2026, Scienceline Publication
World's Veterinary Journal
World Vet J, 16(2): 541-550.
ISSN 2322-4568

DOI: https://dx.doi.org/10.54203/scil.2026.wvj51
PII: S232245682600051-16

Prevalence and Risk Factors of *Balantioides coli* Infection in Pig-Breeding Farms in Bali, Indonesia

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ORIGINAL ARTICLE
Received: March 19, 2026
Revised: April 21, 2026
Accepted: May 25, 2026
Published: June 30, 2026

ABSTRACT

Balantioides coli (*Balantidium coli* [*B. coli*]) infection poses significant health and economic burdens in pigs, causing diarrhea, intestinal dysbiosis, and increased susceptibility to secondary infections. The present study aimed to assess the occurrence of balantidiasis and pinpoint related risk factors in pigs at breeding facilities in Gianyar Regency, Bali, Indonesia. A cross-sectional study with random sampling was conducted from August 2024 to February 2025. Fecal samples were collected from 15 to 35 pigs from 16 pig-breeding farms that utilized a semi-intensive rearing system. In total, 417 fecal samples were collected from pigs in seven districts, including 202 sows and 215 piglets. The samples were preserved in 3% potassium dichromate ($K_2Cr_2O_7$) and examined using the coprological sedimentation method. Morphological identification was based on the detection of *B. coli* cysts in fecal samples. Data on potential risk factors were evaluated using logistic regression analysis, which was conducted on data obtained from structured questionnaires and direct on-farm observations. The results indicated that 43.17% of pigs were infected with *B. coli*, with a higher prevalence in sows (56.95%) than in piglets (30.23%). Logistic regression analysis indicated that sows had a 3.366 times higher risk of infection than piglets. Farms with pig populations exceeding 100 heads also exhibited a higher risk of infection compared to farms housing 100 or fewer pigs. In contrast, farmers who purchased feed from commercial suppliers and those who used ready-made feed had a significantly lower risk of *B. coli* infection, reducing the incidence by 79.3% and 60.2%, respectively, compared to farmers who produced their own feed or used mixed feed. Factors of water source, pigpen condition, and pigpen cleaning practices were not significantly associated with infection. The prevalence of *B. coli* infection in pig-breeding farms in Gianyar Regency is notably high (43.17 %). The analysis indicated that life stage, herd size, feed source, and feed type are significantly associated with the risk of balantidiasis in pigs and should be prioritized in disease prevention and control strategies by farmers in the study region.

Keywords: Balantidiasis, *Balantidium coli*, Piglet, Protozoa, Sow

INTRODUCTION

Balantioides coli Alexeieff, 1931 (*Balantidium coli* [*B. coli*]) is a ciliate protozoan that causes balantidiasis, a disease affecting a wide range of hosts that include primates, pigs, ruminants, rodents, birds, and humans (Ahmed et al., 2020). Balantidiasis is recognized as a zoonotic and neglected tropical disease (Byun et al., 2021). Although infections in pigs are often subclinical, they may also lead to severe gastrointestinal disorders such as diarrhea, ulcerative colitis, dehydration, and growth retardation (Ahmed et al., 2020; Ponce-Gordo and García-Rodríguez, 2021). While specific quantitative data on the economic impact of balantidiasis in pigs are currently lacking, the disease is believed to affect growth performance and increase mortality rates adversely (Ahmed et al., 2020; Zhang et al., 2024). Zoonotic transmission of *B. coli* can reduce productivity, increase healthcare costs, and ultimately decrease profitability, especially among smallholder farming communities (Ngoshe et al., 2022).

The economic ramifications of *B. coli* infection in swine include diminished growth rates, decreased production, and reduced reproductive efficiency, which may indirectly lead to heightened mortality (Ahmed et al., 2020; Muthu et al., 2025). *B. coli* infection compromises overall health, which in turn increases vulnerability to other diseases (Muthu et al., 2025). Nevertheless, the mortality rate in pigs remains uncertain, as *B. coli* infection frequently presents as asymptomatic or mild (Ahmed et al., 2020). In severe instances, *B. coli* infection can result in mortality among piglets (Purnama et al., 2019).

