EAS Journal of Parasitology and Infectious Diseases
Abbreviated Key Title: EAS J Parasitol Infect Dis
ISSN: 2663-0982 (Print) & ISSN: 2663-6727 (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-7 | Issue-1 | Jan-Mar- 2025 |

DOI: https://doi.org/10.36349/easjpid.2025.v07i01.002

Original Research Article

Prevalence and Risk Factors Associated with Cryptosporidiosis among Calves in the North Region of Cameroon

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Article History
Received: 14.01.2025
Accepted: 19.02.2025
Published: 27.02.2025

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: Cattle rearing, one of the main activities of the people of the North Cameroon Region, is limited by cryptosporidiosis, gastrointestinal disease of calves. A study was carried out in 458 calves from the North Cameroon Region during the period August 2022 to January 2023 to determine its prevalence, distribution, and risk factors. A total of 217/458 faecal samples were positive, giving an overall prevalence of 44.56%. This prevalence was significantly higher in the rainy season (59.18%) (p<0.001), and on diarrheic animals (51.44%) (p<0.001). The prevalence of infection is significantly higher in calves aged < 3 (69.28%) (p<0.001), on calves of semi-intensive (55.15%) and intensive (31.25%) farms (p<0.001). The prevalence varied significantly between 35.51% in Mayo-Rey and 53.84% in Mayo-Louti (p<0.05), and between 37.68% in calves from NEC= [3; 5] and 64.28% in those from BCN= [0; 1] (p<0.01). According to risk of infection, calves aged <3 months and 3-6 months were respectively 11.69 and 3.19 at risk to be infected (OR=11.694; p<0.001; OR=3.193; p<0.001 respectively). At the same time, the risk of infection is higher on diarrheic calves (OR=4.43; p<0.001), in the rainy season (OR=4.298; p<0.001), on calves of BCN= [0; 1] (OR=2.76; p<0.05), in the intensive system (OR=0.499; p<0.05). Cryptosporidiosis is present and very distributed among calves of this region. The disease could be a major animal and human health problem considering his impact and the zoonotic oocyst capacity of transmission.

Keywords: Cryptosporidiosis, prevalence, risk factors, calves, North Region, Cameroon.

INTRODUCTION

Cattle farming with an estimated 10 million cattle population, 802,662 of which are located in the Norden region, contributes to Cameroon's economy [1]. Despite its importance, its production remains insufficient to cover the animal protein needs of the population. Among the many problems are gastrointestinal parasitic diseases, including cryptosporidiosis, which causes severe diarrhea in calves [1, 2]. Some neonatal diarrhoea due to the hypersecretion of intestinal mucosal cells and/or to the reduction of the effectiveness of the intestine to absorb nutrients and liquids [2, 3] is a real health problem for cattle. In addition to the economic and psychological losses suffered by the farmer [4], this is a general public health problem [5]. These physiological dysfunctions often attributed to microorganisms such as coronaviruses, rotaviruses, E. coli, could however also be due to gastrointestinal protozoa such as *Gardia*, *Eimeria*, and especially *Cryptosporidium* responsible for cryptosporidiosis [6, 7, 8].

Cryptosporidiosis is a parasitic disease caused by a protozoan of the genus *Cryptosporidium* that infects the gastrointestinal epithelium of a wide range of vertebrates, including humans, and causes diarrhoea [6, 9]. Recognized as the leading cause of diarrhoea in early weaned ruminants, resulting in high morbidity and mortality [10], it is also considered the second leading cause of various types of diarrhoea among young people in developing countries, resulting in high economic

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losses [11]. This disease is also a zoonosis, because one of its pathogens, *Cryptosporidium parvum*, can be transmitted from animals to humans [12, 3, 13]. Cryptosporidium oocysts are highly resistant in the environment and to treating water with chlorine solutions, which poses a high risk of contamination to children and immunocompromised people [14, 13].

In Cameroon and the northern region in particular, there is little information on the incidence of this disease. Some information on cryptosporidiosis has been collected from children and wastewater in the southern regions [15-19]. But there is no information on the epidemiology or impact of cryptosporidiosis, particularly in cattle and calves in the northern region. The general objective of this study is to evaluate the epidemiology of cryptosporidiosis by determining the prevalence and risk factors of the disease in calves in the northern region of Cameroon. More precisely, this study consists to:

- Determine the prevalence of cryptosporidiosis;
- Determine the spatial and seasonal distribution of the disease;
- Evaluate the risk factors associated with the disease.

MATERIALS AND METHODS

Study and Station Area

The study was carried out in the North Cameroon region during the period from August 2022 to January 2023 (Fig 1).

