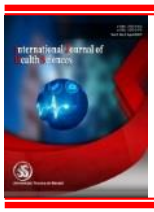

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Cryptosporidium Disease of Small Ruminants in the Region of El Taref and Mostaghanem: Epidemiological, bacteriological and Histopathological Characteristics

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cryptosporidium, histopathological, Northern Algeria, small ruminants, survey,

Abstract

To identify and quantify Cryptosporidium infection in small ruminants in northern Algeria, specifically in the regions of Tarf and Mostaganem, a three-year survey was conducted between 2019 and 2021. The epidemiological investigation covered several aspects of the prevalence and etiology of Cryptosporidium, including various factors suspected to contribute to the spread of the causative agent of this disease. In addition, a confirmatory study was initiated, with bacteriological and histopathological tests performed on samples collected during the survey period from the various farms examined. The results showed that the epidemic takes several aspects for its spread as well as its persistence, the bacteriological results showed a coincidence of the presence of the pathogen in a significant proportion, and the histopathological interpretation of the slides revealed the diversity of lesions at the intestinal level with the predominance and inversion of enterocytes by sporozoites, resulting in the recurrence of lesions in the different organs collected in all species studied, cattle, sheep and goats.

Contents

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1 Introduction

Cryptosporidiosis is an emerging cosmopolitan parasitic disease caused by a protozoan of the genus Cryptosporidium, which affects several animal species and humans (Šlapeta, 2013). Cryptosporidium causes significant economic losses in livestock by leading to high morbidity and mortality rates, especially in newborns (Mohamed et al., 2017; Pumipuntu & Piratae, 2018). Cryptosporidiosis is considered a high-risk infection for neonates and immuno-compromised individuals, it has also been recognised as the second most common cause of various types of diarrhoea in children in developing countries (Juranek, 1995; Makri et al., 2017). Recent studies have established that ruminants, particularly calves, are reservoirs for Cryptosporidium parvum and the most zoonotic species (Robertson et al., 2020; Guo et al., 2021).

Furthermore, within the same species, some subtypes are zoonotic and others are non-zoonotic; In contrast, studies concerning the role of small ruminants in zoonotic transmission are limited. However, some work carried out in the world has demonstrated that, in the same way as cattle, goats and sheep can harbour Cryptosporidium parvum with zoonotic subtypes (Plutzer & Karanis, 2009; Khan et al., 2018; Odeniran & Ademola, 2019).

In Algeria, Cryptosporidium has been the subject of a few studies in cattle, among which molecular characterisation has been carried out on strains isolated in some regions of the Centre, Centre East and East; compared with small ruminants, where only one study has been able to characterise Cryptosporidium spp, in these animals in the Centre region to date; and revealed among the species identified: C.Parvum zoonotic subtype (Ouakli et al., 2018; Hijjawi et al., 2022; Sembiring et al., 2022).

The objectives of the present work are to estimate the diagnostic suspicion of cryptosporidiosis in ruminants in general, to determine the prevalence of Cryptosporidium spp. in cattle, sheep and goats following most of the risk factors and to influence The monitoring of Cryptosporidium spp. oocysts to estimate the intensity of excretion and to determine the rate of transmission of the parasite to healthy individuals, and the demonstration of Cryptosporidium spp. in internal organs of ruminant cadavers by histopathological analysis.

2 Materials and Methods

Etiological section

- *Field survey*

The study was performed in the two extremities of Northern Algeria through investigative visits to 103 ruminant farms in the regions of El Tarf and Mostaganem, from January 2019 to December 2022, after the call of the farmers to treat moderate or severe diarrhoeal cases in newborn ruminants. The first epidemiological survey was carried out in Mostaganem between September 2019 and December 2020, on the study population consisted of all small ruminant farms (goats, sheep) that practice heat synchronization for deseasonalisation (no calving in winter). The sample was prepared by stratified random selection from the exhaustive list of practising livestock farmers (cattle, goats, sheep) with a sampling rate of over 20%. The second cross-sectional survey was carried out in the northeast of Algeria in the Wilaya of El Tarf, in a period from January 2021 to December 2023.