The *B. coli* has a simple life cycle with two main forms, including trophozoites and cysts (Otranto and Wall, 2024). Human and pig transmission predominantly occurs by the fecal-oral route, specifically through the ingestion of cysts that contaminate water or food sources (Ahmed et al., 2020). After passing through the stomach, cysts undergo exocytosis in the small intestine and release trophozoites, which migrate to the large intestine. In the colon, the trophozoites colonize the intestinal lumen, utilize the microflora as a source of nutrition, and reproduce through binary fission or conjugation

To cite this paper: Putra IPC, Suratma NA, Widyasanti NWH, and Sewoyo PS (2026). Prevalence and Risk Factors of *Balantioides coli* Infection in Pig-Breeding Farms in Bali, Indonesia. *World Vet. J.*, 16(2): 541-550. DOI: https://dx.doi.org/10.54203/scil.2026.wvj51

(Ahmed et al., 2020). Under certain conditions, trophozoites can invade the intestinal mucosa and cause inflammation, ulceration, and fluid absorption disorders, which can clinically trigger diarrhea to dysentery (Allievi et al., 2025). The encystation process occurs in the colon and rectum, and the formed cysts are excreted with feces as a source of subsequent infection transmission (Otranto and Wall, 2024).

Currently, no standardized diagnostic method exists for the detection of *B. coli*. Identification is commonly performed through fecal examination using flotation or sedimentation techniques; however, sedimentation is considered more sensitive, as flotation procedures may damage cysts and complicate microscopic identification (Ponce-Gordo and García-Rodríguez, 2021). In addition, recent molecular studies have successfully differentiated two major genetic types of *B. coli*, as types A and B, using the internal transcribed spacer gene (Allievi et al., 2025).

B. coli infections have been widely reported in both animals and humans. In Indonesia, infections have been documented in cattle (Hastutiek et al., 2019), buffaloes (Balkis et al., 2025), long-tailed macaques (Athaillah et al., 2021), elephants (Herdaus et al., 2015), and pigs, which serve as the primary reservoir host (Apsari et al., 2023; Pinatih et al., 2024). Close exposure to pigs increases the risk of *B. coli* transmission to both humans and animals (López Arias et al., 2017; Ponce-Gordo and García-Rodríguez, 2021). Tropical and subtropical climates, coupled with poor sanitation, facilitate the persistence and spread of *B. coli* (Ahmed et al., 2020). Moreover, intensive pig farming systems, inadequate fecal waste management, and unhygienic housing conditions further elevate the risk of infection in animals within and around pig farms (Giarratana et al., 2021). Free-range farming practices without appropriate personal protective equipment also increase exposure to *B. coli* (Aninagyei et al., 2021).

In Bali, Indonesia, epidemiological studies have reported different prevalence rates of *B. coli* infection in pigs, including in the regencies of Jembrana and Buleleng (Pinatih et al., 2024), as well as Badung and Tabanan (Widisuputri et al., 2020). A study conducted in traditional pig markets in Bali reported a prevalence of 61.2% (Agustina et al., 2016), whereas a considerably lower prevalence of 3.5% was observed in pigs slaughtered at the Pesanggaran abattoir (Apsari et al., 2023). Studies on the prevalence of *B. coli* in Bali have shown substantial variation across regions, which may be influenced by geographical location, pig age, and the diagnostic methods used for fecal examination (Li et al., 2020; Ponce-Gordo and García-Rodríguez, 2021).

Pigs are a vital livestock commodity in Bali, as they contribute to the local economy through regional markets and traditional farming practices, which help preserve culture, tradition, and religion (Suarta et al., 2025). Gianyar Regency is one of the major pig-producing areas in Bali, with a pig population of 85,579 in 2022 (Pridayasa et al., 2025). Although the significance of *B. coli* infection in pigs is well recognized, data regarding its prevalence in this region remain limited, and the associated risk factors have not been thoroughly assessed. Consequently, the present study aimed to determine the prevalence of *B. coli* infection in pigs from breeding farms in Gianyar Regency and to identify the associated risk factors.

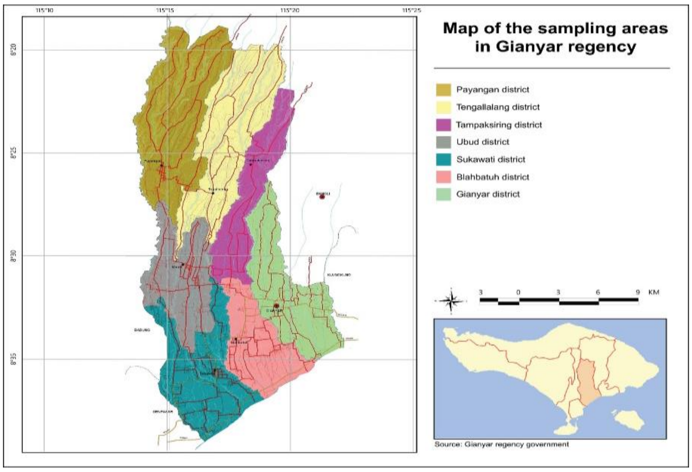
MATERIALS AND METHODS

Ethical approval

No direct interventions were conducted on the pigs in the present study. The present study was approved by the Animal Ethics Committee of the Faculty of Veterinary Medicine, Udayana University, Indonesia (No: B/146/UN14.2.9/PT.01.03/2023).