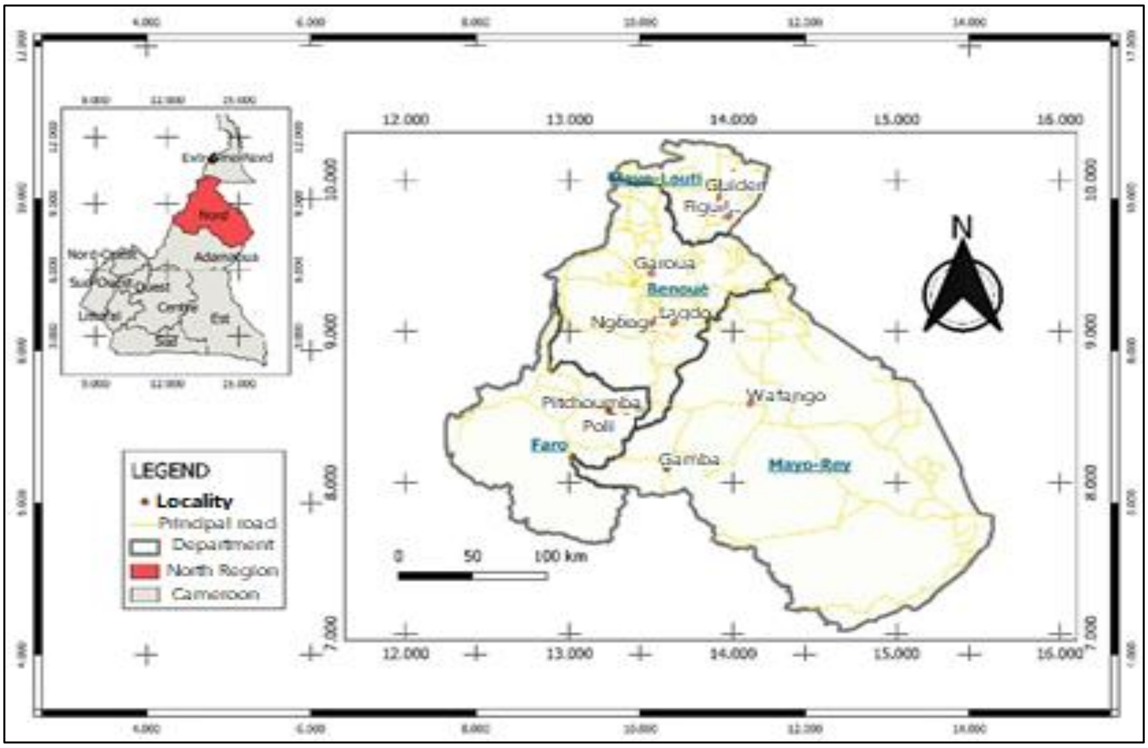

Figure 1: Map of study area and sample sites of collection

It covers an area of 65,576 km^2 and is bordered to the north by the Far North region, to the south by the Adamawa Region, to the east by Chad, and the Central African Republic, and to the west by Nigeria [21]. Administratively, it comprises Benue, Faro, Mayo-Louti and Mayo-Rey Divisions [22]. The climate is tropical of Sudanian type, with the dry season alternating slightly longer (October to April) than the rainy season (May to September). Average annual temperatures hover around 35°C. The hydrographic network is made up of two major rivers (Benue and Faro) and numerous smaller rivers that generally dry up during the dry season. Depending on the area, the vegetation consists of shrub and tree savannahs, and grassy savannahs [22, 23]. The population is made up of Baka, Fali, Bororos, Haoussas, Tupouri, Massa, Guiziga, Mousgoum, Laka, Bamileke, Kapsiki, Mafa... The farming system remains primary and extensive, with animals reproducing naturally [20]. Samples were taken in Figuil and Guider in the Mayo-Louti Division, Pitoa, Ngong, and Lagdo in the Benue Division representing the areas of the Benue plains, et à Pintchoumba, and Poli in the Faro Division, Gamba and Wafango in the Mayo-Rey Division which represent mountainous areas (Fig 1). These localities were chosen on the basis of their accessibility, pastoral importance, and the receptiveness of the herders [23] to cover different geographical areas and different types of farming.

Calf management on farms

On all these farms, after birth, the calves stayed with their mothers until they were two weeks old, after which they were isolated either in communal pens or tethered separately. They do not graze with their parents, but roam around the camps. In the rainy season, they drink from natural water courses and bodies of water, and in the rainy season from troughs near water wells.

Animal selection criteria

Animals were selected on the basis of their age, as only cattle fewer than 1 year old were sampled. Their characteristics were recorded on the basis of the phenotypic description of the cattle, such as the type of horning, the colour of the coat, and the visual assessment of the height at the withers. In addition, information such as sex, body condition score (BCS), quality of the animal's faeces, whether or not the animal had diarrhoea, type of habitat, type of farm, season and department was collected and recorded on a form.

Sample size

Our epidemiological unit here was the individual. The minimum sample size was calculated using the formula of Thrusfield [19], with a significant threshold of 95% and a required precision of 5%. A prevalence of 50% was assumed on the basis of the rule of thumb. Simple random sampling of cattle will be carried out according to the formula:

$$n = \frac{Z^2_{\alpha \times P \times (1-P)}}{\alpha^2}$$

Where:

- n = sample size;
- P = estimated prevalence;
- Zα = confidence level according to the reduced centred normal distribution (1.96);
- α = tolerated margin of error (0.05)

The minimum size of the herd examined is 30 head, and any calf up to one year old found in the herd was subject to our examinations.

Parameters of animal

Sex was identified on the basis of the anatomical characteristics. Age of the calves was determined on the basis of what the owners said about observing the dentition as defined by Ouchene *et al*., [14]. For this purpose, we have grouped them into the following age classes: < 3 months, 3-6 months, and > 6 months. The body condition score (BCS), which assesses the animal's fat covered by palpation of the dorsal spine and transverse processes of the lumbar vertebrae, is scored on a scale of 0 to 5 [10, 24]. Thus, the animals will be grouped into the following brackets: BCN= [1 ; 2] for lean calves, BCN=]2 ; 4[for animals in good condition, and BCN= [4 ; 5] for fat or obese calves [14, 25]. At the time of sampling, the name of the farm (owner), date of sampling, consistency, type of feces (score 0-1, 0: non-diarrheic, 1: diarrheic) and age, sex, breed and address were recorded for each calf on a data recording format [25] to relate them to the prevalences obtained and to evaluate risk factors due to linear regression curve.