The general overview of the surveys was based on a questionnaire aimed at livestock breeders and farmers operating in the rural sector in these Algerian regions, questions were made to gather information, divided into three main components, a causal approach that contains a set of questions to study the main digestive pathologies encountered in ruminants, their epidemiology according to the parameters of influence, type, and importance, etc. The main causes, and frequency of occurrence, of the questionnaire also contained

practitioners' priorities concerning their involvement in rural activities and therapeutic approaches in ruminants in the region.

A questionnaire designed to characterise the breeding and rearing practices was systematically filled in, and the potential explanatory variables (or candidates) were selected after a review of the scientific literature. They aimed to characterise the management of the survey (2 variables), the nature of the breeding and the practices of the breeder (19 variables), the feeding of the goats (7 variables), the rearing of the goats (13 variables), the rearing of the young animals (9 variables) and the rearing of the young animals (14 variables). The statistical unit is the herd of interest were studied: the simple positivity of the herd (at least one The candidate explanatory variables were selected in the pre-models when the statistical link with the variables of interest showed a $p \leq 0.1$ or an Odds Ratio (OR) greater than 3.

The selection of the final models was performed by ordinary logistic regressions. The selection criterion used was a top-down procedure aiming to minimise the Akaike Information Criterion (AIC), design and fitting were performed with Past 3 software.

Diagnostic part

- *Microbiological investigation*

In each selected farm, faeces were collected from 135 animals aged under 60 days (45 samples for each species) in the same survey period, two techniques were used, the Ritchie concentration technique simplified by Allen and Ridley, and the ZiehlNeelsen staining technique modified by Henriksen and Pohlenz, both of which are known for their specificity and sensitivity (Allen & Ridley, 1970; Henriksen & Pohlenz, 1981).

The prevalence (F) was calculated as follows: F = D/N, where D is the number of animals in which the parasite was observed and N = number of samples.

For each set of analyses, Chi-square (X2 calculated), Chi-square theoretical (X2 theoretical) and degree of freedom (ddl) values were calculated at a confidence level maintained at p = 95% and $\alpha < 0.05$, the mean, and the confidence interval are defined for significance. The comparison of the numbers was done by the two tests: Student's t-test and the Chi-square test.

- *Histological and histopathological investigation*

Necropsy studies were carried out on 97 dead animals (29 cattle, 46 goats and 27 sheep) at an advanced stage of the disease, followed by the collection of internal organs for histopathological study.

A. Fixation of organs: The purpose of fixation is to eliminate the risk of retraction and distortion, to protect against bacterial attack and to oppose autolysis (enzymatic action). It can be summarised that fixation has three main purposes: to coagulate, precipitate and insolubilise the harvested fragments.
B. Post-fixation: Remove the fixed parts and put them under tap water for at least three hours, then cut 3 to 6 fragments according to the size of the organ taken and place them in plastic cassettes, writing the corresponding numbering (age, organ) on top.
   The following successive passages are used:
   Ethanol 80% (4 hours); Ethanol 95% (2 hours); Ethanol 100% (1.5 hours); Ethanol 100% (1.5 hours); Xylene (1 hour); Xylene (1 hour); Paraffin (6 hours); Paraffin (7 hours).
C. Blocking: Paraffin embedding is carried out in an apparatus set at 55° (photo: 06); the parts are placed in stainless steel moulds, the heated paraffin is poured into the moulds and the labels are placed on top of the moulds; the moulds are then removed after complete cooling. The pieces are put in blocks and kept cold indefinitely.
D. Microtomisation and gluing of sections on a slide: This is used to obtain sections with a thickness of 5 to 7µ and to place them on a transparent glass support.
   The procedure described by Darboux (1994) must be followed, which includes the following steps:
   - Squaring by removing the excess paraffin with a knife.
   - Mounting the block on its support; the block must remain parallel to the knife.
   - The roughing with the microtome allows for the elimination of the paraffin which is in front of the sample to obtain a complete cut of the tissue to be stained.
   - The actual cut is obtained by regularly passing the piece to be cut in front of the microtome's razor or knife.

- The sections are glued to a glass slide; each glass slide is engraved with the identification number of the block.
- The cut is made on a heating plate.
- The drop of gelatinous water deposited on the slide maintains the cut on the slide.

E. Drying of the slides: This is done in an oven at 60°C for 24 hours, the sections are then covered with a thin film of paraffin which allows them to breathe freely and is preserved indefinitely.