Study site and period

The study was conducted in Gianyar Regency, Bali, Indonesia (8.4667˚S, 115.2833˚E), from August 2024 to February 2025. Fecal samples were obtained from pig breeding farms located in all sub-districts of Gianyar Regency, as Payangan (139 samples), Gianyar (19 samples), Tegallalang (130 samples), Sukawati (71 samples), Blahbatuh (23 samples), Ubud (15 samples), and Tampaksiring (20 samples; Figure 1). The variation in the number of samples in the current study was due to differences in the number of pig breeding farms in each sub-district, with pig farmers being predominantly located in the Payangan and Tegallalang sub-districts.


Map of the sampling areas in Gianyar regency

Source: Gianyar regency government

Figure 1. Geographic distribution of sampling locations in Gianyar Regency, Bali, Indonesia.

Study design and sample collection

The present study is a cross-sectional study. Pig breeding farms were selected using multistage random sampling to ensure representative coverage of each district in Gianyar Regency. In total, 16 pig farms were included in the present study, which are distributed in Payangan (4 farms), Tegallalang (4 farms), Blahbatuh (1 farm), Gianyar (1 farm), Sukawati (3 farms), Tampaksiring (1 farm), and Ubud (1 farm). The pig breeding farms in Gianyar that were used as samples implemented a semi-intensive production system. At each pig-breeding farm chosen for sampling, 15 to 35 fecal samples were collected. The variation in the number of samples and their distribution across districts was influenced by the unequal distribution of pig farms in the study area. In Gianyar Regency, pig-farming activities were primarily concentrated in Payangan and Tegallalang, where the number of pig farmers and farm populations were relatively high. In contrast, other districts had fewer pig farmers, which resulted in a limited number of farms available for sampling. Therefore, the sample distribution reflects the actual population distribution of pig farms in the study area.

Fecal samples were collected randomly from individual pigs, regardless of the presence or absence of clinical signs, because *B. coli* infection in pigs is frequently asymptomatic. Approximately 10 g of fecal material was collected from each individual pig and placed into labeled tubes containing 3% potassium dichromate ($K_2Cr_2O_7$). Each sample was labeled with the district, farm name, and sample code. The samples were immediately stored in a cooler at approximately 4˚C after collection and transported to the Veterinary Parasitology Laboratory, Faculty of Veterinary Medicine, Udayana University, Bali, Indonesia, within 24 hours.

All samples were processed within 24-72 hours after arrival at the laboratory to maintain sample integrity. The required sample size was determined using the formula $n = z^2 p (1 - p) / d^2$ (Thrusfield, 2018). In this equation, n denotes the minimum required sample size, z represents the value corresponding to the confidence level (set at 95% [1.96]), p is the expected prevalence based on prior studies (estimated at 61.2% [0.612, Agustina et al., 2016]), and d signifies the desired level of precision (set at 5% [0.05]). The calculated minimum required sample size was 365. However, the present study included 417 fecal samples in total.

Risk factor assessment

Data on potential risk factors were collected using a structured questionnaire administered by the research team and direct on-farm observations. The questionnaire underwent preliminary testing with three pig farmers who were not included in the study population to assess clarity, relevance, and face validity of the items. Based on the feedback obtained during the pilot testing, minor revisions were made to improve wording and comprehension. Minor revisions were made to the risk factor variables, specifically water sources, where the river category was excluded because of the absence of river-derived water sources in the study area. Additionally, adjustments were made to the average population categories to reflect the actual farm population better, as observed in the field. The farmers were not apprised of the specific hypotheses or objectives of the study. In instances where the responses were ambiguous, clarification was sought from the participants during the interview process; however, if the data remained unclear, they were excluded from the statistical analysis. The inclusion criteria were farmers who agreed to participate in the study, had active farms at the time of data collection, operated farms with breeding sows, and provided complete and clearly verifiable questionnaire responses during the interview process. To ensure the integrity of the questionnaire data, the completed questionnaires were cross-verified and confirmed for their completeness.