Sample collection and preservation

During the visit to each farm, a single fresh rectal fecal sample was taken directly from the rectum (using the gang-covered hand) as soon as they were emitted, either spontaneously or after excitation of the animal's anal orifice. Once collected, they were put directly into sterile dry tubes to which a few drops of 10% formalin were added and sent to the National Veterinary Laboratory in Garoua where they were preserved at 4°C. Only one sample was taken from each animal. These samples were quickly transported in a cool box to the LANAVET parasitology laboratory in Garoua, where they were stored for a maximum of three days at a temperature of 4°C with a view to subsequent testing for the targeted parasites.

Search and identification of oocysts

Cryptosporidium infection was tested using the modified Ziehl-Neelsen method [26]. This technique, to sensitive but not specific, can helps better enumerate oocysts [26, 27]. 0.2 g of feaces concentrated with saccharose was emulsified by vortex and spread on a slide to form a thin smear. These slides were then air-dried and placed on the colouring support, flooded with alcohol at 95° C. for 5 min, and then ignited using a gas flame. The hot slides were then coated with phenolic fuchsin for 5 minutes and rinsed with distilled water. The slides were then stained with a 95% HCl solution and rinsed immediately. They were then counter-stained with methylene blue for 30 seconds. These slides were again washed with distilled water, drained and then dried in air for approximately 10 min [27] before being observed each on the optical microscope DM 500, LEICA®. Positive slides showed coloured oocysts in the form of red round beads on a blue background [26, 27].

Statistical analysis of the data

Data was collected and analysed using SPSS software statistical package. The prevalence of the disease, which represents the proportion of positives in the population, was calculated. The confidence interval, which is a range of values likely to include a defined proportion of the population, was estimated at 95% and calculated using the following formula from [12]: CI= [p-1.96*√(p*q/n); p+1.96*√(p*q/n)]; where p is the prevalence, q= (1- p), n is the sample size. The chi-square test (χ^2) was used to compare percentages. The Z test was used to classify the percentages obtained by comparing them in pairs. Variable significance thresholds varied from $p<0.05$ to $p<0.001$. Univariate logistic regression method on SPSS software was used to determine the association between potential risk factors and occurrence of cryptosporidiosis infection. Cox-Snell test was used to determine the degree of involvement of these risk factors. The result was statistically significant if the P value is ≤ 0.05.

RESULTS

Overall prevalence of bovine cryptosporidiosis

Of the 487 calves' faeces samples examined, *Cryptosporidium* spp oocysts were observed in 217 samples. This result shows that cryptosporidiosis is present in the cattle herd of the North Cameroon region with an overall prevalence of 44.55%.

Distribution of infection as a function of intrinsic factors

In this case, we have looked to intrinsic factors specific to the animal like account age, breed, Body Condition Note (BCN), sex, and the presence or absence of diarrhoea.

Prevalence according to breed

Calves of the "Red Fulani" breed were more infected with *Cryptospoidum* spp oocysts (51.20%; CI=43.60-58.81) than those of the "White Fulani" breed (42.69%; CI=35.43-49.96) and the "Bokolo" breed (39.16%; CI=31.16-47.16). However, the difference between these prevalence's was not statistically significant (χ^2=4.90; ddl=2; p=0.086).

Variation of prevalence by sex

Looking at infection of calves by sex, the prevalence of infection was higher in males (46.52%; CI=40.60-52.44) than in females (42.05%; CI=35.44-48.67). However, this difference is not statistically significant (χ^2=0.97; ddl=1; p=0.325).

Prevalence of calves' cryptosporidiosis infection according to age

The information's in Figure 2 present the prevalence of cryptosposidiosis according to the ages of calves.