F. Staining: For staining the following method is used: Xylene (2 minutes); Xylene (2 minutes); Ethanol 100% (1 minute); Ethanol 100% (1 minute); Ethanol 95% (1 minute); Tap water (10 minutes); Haematoxylin (15 minutes); Tap water (wash); Alcohol acid : 3 to 5 dips; Tap water briefly; Ammoniacal water (ammonia waters): 3 to 5dips; Tap water (10 to 20 minutes); Eosin (15 seconds to 2 minutes); Ethanol 95% (2 minutes); Ethanol 100% (2 minutes); Xylene (2 minutes) (Tarek et al., 2018).

▪ *Statistical study of the outcomes*

In this section, we have only described the results obtained by expressing them in the most readable way.

3 Results and Discussions

3.1 Etiological section

Field survey

The results of our survey have been collected and sorted and presented in the following table:

Table 1
Cross-sectional survey in the north-east of Algeria from January 2021 to December 2023

Parameters		Prevalence	OR	*p*
Species	Cattle	15	1.9	NS
	Goats	80	8.8	***
	Sheep	5	3.4	*
Age	Between 0d et 4d	80	4	***
	Between 4d et 15d	15	2.3	**
	Between 15d et 30d	5	0.5	NS
Sex	Female	64	0.05	NS
	Male	36	0.01	NS
Type of breeding	Intensif	80	3.2	**
	Extensif	20	2.4	*
Co-infection	Yes	60	3.8	*
Infestation	Yes	30	2.2	***
Mortality	Yes	90	3.5	*
	No	10	0.32	***
Morbidity	Yes	94	3.9	***
	No	6	1.1	NS
Mortalitywithbacterial infection	Yes	82	4.4	***
	No	18	0.9	*
Heat synchronization	Yes	90	6.1	***

Source of drinking water	Municipal	83	8.3	***
	Water well	9	4.1	**
	Boreholes	9	0.1	*
Allotment practice	Yes	90	3.9	***
	No	10	0.2	NS
Artificialinsemination	Yes	86	2.1	**
	No	14	1.3	NS
Pasture/concentrated feed practice	Yes	65	6.5	***
Pasture/hay practice	Yes	20	0.01	NS
Disinfection of premises	Yes	15	5.9	*
Hay/feed/concentrate practice	Yes	98	4.1	***
Premiseswall	Cement /Brick	75	3.9	***
	Wood/Steel	25	2.3	*
Colostrum distribution	Bottle-fed	72	3.8	***
	Withbucket	28	0.01	NS
Ventilation	Roof ridge	87	4	***
	Static	23	1.1	*
*** $p < 0,001$, ** $p < 0,01$, * $p < 0,05$, NS : $p > 0,05$				

The statistical analysis gives us a statistically significant description of the pathogenic and etiological profile of cryptosporidium in ruminants, which can be described as follows (Table 1): All ruminants can be affected, especially goats, females are more commonly at risk, animals less than four days old, not dewormed, do not have synchronised heat. In terms of breeding practices, we have noted a municipal drinking water source, the practice of allotment, the practice of grazing, concentrated feeding and bottle-feeding of newborns with no distribution of colostrum, Building walls made of cement and brick and the ventilation at the ridge of the roof is the most remarkable feature.

Reported mortalities are the result of bacterial infection.
For this first model, the risk factors identified were the species, the distribution of municipal water to the animals, the absence of pasture management, the nature of the fodder distributed to the animals, the nature of the walls and the type of ventilation on the farms. Ruminant rearing practices seem to have little impact on the epidemiology of cryptosporidiosis, so the parasite is probably transmitted from the very first hours of life from soiled materials present in the goat house (litter, udder, rearing equipment, etc.). Most of the variables selected in the pre-models concerned rearing practices, goat feed and environmental conditions in the goat house. Variables characterizing the disinfection of premises were poorly represented.

After accounting for confounding factors using logistic regression, the variables significantly associated with the presence of C. parvum in young animals were the type of goat feed and the ventilation of the goat house. The risk increased significantly in the presence of chimney ventilation (ridge ventilation) and decreased in the case of pasture-fed goats fed leguminous hay. A late survey (February/March), a municipal water supply, the feeding of grass hay and the presence of hard walls (cement, stone or brick) in the goat house also seemed to have an impact.