The questionnaire was administered directly by the research team to the farmers during farm visits. The questionnaire was designed by the research team based on relevant literature (Dohoo et al., 2003) as well as field conditions and practical risk factors observed in local pig farming systems. A combined literature-based and field-adapted approach was used to ensure that the variables included in the questionnaire were relevant to the actual management practices and environmental conditions in the study area. Therefore, the questionnaire was developed according to the epidemiological framework described by Dohoo et al. (2003) and adapted to the field conditions observed on pig farms in Gianyar. In total, ten risk factors were evaluated, each categorized into two or three levels. The risk factors were pig life stage, herd size, feed source, feed type, water source, pigpen cleaning frequency, pigpen cleaning method, frequency of pigpen disinfection, type of pigpen floor, and pigpen condition.

Coprological sedimentation examination

Sedimentation examination was performed using 3 g of feces per sample. The sample was placed in a beaker, mixed with 30 cc of distilled water, and thoroughly homogenized using a stirring rod (Suji Premium Handcrafted, Indonesia) before being filtered to remove debris. The filtrate was transferred into a 15 mL centrifuge tube until it reached approximately one-third of the tube volume; then, centrifugation at 1,500 rpm was performed for 5 minutes. Following centrifugation, the supernatant was gently removed, leaving the sediment undisturbed. A tiny portion of the sediment was mounted on a glass slide, combined with a drop of distilled water, and sealed with a coverslip. The sedimentation examination was performed following a protocol for fecal sedimentation in parasitology (Zajac et al., 2021).

Microscopic (Olympus Corp, Japan) examination was conducted using a light microscope at 100× and 400× magnification to identify *B. coli* cysts, following the standard morphological criteria described by Otranto and Wall (2024) and Barbosa et al. (2018). *B. coli* cysts are typically spherical, have a diameter of approximately 40-65 µm, and possess a relatively thick cyst wall (Otranto and Wall, 2024). The cysts contain a dense nucleus with a clearly visible macronucleus, whereas the micronucleus is usually not readily observed (Barbosa et al., 2018). *B. coli* cysts can be confused with *Entamoeba* protozoa due to their similar round shape, but *Entamoeba* are smaller (4-17 µm) and have one or more nuclei depending on the species (Otranto and Wall, 2024). Molecular analysis was not performed due to limited study funding. The applied microscopic methods were sufficient for the study objectives, and the study focused on a field-based epidemiological survey.

Data analysis

Prevalence was calculated as the number of pigs positive for *B. coli* divided by the total number of examined pigs, multiplied by 100. Associations between potential risk factors and *B. coli* infection were evaluated using logistic regression analysis. Statistical significance was analyzed using the Wald test, with $p < 0.05$ being considered statistically significant. Odds ratios (ORs) were obtained from the Exp(B) values of the logistic regression model, and 95% confidence intervals (CIs) were calculated accordingly (Boateng and Abaye, 2019).

RESULTS

The results of the sedimentation examination indicated that the overall prevalence of *B. coli* infection in pigs in Gianyar Regency was 43.17%. Microscopic examination revealed spherical cysts with a thick cyst wall measuring approximately ± 45 µm and a clearly visible macronucleus, which are consistent with the morphological criteria of *B. coli* (Figure 2). The lowest prevalence was observed in Gianyar District (21.05%), whereas the highest prevalence was recorded in Blahbatuh District (56.52%; Figure 3). Risk factor analysis revealed that different variables were significantly associated with *B. coli* infection in pigs in Gianyar Regency ($p < 0.05$; Table 1).

The pig life stage had a significant effect on infection prevalence ($p < 0.05$). The prevalence of *B. coli* infection was significantly higher in sows (56.9%) compared to piglets (30.2%), with piglets used as the reference group ($p < 0.05$). Sows were 3.366 times more likely to be infected than piglets (OR = 3.366). The population size of farm pigs was also significantly associated with infection ($p < 0.050$). Farms housing more than 100 pigs had a higher prevalence of infection (48.8%) compared to farms housing 100 or fewer pigs (37.5%), and pigs from larger farms were 3.509 times more likely to be infected (OR = 3.509; $p < 0.05$).