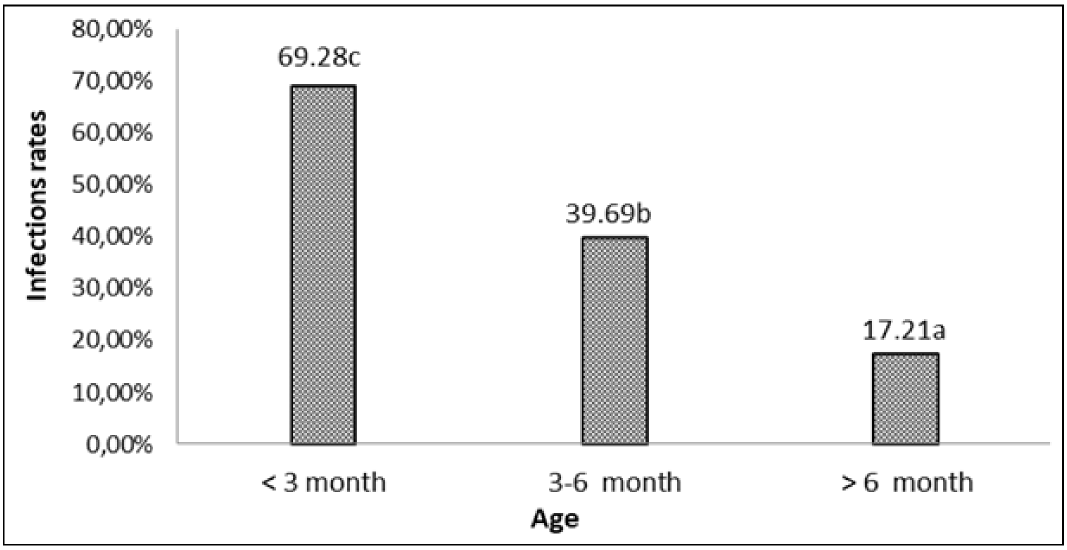

Figure 2: Variation in bovine cryptosporidiosis according to age values followed by the same letters are not significantly different at the 5% level

Youngsters aged < 3 months have a higher infection rate (69.28%; CI=59.23-79.94) than those aged 3-6 months (39.69%; CI=34.17-45.20) and > 6 months (17.21%; CI=14.24-20.17). The difference between these values is statistically highly significant. (χ^2=86.567; ddl=2; p=0.000). The Z-test showed significant differences between calves aged < 3 months and 3-6 months (Z=3.12; ddl=2; p=0.05), < 3 months and > 6 months (Z=2.31; ddl=2; p=0.05) and 3-6 months and > 6 months (Z=1.99; ddl=2; p=0.05). This means that calves aged < 3 months are the most infected, while those aged 3-6 months are moderately infected and those aged > 6 months are the least infected.

Prevalence of infection according to Body Condition Note (BCN)

The information's in Figure 3 present the prevalence of calves' cryptosposidiosis infection according to the body condition note (BCN) of calves.

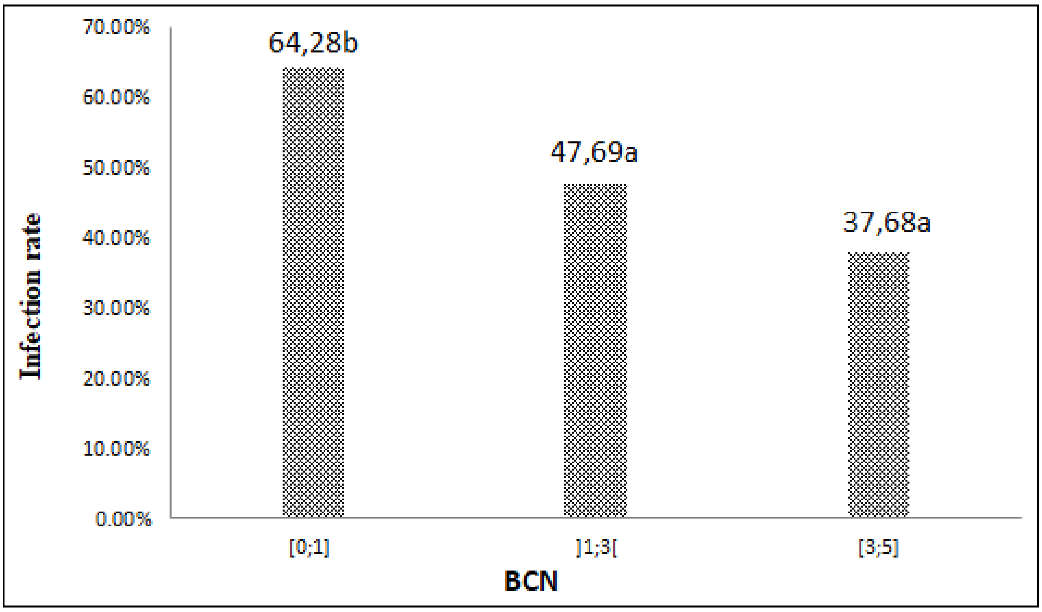

Figure 3: Variation of cryptosporidiosis infection according to BCN of calves, values followed by the same letters are not significantly different at the 5% level

Animals with BCN= [0; 1] were more affected (64.28%; CI=40.65-87.91) than those with BCN= [1; 3] (47.69%; CI=41.95-53.42) and BCN= [3; 5] (37.68%; CI=32.52-42.85). These results show a statistically significant difference (χ^2=9.283; ddl=2; p=0.010). The Z test showed highly significant differences between calves from BCN= [0 ; 1] and BCN= [1 ; 3[(Z=4,22 ; ddl=2; p=0,05), BCN= [0 ; 1] and BCN= [3 ; 5] (Z=3,51; ddl=2; p=0,05) and from BCN= [1 ; 3[and BCN= [3 ; 5] (Z=2,67; ddl=2; p=0,05). This makes it possible to classify calves from BCN= [0; 1] as more infected, followed by those from BCN= [1; 3[as moderately infected and those from BCN= [3 ; 5] as less infected.

Prevalence of cryptosporidiosis according to the status of diarrhoea

The distribution of prevalence according to the presence or not of diarrhoea (Table1) shows that calves suffering from diarrhoea were more affected (55.09%) than those without diarrhoea (25.43%). These results show the existence of a highly significant statistical difference (χ^2=41.118; ddl=1; p=0.000).