The variables significantly associated with high C. parvum contamination were the survey period, the type of goat feed and the goat house environment (Table 1). The risk increased at the end of the winter season (February/March), in the presence of grass hay, ventilation of the goat house by chimney effect, and with the surface area available per goat.

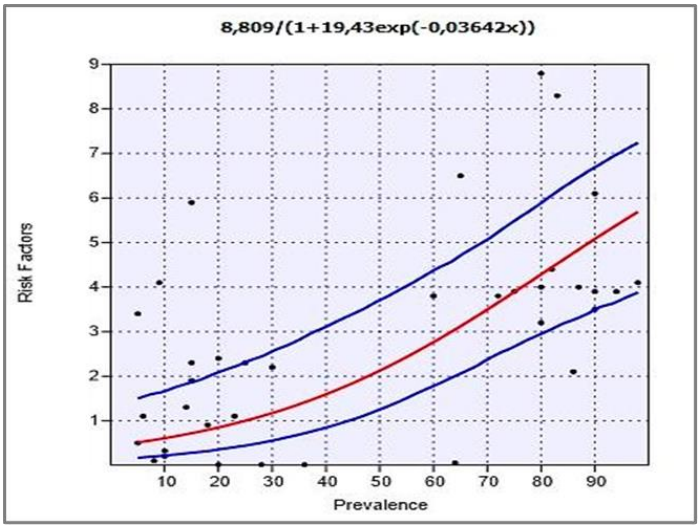
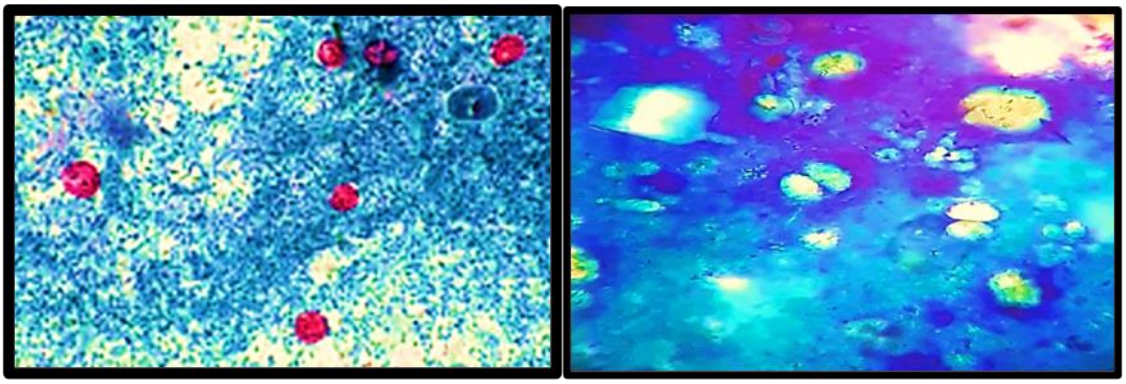


Figure 1. Ordinary logistic regressions model for risk factors and epidemiological survey

Risk factors were studied using ordinary logistic regression with variables of interest. The selection criterion used was a top-down procedure aimed at minimizing the Akaike Information Criterion (AIC); fitting and representation were performed with Past 3 software. Candidate explanatory variables were selected from the epidemiological survey summary table when the statistical relationship with the variables of interest showed a significance level of p 0.001 or an Odds Ratio (OR) greater than 3. Final model selection was performed using ordinary logistic regressions. (Figure 1)