Feed-related factors were also significantly associated with *B. coli* infection ($p < 0.05$). Pigs fed store-bought feed had a 79.3% ([1-0.207] × 100%) lower risk of infection compared with those who are fed home-produced feed (OR = 0.207; $p < 0.05$). Similarly, pigs fed ready-made feed had a 60.2% ([1-0.398] × 100%) lower risk of infection compared with those who are fed mixed feed (OR = 0.398; $p < 0.05$). Together, these data indicated that both store-bought and ready-made feeds are protective against *B. coli* infection. In contrast, the other factors of water source, pigpen cleaning frequency, pigpen cleaning method, disinfection frequency, type of pigpen floor, and pigpen condition were not significantly associated with *B. coli* infection in pigs in Gianyar Regency, Bali ($p > 0.05$).

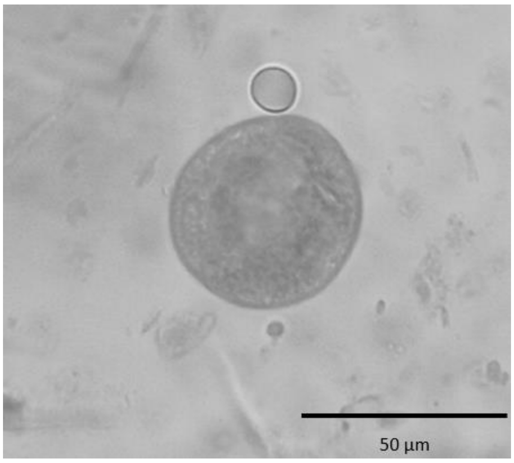


Figure 2. *Balantioides coli* cysts collected from breeding pigs across seven districts in Gianyar Regency, Bali, Indonesia

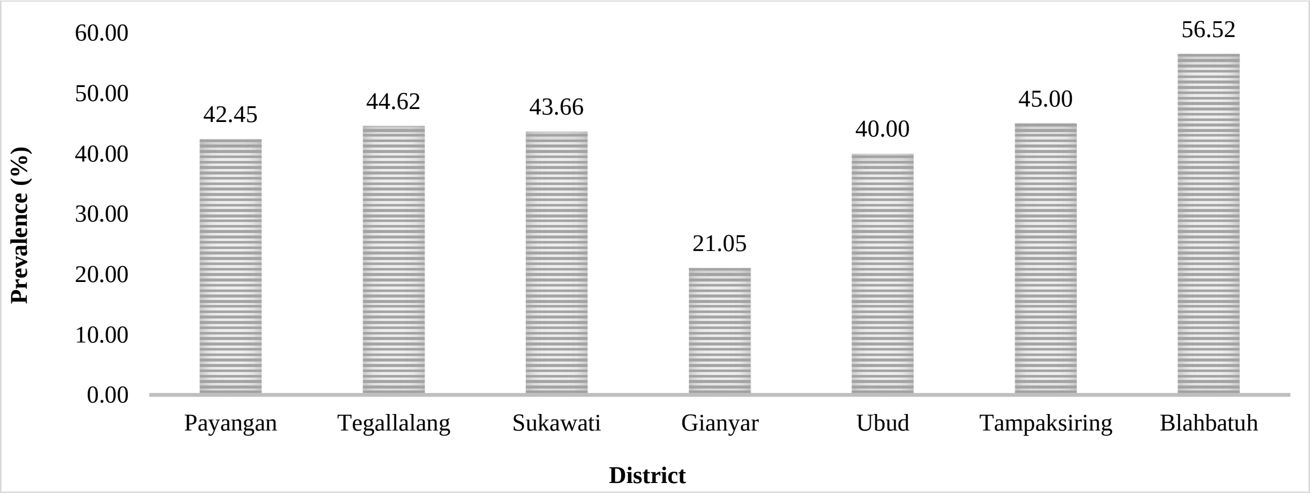


Figure 3. Prevalence of *Balantioides coli* infection in breeding pigs across seven districts in Gianyar Regency, Bali, Indonesia. Prevalence varied among districts, with the highest in Blahbatuh (56.52%) and the lowest in Gianyar (21.05%).