Table 1: Overall prevalence of calves' cryptosporidiosis

Prevalence according to diarrheal status					
Diarrheal status	**NE**	**NI**	**P (%)**	**IC**	**Pvalue**
Diarrheic	314	173	55.09	49.05-61.13	0.000
Non Diarrheic	173	44	25.43	21.71-29.14	
Prevalence according to season					
Season	**NE**	**NI**	**P (%)**	**IC**	**Pvalue**
Rainy	245	145	59.18	51.83-66.53	0.000
Dry	242	72	29.75	26.06-33.43	
Prevalence according to hygienic condition					
Hygienic condition	**NE**	**NI**	**P (%)**	**IC**	**Pvalue**
Good (good sanitation)	50	13	26.00	21.16-32.16	
Medium (satisfactory sanitation)	156	58	37.18	23.60-48.81	
Poor (unsatisfactory sanitation)	281	146	51.96	35.43-59.96	0.003
Prevalence according to Source of water					
Source of water	**NE**	**NI**	**P (%)**	**IC**	**Pvalue**
Fountains/Well	62	7	11.29	21.16-28.16	
Fountains/Well and Natural Watercourse	141	57	40.43	33.60-42.81	
Natural Watercourse	284	153	53.87	43.43-64.96	

Legend: No= Number; NE= Number examined; NI= Number infected; CI = 95% confidence interval; P=Prevalence

3.1.4. Distribution of infestations according to extrinsic factors

In this study, extrinsic factors including we took into account the season, department, locality, housing type, rearing method, hygienic conditions, and source of water drinking.

Prevalence of infection of calves' according to season

The prevalence according to season (Table1) of infection was higher in the rainy season (59.18%; CI=51.83-66.53) than in the dry season (29.75%; CI=26.06-33.43) with a higher significant statistical difference (χ^2=43.382; ndl=1; p=0.000).

Prevalence of calves' cryptosporidiosis according to department

The results in Figure 4 present distribution of the prevalence of cryptosposidiosis according to the division area origin of the calves.

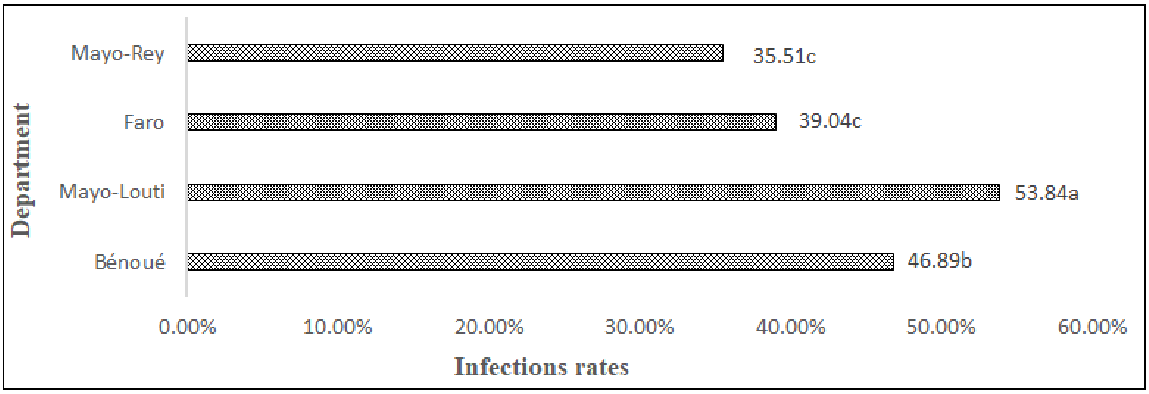

Figure 4: Distribution of cryptosporidiosis infection by department, values followed by the same letters are not significantly different at the 5% level

Calves of Mayo-Louti division are more affected (53.84%; CI=45.26-62.42) than those of Benoue (46.89%; CI=38.77-55.02), Faro (39.04%; CI=29.72-48.38), and Mayo-Rey (35.51%; CI=26.45-44.58). This difference is statistically significant (χ^2=9.740; ddl=3; p<0.05). The Z test showed that animals from the Mayo-Louti department are more infected, followed by those from Benoue, Faro, and Mayo-Rey division (Z_1=4.12, ddl=3; p<0.05; Z_2=2.23, dl=3, p<0.05; Z_3=1.87, ddl=2, p<0.05; Z_4=1.16, ddl=2, p<0.05).

Distribution of infection according to housing type

The results of the investigations show that animals kept in stall houses were more vulnerable to the disease (48.27%) than enclosure animals in pens (44.48%) and cowsheds (44.06%). However, this difference is not significant (χ^2=0.18; ndl=2; p>0.05).