3.2 Diagnostic part

Microbiological investigation
Modified Ziehl-Neelsen technique



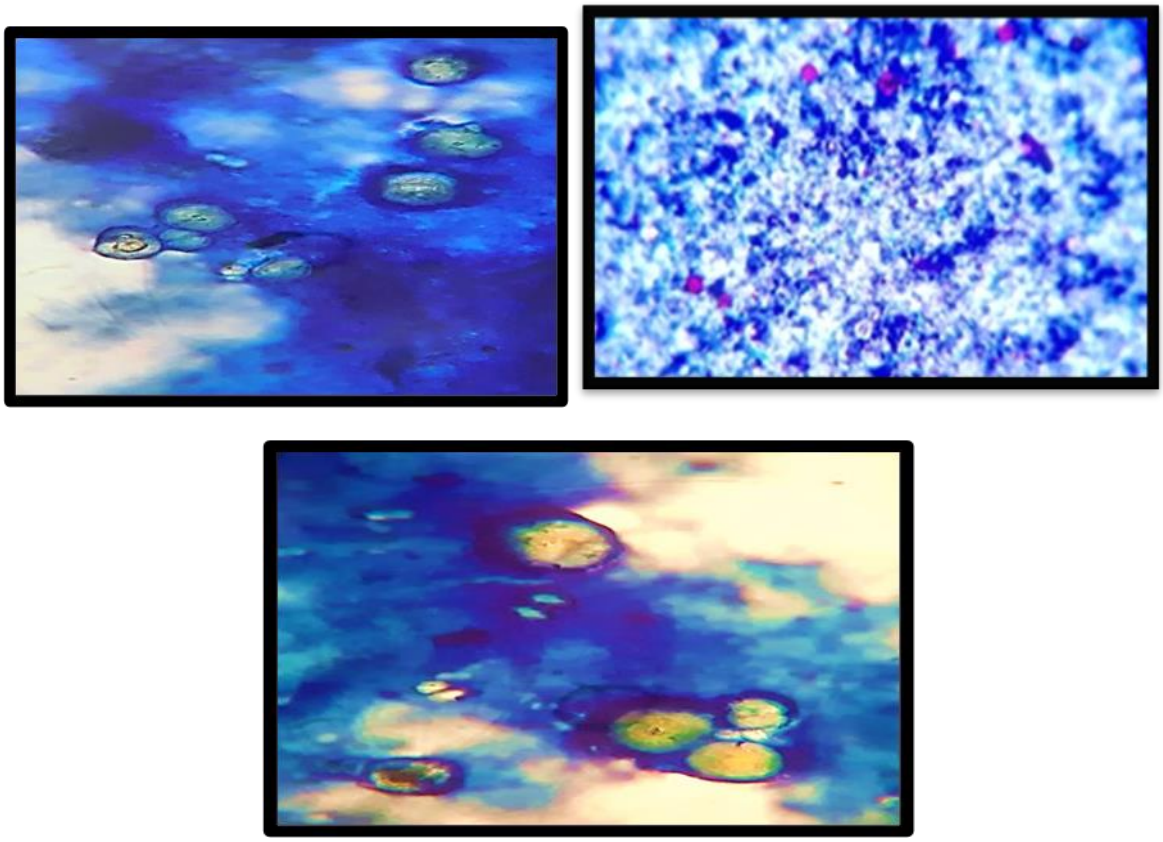


Figure 2. Oocystes of Cryptosporidium spp

Oocytes of cryptosporidia appear red on a blue background (Fig. 2). They are 5 to 6 micrometers in diameter, contain black granules, and often contain a vacuole that appears as a lighter area. When oocysts contain sporozoites, they do not have a visible vacuole, are fainter in color and therefore less easily detected, hence the need to read using a 40° objective.

When the stool is preconcentrated using the ether technique, oocysts are often found in the vicinity of the deposits on the slide. This technique can also be used to diagnose Cyclospora sp and Isospora belli oocysts. The differential diagnosis is primarily pigment spots (irregular in size and shape), some phytobacteria, and cyclospore oocysts; They were initially thought to be atypical forms of Cryptosporidium pallidum; The latter is 8 to 10 micrometers in diameter, and the dye is taken up inconsistently on the same slide. It should be noted that the Ziehl-Neelsen technique used to detect alcoholic acid-resistant bacillus, which involves hot staining with phenolfuchsin, does not detect cryptosporidium oocysts.

