	1 (0.3, 0-0.8)
	Strongyles + *A. suum*	1 (0.3, 0-0.8)
Triple infection	*B. coli* + *A. suum* + Strongyles	1 (0.3, 0-0.8)
Total*		170 (46.7, 41.6-51.8)

*The total number of samples is 364.
**CI, 95% confidence intervals.

in pigs in Korea, and 3 have reported the prevalence of *B. coli* in pigs reached 79.4% (108/136), 66.6% (263/395), and 42.9% (79/184) in samples collected from different regions. This result suggests that *B. coli* is prevalent in pigs in this country [1,6,7]. In the past, the prevalence of strongyles, *Ascaris*, and *Trichuris* was high in Korea [7], but these parasites are currently decreasing as confirmed in our study. Our results collectively suggest that the prevalence and diversity of gastrointestinal parasites in domestic pigs are decreasing.

The pig farms in Korea are currently administrating anthelmintics regularly. The commonly used anthelmintics contain ivermectin as an effective ingredient to prevent arthropods and gastrointestinal nematodes. It is known that ivermectin shows high efficacy against gastrointestinal nematodes, including *A. suum* and *T. suis*, but not against protozoans [13]. The relatively high prevalence of *B. coli* and low prevalence of nematodes in this study could be attributed to the widespread of *B. coli* and regular treatment of anthelminthics in pig farms in Korea.

Regarding the seasonal trend of parasite distribution, the highest prevalence was observed in spring and the lowest in winter. The prevalence rates in summer and autumn were similar. Because parasites thrive at moderate-to-high temperatures, the highest prevalence is expected in summer [10]. However, the lowest prevalence was observed in winter, which was con-

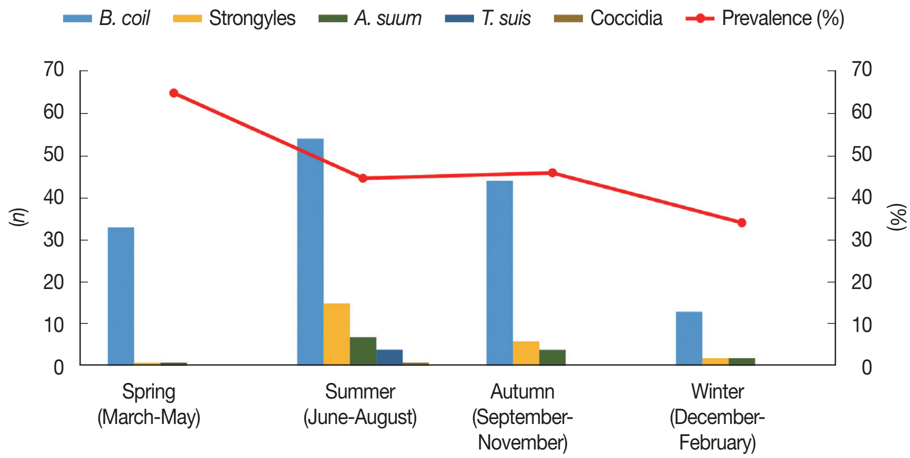

Fig. 2. Seasonal distribution of gastrointestinal parasites in pigs in Korea. Five species of gastrointestinal parasites were identified, which included *Balantioides coli*, strongyles, *Ascaris suum*, *Trichuris suis*, and coccidia. The number of infected parasites is indicated as a numerical number (left) and prevalence as percentage (right). Regarding prevalence, co-infected cases are calculated as a single case. Detailed information is provided in Supplementary Table S1.

sistent with our expectations, and the highest prevalence was observed in spring. This result may be attributed to the intensive and industrialized breeding system, which minimizes seasonal factors, such as temperature and humidity from the outside. According to region, all provinces showed a positivity rate of more than 30%. Considering that almost all farms showed at least 1 infection case, disease outbreaks and transmission will last longer without appropriate biosecurity measures.

Different techniques are available for diagnosing gastrointestinal parasitic infections in animals and humans. Microscopic examination of eggs or oocysts after flotation/sedimentation or direct smears, has traditionally been the most common method employed. Diagnostic techniques should be selected carefully according to the target parasites because some eggs might not float, or their morphology might be affected by the floating solution [6,12,14]. The fully saturated sodium nitrate as floatation solution used in this study has the advantage of high specific gravity, which makes it possible to identify the most common parasite eggs and oocysts. However, owing to their high osmotic pressure, some parasite eggs and oocysts may be quickly ruptured. Moreover, microscopic examination has lower sensitivity than molecular-based methods; therefore, the true prevalence of gastrointestinal parasitic infection in pigs in Korea might be higher than that reported in this study.

The results of this study indicate that gastrointestinal parasite infection in domestic pigs in Korea is prevalent. Although the prevalence of *B. coli* is comparatively higher than that of other gastrointestinal parasites, there is debate regarding the pathogenicity of *B. coli* in pigs [6]. Regular treatment with anthelmintics, maintaining an all-in all-out system, and maintaining a high level of hygiene could prevent economic loss due to gastrointestinal parasitic infection. Unfortunately, this study evaluated gastrointestinal parasites using microscopy alone; protozoan parasites such as *Cryptosporidium*, *Giardia*, *Entamoeba*, and coccidia could be underestimated. Continuous monitoring of parasitic infections using molecular techniques should be performed in the near future.

In conclusion, the present study demonstrated the nationwide distribution of gastrointestinal parasitic infections in pigs in Korea between 2020-2021. Our results showed that gastrointestinal parasites were highly dispersed in domestic pigs in Korea, but the diversity of parasites was relatively limited. This study may contribute to establishment of biosecurity programs to fill knowledge gap on the epidemiology of swine gastrointestinal parasites in Korea.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to this work.

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