Distribution of cryptosporidiosis according to herd breeding system

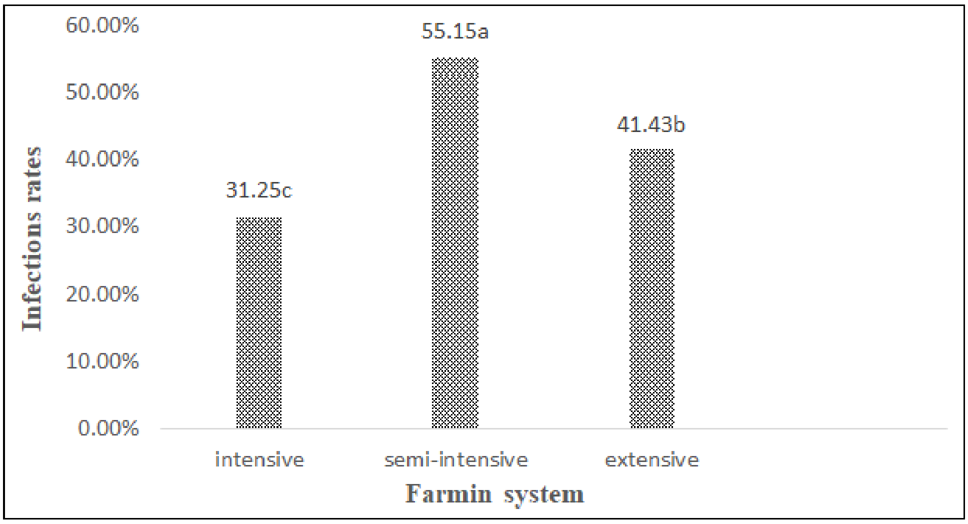

Figure 5: Prevalence of bovine cryptosporidiosis according to the herd breeding system, values followed by the same letters are not significantly different at the 5% level

The results in Figure 5 show that infection in semi-intensive farms is higher (55.15%; CI=47.46-62.84) than those in extensive (41.43%; CI=35.47-47.39) and intensive (31.25%; CI=25.55-36.94) farms. The difference between this prevalence is highly significant (χ^2=17.763; ddl=2; p<0.001). The Z test classifies animals as more infected in semi-intensive farming, followed by moderately infected in extensive farming and less infected in intensive farming (Z_1=3.10; ddl=2, p<0.05; Z_2=2.32; ddl=2, p< 0.05; Z_3=1.99; ddl=2, p<0.05).

Prevalence of infection associated with hygienic conditions and water source

From the 487 calves examined, 26%, 37.18%, and 51.96% infection rates of cryptosporidiosis were obtained from good, moderate, and poor hygienic farm conditions, respectively (Table 1). There was a statistically higher significant association between infection with cryptosporidiosis and hygienic status (P<0.01). According to the source of water, 22.58%, 40.43%, and 51.41% prevalence were obtained from does who drink water from fountains or well, fountains/well/natural watercourse, and Natural watercourse only. This result presents a higher significant statistical association between infection of *Cryptosporidium* spp and the source of water.

Risk factors for cryptosporidiosis among calves

The odds ratios for risk factors (Table 2) show that animals aged <3 months were 11.69 times more likely to be infected by *C. parvum* (OR=11.694; p<0.001), while those aged between 3-6 months were 3.19 times more exposed to the parasite than those aged over 6 months (OR=3.193; p<0.001). The presence of diarrhoea in the animal increased the risk of infection 4.42 times (OR=4.426; p<0.001). The season had a major influence on the disease, as animals were 4.29 times more vulnerable in the rainy season than in the dry season (OR=4.298; p<0.001). NEC= [0;1] animals are more at risk (OR=2.763; p<0.05) and are 2.76 times more exposed than NEC= [3;5] animals. According to the animal's department of origin, only Mayo-Louti (OR=2.478; p<0.01) represented a risk factor and was 2.47 times more at risk than Mayo-Rey. For the farming system, it emerges that only animals in intensive systems (OR=0.499; p<0.05) are more at risk and are 0.49 times more likely to be affected by the disease than those in extensive systems. Calves on farms with poor and average hygiene conditions, respectively, are 3.94 (p<0.01) and 1.41 (p<0.05) times more likely to contract the disease than those on farm with hygienic conditions. Calves that drink from natural water sources and those drinking from all water sources are, respectively, 3.94 (p<0.01) and 1.41 (p<0.05) times more likely to be infected than those who drink water from fountains and wells.

Table 2: Odds Ratios of risk factors for calf and cryptosporidiosis infection

Parameters'	Variable	OR	IC	Pvalue
Age	<3 month	11.69	6.12-22.32	0.000
	3-6 month	3.19	1.73-5.86	0.000
	>6 month			
BCN	[0 ; 1]	2.76	1.04-7.27	0.040
	] 1 ; 3[	1.32	0.82-2.11	0.245
	[3 ; 5]			
Diarrheal status	Diarrheic	4.42	2.67-7.32	0.000
	Non Diarrheic			
Season	Rainy	4.29	2.71-6.80	0.000
	Dry			
Department	Benoue	1.28	0.66-2.45	0.455
	Mayo-Louti	2.47	1.26-4.84	0.008
	Faro	1.15	0.58-2.28	0.677
	Mayo-Rey			
Farming System	Intensive	0.49	0.26-0.92	0.027
	Semi-intensive	1.30	0.78-2.16	0.303
	Extensive			
Hygenic condition	Good (good sanitation)			
	Medium (satisfactory sanitation)	1.41	0.26-2.92	0.047
	Poor (unsatisfactory sanitation)	3.94	0.78-4.16	0.008
Source of water	Fountains/Well			
	Fountains+Well + Natural Watercourse	2.31	0.26-4.92	0.067
	Natural Watercourse	4.54	0.78-6.16	0.002

Legend: CI = 95% confidence interval; OR= Odds ratio

DISCUSSION

The aim of our study was to determine the prevalence and risk factors of cryptosporidiosis in calves on farms in the North Cameroon region. We obtained an overall prevalence of 44.55%. This prevalence is higher than those obtained by Follet *et al.* [28] in France (34%), Zouagui *et al.*, [29] in Morocco (33.1%), Chen and Huang [30] in China (19%), Holzhausen *et al.*, [31] in Germany (25%), Dejene [32] in Ethiopia (16.2%), and Tarekegn [33] in Nigeria (26.1%). But it is lower than that reported by Ouchene *et al.*, [11] in Algeria (69.2%) and Abeywardena *et al.*, [34] in Australia (62%). The difference could be explained by the existence of a particular distribution of the disease according to geographical area, environmental and agroecological zone, differences in levels of farms' management, husbandry system of livestock, production system, and animals' susceptibility related to age [35, 36]. Besides, the sensitivity of the diagnostic methods utilized might also cause this difference; other tests with higher sensitivity such as PCR should be employed [28].