Table 1. Risk factors associated with *Balantioides coli* infection in pigs at breeding farms in Gianyar Regency, Bali, Indonesia, from August 2024 to February 2025

Risk factors	Category	N	Positive	Prevalence (%)	OR	CI 95%	p value
Life stage	Sow	202	115	56.931	3.366	2.194 - 5.165	0.001*
	Piglet	215	65	30.233			
Pig population on farm	≤ 100 heads	208	78	37.500	3.509	1.670 - 7.372	0.001*
	> 100 heads	209	102	48.804			
Feed source	Purchased from store	354	157	44.350	0.207	0.074 - 0.580	0.003*
	Self-produced	63	23	36.508			
Feed type	Ready-made feed	117	47	40.171	0.398	0.184 - 0.863	0.020*
	Mixed feed	300	133	44.333			
Water source	Spring	181	74	40.884	0.720	0.452 - 1.147	0.167
	Well	135	65	48.148			
	Municipal waterworks	101	41	40.594			
Pigpen cleaning frequency	Once daily	51	19	37.255	0.533	0.207 - 1.369	0.191
	Twice daily	366	161	43.989			
Pigpen cleaning method	Water spraying only	155	65	41.935	1.262	0.524 - 3.040	0.604
	Water spraying + manure removal	262	115	43.893			
Pigpen disinfection frequency	Daily	195	85	43.590	0.908	0.568 - 1.453	0.688
	Weekly	172	81	47.093			
	Irregular	50	14	28.000			
Type of pigpen floor	Cement	328	142	43.293	0.745	0.362 - 1.535	0.425
	Iron slatted floor	89	38	42.697			
Pigpen condition	Dry	265	120	45.283	0.525	0.208 - 1.324	0.172
	Occasionally wet	152	60	39.474			

N: Total sample, OR: Odds ratio, CI: Confidence interval. The Wald test was used to determine the statistical significance of each risk factor listed in the table. The results are shown in the p-value column, and significant variables are indicated with (*). Therefore, the test applies to all rows in the table rather than a specific row or column.

DISCUSSION

A prevalence of *B. coli* infection of 43.17% was observed in pigs in Gianyar Regency. The prevalence rate in the present study falls within the global prevalence range of 30-100% reported for *B. coli* infections in pigs and wild boars (Ponce-Gordo and García-Rodríguez, 2021). However, it is higher than prevalence rates previously reported in Bali, including the 3.5% in the Pesanggaran abattoir in Denpasar by Apsari et al. (2023) and the 5.1% in Buleleng Regency and Jimbaran Regency by Pinatih et al. (2024). Such prevalence rate discrepancies may be partly explained by differences in diagnostic methods. Apsari et al. (2023) employed a flotation technique, whereas the present study used the sedimentation method. Flotation techniques could damage *B. coli* cyst morphology, which would complicate microscopic identification and reduce diagnostic sensitivity (Ponce-Gordo and García-Rodríguez, 2021). The low sensitivity of the flotation method is supported by Pinilla et al. (2021), who reported that the most efficient approach for diagnosing *B. coli* infection is direct microscopic examination using Lugol's iodine solution and buffered saline. In contrast, flotation techniques, including centrifugation, flotation, and the McMaster method, were found to be ineffective for detecting *B. coli* cysts (Pinilla et al., 2021). Nevertheless, Pinatih et al. (2024), who applied the three diagnostic methods of direct examination (wet mount), sedimentation, and flotation, still reported a lower prevalence than what was observed in the present study using the sedimentation method. Compared to the higher prevalence reported by Widisuputri et al. (2020) of 79% using three methods (wet mount, sedimentation, and saturated sugar flotation) and Agustina et al. (2016) of 90% using two methods (Ritchie method and $ZnSo_4$ flotation), the prevalence observed in the present study is still lower. Such variation in prevalence rates may reflect differences in farm management practices and other risk factors that influence the transmission and persistence of infection.