Table 2
Microbiological diagnosis of Cryptosporidium

		Cattle								Goat														Sheep								
		C 1		C 2		C 3		C 4		G 5		G 6		G 7		G 8		G 9		G 10		G 11		S 12		S 13		S 14		S 15		
		A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	Σ
Less than 15 Days	**M**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**1**	**1**	**2**	**0**	**0**	**0**	**1**	**2**	**1**	**2**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**2**	**0**	**1**	**1**	**1**	**21**
	T	0	1	2	2	1	1	2	2	2	1	2	0	0	1	2	2	1	1	2	2	2	1	2	0	1	0	2	1	1	1	**38**
15 to 60 Days	**M**	0	0	1	1	2	1	1	2	1	3	2	3	0	1	0	3	2	2	0	1	0	2	2	0	1	0	3	2	2	2	**40**
	T	1	1	2	2	1	2	1	3	2	3	0	1	0	3	2	2	2	2	0	1	0	2	2	0	1	0	3	2	2	2	**45**
More than 60 days	**M**	0	0	1	2	2	3	2	3	2	1	2	1	0	2	0	2	2	3	1	2	0	3	2	1	0	1	0	2	3	1	**43**
	T	2	2	0	1	0	2	2	3	1	0	3	2	2	2	2	2	2	2	0	1	0	2	2	0	1	0	3	2	2	2	**45**
Σ		**3**	**4**	**6**	**9**	**8**	**9**	**8**	**14**	**9**	**10**	**9**	**7**	**2**	**9**	**8**	**12**	**11**	**10**	**4**	**8**	**2**	**10**	**10**	**1**	**5**	**3**	**11**	**10**	**11**	**10**	**187**
F		**7.625**								**7,930**														**7,625**								**6,24**

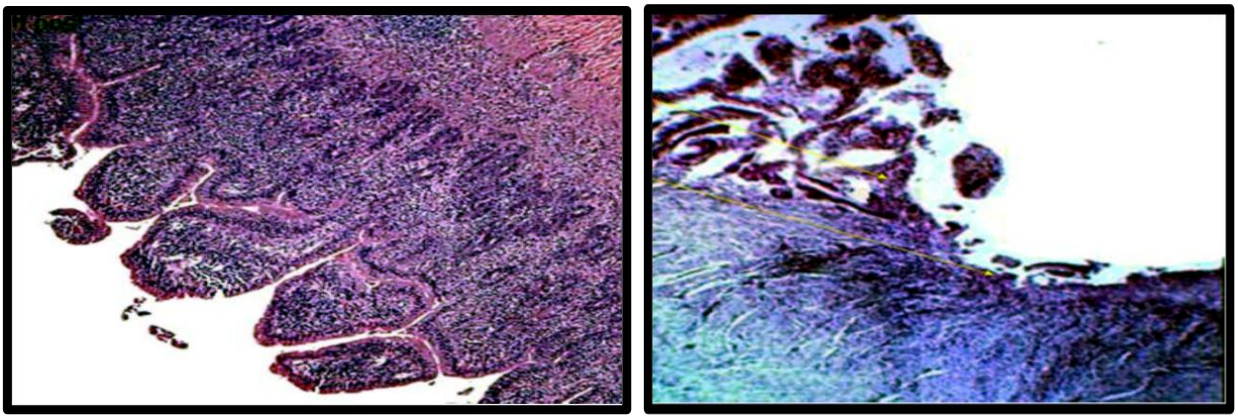
0: absence of oocysts; 1: less than 1 oocyst per field; 2: 2–10 oocysts; 3: 11–20 oocysts; 4: 21–30 oocysts; 5: more than 30 oocysts.
M: Mostaghanem, T: El Taref, F: absolute frequency, A: Autumn, S: Spring.

The prevalence (***F***) calculated for each species is as follows, $\boldsymbol{F_{cattle}}$ = 7.625, $\boldsymbol{F_{goats}}$ = 7.930 and $\boldsymbol{F_{sheep}}$ = 7.625.

The results of microbiological diagnosis of Cryptosporidium in ruminants show the risk associated with this pathology. Firstly, there is a predominance of Cryptosporidium oocytes in animals aged less than 60 days compared with the others, and the weaning of goats (Fgoats = 7.930) compared with cattle and sheep is the

same (F = 7.625). Also, the summer period (hot) is characterized by the dominance of oocytes which is explained by several arguments the most likely being the high consumption of water by animals. On the other hand, the two regions of El Taref and Mostaghanem are different in terms of the distribution of pathologies, especially in cattle, which can be explained by the intensive breeding of cattle in El Taref and the existence of goat breeding in Mostaghanem.

Histopathologiques des organs



(a) **(b)**

Figure 3. Oocystes of Cryptosporidium spp.