Animals of age <3 months were more infected and 11.69 times more at risk, and animals 3-6 months of age were 3.19 times more at risk than those >6 months of age. These results are similar to those of Platts-Mills *et al.*, [16] who reported in Scotland a higher prevalence in calves aged 1-6 months (63.26%) than in those aged 7-12 months (30.47%), Cherif and Abdelaziz [5] in Algeria who obtained higher infection rates in diarrhoeic calves aged 1-2 months (42.62%) than in those aged 3-6 months (25.93%) and 7-10 months (11.54%). Similarly in Turkey, Sevinc *et al.*, [37] observed variations in infection rates in calves aged 1-10 days (50.75%), 10-20 days (35.71%), 20-30 days (25.45%), 30-45 days (14.71%) and over 45 days (13.24%). The vulnerability of young animals could explain these results, as at this age the immune system of young infants is weaker than that of older animals, which has strengthened with age, making them less vulnerable to parasites [38]. In addition, Xiao and Herd [39] state that the best-known risk factor for *C. parvum* diarrhoea in animals is exposure at an early age.

The non-significant association between breed and cryptosporidiosis infection was also found by Abderrazek *et al.*, [40] in eastern region of Algeria. This result also indicates that both races are equally likely to be infected by *Cryptosporidium* oocysts during feeding and at infection sites [41]. There is no difference in protective immunity for the disease.

Considering infection by sex, the prevalence statistically non-significant found in males and in females was also reported by Jokar *et al.*, [17] in Iran, who obtained 18.7% of infection rate in male cattle and 14.5% in females without significant statistical difference. Zhang *et al.*, [42] obtained also the same results in northern China. Abderrazek *et al.* [40] and Venu *et al.*, [43] have reported equal infection on male and female calves. In contrast, Bamaiyi *et al.*, [44] reported higher prevalence's of *Cryptosporidium* oocysts in female birds than in male birds. This difference could be attributed to the high susceptibility of females to infection due to reduced immunity at a certain period of the breeding cycle [45, 40]. This also indicates that females are more susceptible to intestinal protozoa than males [46]. This result also indicates that both sexes are equally likely to be infected by *Cryptosporidium* oocysts during feeding and at infection sites [41, 47].

The prevalence of cryptosporidiosis in diarrhoeic calves is higher than in non-diarrhoeic calves, and the risk of being infected is 4.42 times higher when the animal shows signs of diarrhoea. These results are similar to those of Ouakli [9] who reported a higher prevalence (65%) in diarrhoeic calves than in non-diarrhoeic calves (35%) in Blida in Algeria, to those of Santoro *et al.*, [13] where the prevalence was higher in diarrhoeic calves (43.4%) than in non-diarrhoeic calves (17.9%) in Estonia, to those of Silva *et al.* [47] who obtained a higher prevalence in diarrhoeic calves (81.78%) than in non-diarrhoeic calves (16.43%) in Brazil. In Uganda, Tumwine *et al.*, [45] reported 100% prevalence in diarrhoeic calves compared with 27.3% in non-diarrhoeic calves. Similarly, Sevinc *et al.*, [37] reported a prevalence of 63.92% in diarrhoeic calves compared with 9.85% in non-diarrhoeic calves in Turkey. This difference in prevalence between diarrhoeic and non-diarrhoeic calves could be explained by the fact that bovine cryptosporidiosis is the main cause of diarrhoea in ruminants [10, 29].

According to the Body Condition Note, higher infections in animals with BCN= [0; 2] who were more at risk and 2.76 times more exposed than animals with BCN= [4; 5] are similar to those of Birhanu *et al.* [48] in Ethiopia where animals were classified as having poor, fair and good BCN and had prevalence's of 30.4%, 20.2% and 8.0% respectively. Yemane [7] obtained in Ethiopia a similar prevalence of 41.68% in calves with poor BCN, 27% in those with average BCN, and 10.5% in calves with good BCN. This difference could be explained by the fact that BCN [0; 2] and]2; 4[correspond to animals suffering from diarrhoea and that bovine cryptosporidiosis is the main cause of diarrhoea in ruminants [10].