The association between infection and pig life stage, herd size, feed source, and feed type highlights the importance of both host-related factors and management practices in the transmission of *B. coli.* Sows were found to be at a higher risk of infection than piglets, which may be attributable to prolonged environmental exposure and the accumulation of chronic infections over time, which potentially positions sows as a major reservoir of *B. coli* within farms (Giarratana et al., 2021). The results of the present study are consistent with previous studies reporting an age-related increase in *B. coli* prevalence (Yui et al., 2014; Symeonidou et al., 2020; Zhang et al., 2024). Yui et al. (2014) demonstrated that infection rates were significantly higher in pigs older than four months compared with those younger than one month, while suckling piglets and one-month-old piglets exhibited relatively low prevalence rates. Similar findings were reported by Symeonidou et al. (2020) in Greece, where sows had the highest risk of infection among all age groups. Both suckling piglets and weaners were indicated to have a significantly lower risk than sows, and although grower and fattening pigs had a higher risk than piglets, their risk remained lower than that of sows. Despite the general trend of increasing prevalence with age, a study had demonstrated that *B. coli* could infect pigs of all age groups, with considerable variation in prevalence. The mentioned condition may be attributed to differences in farm management practices, study locations, used diagnostic methods, sanitation conditions, and host-related factors (Paul et al., 2019). In some cases, pre-weaned piglets were indicated to have infection rates comparable to those of weaned pigs, with no statistically significant difference. Moreover, fattening pigs have been identified as the most susceptible age group in certain settings (Zhang et al., 2024). Contrasting findings have also been reported. For example in Ukraine, piglets aged 2-4 months from small-scale farms exhibited the highest prevalence at 17.2%, exceeding the rates observed in fattening pigs and sows (Bohach et al., 2023). The high prevalence observed in piglets in a study by Bohach et al. (2023) was not solely due to age, but rather a combination of the piglets' high susceptibility at that age and the conditions on small-scale farms (< 25 sows), which were characterized by poor hygiene, extensive management, and traditional farming practices. Similarly, in a study conducted in Shaanxi Province, northwestern China, a lower prevalence was reported in adult pigs (5.7%) compared to suckling piglets (7.1%), while weaners were indicated to have the highest prevalence at 18.2% (Li et al., 2020). Nevertheless, Li et al. (2020) suggested that age might not be a direct predisposing factor for *B. coli* infection. Instead, management practices, hygiene standards, stocking density, and overall farm conditions likely play a more influential role in shaping the observed prevalence patterns that are related to age.

The pig population size on a farm was also identified as a significant factor associated with *B. coli* infection in Gianyar Regency, with farms housing more than 100 pigs indicating a higher prevalence of infection. The increased infection risk in larger farms may be related to the increased stocking density and more frequent animal contact in larger farms, which can facilitate environmental contamination and the transmission of *B. coli* cysts through fecal-oral routes, including contamination of feed and water sources (Aninagyei et al., 2021). In Gianyar Regency, larger herd sizes are generally associated with more intensive husbandry systems, whereas farms with 100 or fewer pigs are typically managed at a household scale. The tendency of larger farms in Gianyar Regency to operate under more intensive husbandry systems is consistent with Giarratana et al. (2021), who reported that intensive husbandry systems are associated with an increased risk of *B. coli* infection. In contrast, Bohach et al. (2023) reported different results in the

Northern Black Sea region of Ukraine, where *B. coli* infection was not detected on large-scale farms with more than 100 sows, while moderate prevalence was observed on medium-scale farms with 20-100 sows (4.88%) and small-scale farms with fewer than 25 sows (12.7%). The observation that infection rates were lower in larger farms than in smaller farms in the study by Bohach et al. (2023) contrasts with the findings of the present study and may reflect regional differences in management practices, sanitation, and biosecurity measures.

Pig-breeding farms in Gianyar Regency predominantly implement semi-intensive production systems. Semi-intensive management practice could contribute to the occurrence of *B. coli* infection. Giarratana et al. (2021) similarly reported that the prevalence of *B. coli* infection was higher in commercial hybrid pigs (64.84%) than in local pigs (27.91%), which indicates that infections are more common in intensively-raised pigs than in those managed under extensive systems. Different mechanisms may explain why intensive husbandry systems are associated with increased *B. coli* infection. Previous studies have suggested that high animal densities may promote close contact between pigs and increase environmental contamination with cyst-containing feces, thereby facilitating fecal-oral transmission (Symeonidou et al., 2020; Giarratana et al., 2021). Maintaining optimal hygiene can also be challenging on farms with large pig populations, where fecal accumulation and contamination of feed and drinking water are likely (Giarratana et al., 2021; Mian et al., 2025). In addition, intensive systems often involve limited space and suboptimal waste management, which can result in contamination of soil and water sources that serve as reservoirs for *B. coli* cysts (Ponce-Gordo and García-Rodríguez, 2021; Patel et al., 2025). Furthermore, pigs raised under intensive conditions are frequently exposed to higher stress levels due to overcrowding and restricted movement, which may impair immune function and increase susceptibility to infection (Patel et al., 2025).