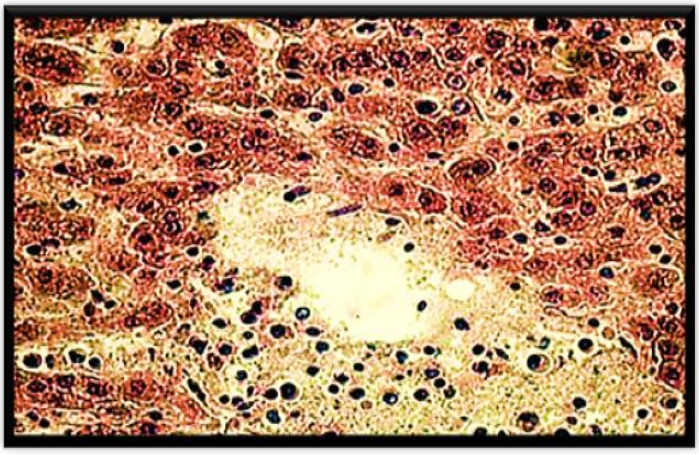


Figure 4. Oocystes of Cryptosporidium spp.

Microscopic examination of histopathological sections revealed at first sight, that the parasites protrude into the intestinal lumen and appear to cling to the apex of the enterocytes (Fig. 3a) with a change in intestinal tissue caused by parasite development, mainly villous atrophy, disappearance of microvilli, hypertrophy of glandular crypts, necrosis and infiltration of the lamina propria by inflammatory cells. The cell populations mobilised are made up of monocytes and macrophages, lymphocytes and eosinophilic granulocytes, and some macrophages flow into the intestinal lumen. Hyperplasia of the crypts or Liberkuhun gland is associated with villous atrophy. (Fig. 3b).

Biopsy sections of the parasitized intestinal mucosa show an inflammatory mucosa; the villous cells are undermined by atrophy or fusion, and appear more elongated; an inversion of intestinal cells by sporozoites has been observed; Cryptosporidium zoites have rhoptries, micronemes and dense granules. (Fig. 4)

The histopathological examination was performed on cadaver samples from goats belonging to breeders who had already been warned to inform us as soon as possible after the animal's death. They were also

warned that there was no point in informing us after a few hours of death, to avoid the passage of microorganisms from the intestinal contents to the various tissues and consequently their decomposition and the putrefaction of the cadaver, which would alter our results. The choice of the intestinal segment to be sampled, i.e. the ileum, is based on previous studies. Some authors recommend sampling the terminal portion of the jejunum and the ileum, which present the most severe lesions. Others state that in the large intestine, cryptosporidia are not observed either on the surface epithelium or in the cryptic epithelium and that the large intestine is not severely affected.

Discussion

Cryptosporidiosis infects a very large number of animal species, both domestic and wild. Among domestic ruminants, which are of interest because of the economic losses caused by the disease, goats are the most susceptible, followed by cattle and sheep (De Graaf et al., 1999; Mosier & Oberst, 2000; Ryan et al., 2014). The most important source of parasites is young goats that are already sick. They are capable of shedding around a billion oocysts during the patent period. This has been demonstrated in lambs (Robertson et al., 2014; Abbott, 2018).

Previous studies predict that calves can excrete up to millions of oocysts during a primary infection and the maximal excretion levels occur on the sixth day of life, a further source is non-symptomatic shedding adults. Other studies have shown that ewes shed oocysts during the post-natal period (Van Metre et al., 2008; Erling, 2022).

The viability and infectivity of oocysts should be measured to assess their resistance under natural or experimental conditions, and thus validate or invalidate disinfection studies. Cryptosporidium parvum oocysts are highly resistant in the external environment, whether in water, soil or faeces (Reinoso et al., 2008; Rousseau et al., 2018). They can remain infectious for a long time without being able to multiply. Their survival in different substrates explains the difficulty of treating and disinfecting them (Lefebvre et al., 2021; Silva & Sabogal-Paz, 2021). Generally in the case of ruminants, differences in the prevalence of the disease between suckler breeds and dairy breeds are thought to be due to differences in the way the latter are reared, with suckler breeds being reared extensively and therefore being less susceptible to the parasite (Lefay et al., 2000; Kaupke & Rzeżutka, 2022).