The infection of calves was higher in the rainy season and 4.29 times more at risk in the rainy season than in the dry season are similar to those reported in Malawi by Meutchieye *et al.* [49], with a prevalence of 8.1% in the rainy season compared with 3.7% in the dry season and in Uganda by Tumwine *et al.*, [45] and Ouakli

[9], who found a higher prevalence in the rainy season during the months of April to June. In Europe, there is also a concordance with our results. In France, a preponderance of cases was reported in late summer and autumn, corresponding to the rainy season in North Cameroon. In the UK and Ireland, there is a second peak in frequency in spring, corresponding to the end of the dry season and the start of the rainy season in North Cameroon, mainly due to *C. parvum* [50]. This difference in prevalence between seasons could be explained firstly by the fact that oocysts can survive up to 18 months in cold water at 4°C, 7 months in warm water at 15°C and are only inactivated at temperatures above 60°C or below -22°C [31, 51]. Finally, during the rainy season, oocysts spread and are more resistant to climatic conditions, whereas during the dry season, the spread of oocysts is limited by very high temperatures, which restrict their survival [51, 8].

The prevalence of cryptosporidiosis is higher in the semi-intensive farm than those of extensive and intensive farms, and 0.49 times more at risk than extensive livestock, meaning that extensive livestock were 2 times more exposed are similar to those of Geurden *et al.,* [15] in Zambia, who reported that the prevalence of cryptosporidiosis varies according to the farming systems encountered : dairy/intensive (42.8%), cattle/semi-intensive (8.0%), and traditional/extensive (6.3%), and to Abeywardena *et al.,* [34], who argue that the molecular epidemiology of cryptosporidiosis in cattle in developed countries may differ from that in developing countries, as cattle farms in developed countries are intensively managed, yet the majority of farms in developing countries are extensive or semi-extensive. However, these results contradict those of Tarekegn *et al.,* [33], who carried out studies on two types of farms, intensive and extensive, and reported that the prevalence was higher in the intensive farm (14.2%) than in the extensive farm (7.7%). This could be explained by the fact that soil has a protective effect on oocysts, increasing their survival time [34, 52]. In semi-intensive and extensive farming, the animals are in contact with the soil compared with intensive farming. We could also mention hygiene conditions, which are better in intensive farming than in the others.

Animals of Mayo-Louti division were more infected than those of the Benoue and Mayo-Rey divisions, while only calves in Mayo-Louti were 2.47 times more at risk than those in Mayo-Rey. Our results are similar to those reported by Hocine and Bouzid [53] in eastern Algeria, and Ouakli [9] in Blida, who obtained prevalence's of 24.11% and 65% respectively. These results could be explained by the existence of a particular distribution of cryptosporidiosis in the world [35]. The variation between prevalence in the different departments of the North can be explained by the diversity of farming methods. Indeed, with the phenomenon of insecurity due to kidnappings in the Faro and Mayo-Rey zones, livestock farmers are increasingly practising intensive livestock farming, whereas in Mayo-Louti and Benue Divisions, livestock farming is mainly extensive.

Calves raised in farms with poor hygiene were more infected and 3.9 at risk of infection than those in farms with better hygiene (26%), mainly due to poor hygiene in the calving and calf housing areas but also poor management of housing. The same result has been reported by Abderrazek *et al.,* [40] in easthern region of Algeria. Other studies have also reported infection correlated with hygienic defections [52, 50, 18, 47]. This result can be explained by the presence and accumulation of discarded fecal matter, as observed in our study, represent a source of contamination with infective oocysts.

Calves that drink from natural watercourses have a higher prevalence and are 4.54 times more exposed to the risk of infection by *Cryptosporidium* oocysts than those that drink from fountains or wells (11.29%), mainly due to the dumping of animal waste in nature, human defecation and especially adult cattle in the open air, and the survival of oocysts in the water. Asymptomatic adult cattle are known to play a role in maintaining the enzootic situation, since a single bovine animal can excrete between $9\ 10^2$ and $1.8\ 10^4$ oocysts per gram of faeces, or $3.6\ 10^6$ to $7.2\ 10^8$ oocysts per animal per day [18, 47, 21]. This excretion by adult cattle allows oocysts to be disseminated, especially when they are discharged into water [18, 14].

CONCLUSION

At the end of this study, we found that cryptosporidiosis is present in the North region of Cameroon, with an overall prevalence of 44.56%. This disease is more prevalent in the rainy season than in the dry season and affects calves from Mayo-Louti division, diarrhoeic calves, and younger calves the most. Calves reared semi-intensively were more exposed than those reared intensively and extensively. According to BCN, calves with BCN = [0; 2] were more infected. Age, diarrhoea status, BCN, season, rearing system, hygienic condition, and source of water drinking were found to be the most important risk factors of infection of calves by oocysts of *Cryptosporidium* spp. However, in order to better understand the epidemiology and zoonotic impact of this disease, it would be desirable to determine the molecular diversity and distribution of the different species of *Cryptosporidium* present in calf and adult cattle, and to identify their importance in zoonotic transmission to human populations.

Conflict of Interest: The authors declare no conflict of interest.

Authors' Contribution: All authors equally contributed

Funding Source: This study was not supported by any funding

Declaration of Cattle Owner's Consent for Publication: We declare that during our study on "the prevalence and risk factors of cryptosporidiosis in calves farms the North Cameroon region", the consent of the calf owners for the collection of faeces samples and the analysis and publication of the research results was obtained beforehand.

Availability of Data and Materials: The research data and materials for this study are available upon request.

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Cite This Article: Augustin Siama, Radaiwa, Rodrigue Simonet Poueme Namegni, Samuel Abah, Alexandre Michel Njan Nloga (2024). Prevalence and Risk Factors Associated with Cryptosporidiosis among Calves in the North Region of Cameroon. *EAS J Parasitol Infect Dis*, *7*(1), 7-18.