Feed management was also closely associated with *B. coli* infection in pigs at breeding farms in Gianyar Regency. Home-produced and compounded feeds were associated with a higher risk of infection compared with commercially manufactured feeds. The higher risk of infection associated with feeds that are produced and mixed on-site may be related to a greater potential for cross-contamination under unhygienic handling conditions, as suggested in a previous study (Ahmed et al., 2020), whereas commercial feeds typically undergo standardized processing and quality control. In particular, on-farm feed mixing practices in Gianyar, especially those conducted directly on the floor, may increase the likelihood of contamination with feces containing *B. coli* cysts. However, unhygienic handling conditions and on-farm feed mixing were not directly observed or quantified in the present study. Contaminated feed and water sources can serve as important vehicles for parasite transmission (Ponce-Gordo and García-Rodríguez, 2021).

In addition, compounded and home-produced feeds used in Gianyar Regency are generally rich in carbohydrates, as they are primarily composed of rice bran and corn bran. Carbohydrate-rich diets, especially those high in starch, are known to support the growth and proliferation of *B. coli* (Ponce-Gordo and García-Rodríguez, 2021). The high risk of *B. coli* infection in pigs fed high-carbohydrate diets is supported by findings from studies involving balantidiasis in symphysomal animals. The other study had demonstrated higher trophozoite counts during periods of high-starch feeding compared with low-starch feeding, which findings suggested that starch-rich diets may increase infection intensity and promote the development of clinical balantidiasis (Schovancová et al., 2013).

Although water source, pigpen cleaning frequency, pigpen cleaning method, disinfection frequency, type of pigpen floor, and pigpen condition were not statistically significantly associated with *B. coli* infection, their potential roles in parasite transmission cannot be excluded. The lack of statistical significance may be attributable to variations in husbandry practices among farms or limitations in sample size. Consequently, further studies are warranted to investigate additional and more specific risk factors, including the design and placement of drinking water systems. A practice commonly observed on small-scale family farms is the direct placement of drinking water containers on the pigpen floor. This may facilitate contamination of drinking water with feces containing *B. coli* cysts, thereby increasing the risk of reinfection (Class et al., 2025).

CONCLUSION

The present study demonstrated that the prevalence of *B. coli* infection in pigs at breeding farms in Gianyar Regency, Bali, Indonesia, is relatively high at 43.17%. This confirmed that the protozoan remains a significant concern for pig health and poses a potential zoonotic risk. The four factors of pig life stage, herd size, feed source, and feed type are significantly associated with *B. coli* infection. The finding of these four risk factors highlights the importance of prioritizing herd population management, age-related susceptibility, and improvements in feeding practices to reduce the risk of balantidiasis in pigs in Gianyar Regency. The cross-sectional design limits causal inferences between risk factors and infection. Identification based solely on morphology prevented differentiation of *B. coli* genetic types as well as co-infections with other enteric pathogens were not evaluated, which restricts the interpretation of clinical relevance. Future studies should employ molecular characterization, longitudinal designs, and comprehensive pathogen screening to elucidate better infection dynamics and disease impact in pigs.

DECLARATIONS

Acknowledgments

The authors would like to thank the Faculty of Veterinary Medicine, Udayana University for providing the research facilities. The authors also express their appreciation to all pig farmers in Gianyar Regency for their willingness to participate in the sample collection.

Authors' contributions

I Putu Cahyadi Putra, contributed to the sample examination, conceptualization, methodology development, statistical analysis, and writing and reviewing of the original draft. Nyoman Adi Suratma was responsible for supervision, validation, and project administration. Ni Wayan Helpina Widyasanti contributed to the investigation, data curation, and writing of the original article. Palagan Senopati Sewoyo contributed to the visualization and review of the original draft. All authors contributed to the writing and revision of the manuscript and have read and approved the final version.

Availability of data and materials

All data obtained in the present study were analyzed and are presented in tables and figures within this manuscript. Additional information or datasets are available from the corresponding author upon reasonable requests.

Competing interests

The authors confirmed that they have to competing interest to declare rated to the publication of this article.

Ethical considerations

The present study was conducted as an observational investigation without experimental intervention. Pigs were used solely as observation subjects, and fecal samples were collected for analysis. The authors have checked for ethical issues related to publication, including plagiarism, consent to publish, ethical misconduct, data fabrication, data falsification, double submission, and redundancy. The Paperpal by Editage (https://edit.paperpal.com) tool was employed to facilitate language editing and sentence structuring. The authors independently conducted the entirety of scientific content development, data interpretation, and study design.

Funding

Funding for the present study was provided by the Institute for Research and Community Service (LPPM), Udayana University, Indonesia, under the 2024 PNBP Research Funding scheme, as outlined in the Implementation Assignment Agreement Letter (SP3), reference number B/255.158/UN14.4.A/PT.01.03/2024.

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