Similarly, in small ruminants, the prevalence of cryptosporidiosis varies according to the age of the animals and is higher in young animals than in adults (De Graaf et al., 1999; Robertson et al., 2014). In young ruminants, colostrum intake in the first few hours of life enables immunoglobulins to be transferred from the mother to the newborn, protecting it from some infections. A shortfall in the quantity and quality of colostrum is therefore often associated with outbreaks of cryptosporidiosis on farms (Kirikci & Cam, 2020). The seasonal effect observed could be due to the grouping together of animals during these periods, resulting in greater environmental contamination. Thus, overall, the incidence of cryptosporidiosis is at its maximum at breeding time (Bamaiyi & Redhuan, 2016).

A study carried out on goats has revealed a risk factor linked to the peak of the farrowing season. If the kidding season takes place in winter, there is a difference between animals born before February and those born after, which are more likely to be infected. This is attributed to the accumulation of oocysts in the environment as the farrowing season progresses (Maddox-Hyttel et al., 2006; Brook et al., 2008). It may also be the result of the farmer being less vigilant in caring for the young animals after the peak of the births: tiredness, fatigue or the quota of replacement young animals being reached (Chalmers & Katzer, 2013). In the same way and with the same conclusions, lambs born during the 2nd period of the farrowing season have an increased risk of becoming infected (Causapé et al., 2002). Other studies have estimated the prevalence of cryptosporidiosis to be more than 50% on goat farms. In goats, the prevalence can reach 100% at the end of the farrowing period (O'Handley & Olson, 2006).

In sheep farming, the prevalence of cryptosporidiosis is highest in animals less than three weeks old (Ulutaş & Voyvoda, 2004). The occurrence of epizootics such as cryptosporidiosis in these populations has serious repercussions, given the high numbers of animals in the nurseries at the peak of the farrowing season (Nichols, 1992). The introduction of prophylaxis for dams against neonatal diarrhoea is associated with an increase in the prevalence of parasite excretion. This could be because such prophylaxis is often implemented

on farms with a high incidence of diarrhoea in sheep, however, these prophylactic measures prove ineffective against cases of cryptosporidiosis.

Among livestock on concrete floors, the prevalence of oocyst excretion is lower. This is because concrete floors are easier to clean regularly than sand, earth or gravel floors. Similarly, the use of soap or detergent to clean feeding utensils is associated with a reduced risk of oocyst excretion (Barrington et al., 2002; Panousis et al., 2008; Thomson et al., 2017). In ruminants, Cryptosporidium parvum mainly affects the distal jejunum and ileum, although lesions have been found in the caecum, colon and, more rarely, the duodenum (Peek et al., 2018).

Invasion of the mucosa leads to moderate to severe atrophy of the villi associated with a reduction in the total surface area of the intestinal mucosa. This is due to the destruction of mature enterocytes, atrophy of the microvilli and an increase in intestinal permeability (Tzipori, 1983; Gookin et al., 2018). As previously mentioned, in small ruminants, infection occurs in animals between 5 and 20 days old, the cryptosporidiosis mainly affects young, unweaned animals. In adults, infection is generally asymptomatic (Kusiluka & Kambarage, 1996; Chalmers & Giles, 2010).

Affected animals present with soft to liquid, yellowish diarrhoea, associated with high excretion of oocysts, apathy, abdominal pain and anorexia, leading to weight loss and stunted growth. The diarrhoea lasts for 3 to 5 days, and can even last two weeks in more severe cases. Oocyst excretion peaks 5 to 6 days post-inoculation and then declines rapidly between 10 and 15 days (Zeleke et al., 2017; Kalkanov et al., 2019). The quantity of oocysts excreted correlates with the severity of diarrhoea in young animals, but not in lambs (Bartley et al., 2023).

On the other hand, Some studies showed that the probability of observing diarrhoea was higher in lambs excreting oocysts than in those not excreting oocysts (Saratsis et al., 2011). In young animals, morbidity can reach 80 to 100% and mortality can exceed 50%. There is no transition to chronicity: sick young animals either recover spontaneously or succumb (Santín, 2013; Tomazic al., 2018). In small ruminants, the contents of the intestine appear more or less liquid and distension of the caecum and colon may be observed (Fayer & Ungar, 1986).

The distal third of the ileum is congested and haemorrhagic, and the mesenteric lymph nodes are enlarged; the macroscopic lesions described in cryptosporidiosis are not pathognomonic (Sherding & Johnson, 2006; Kalkanov et al., 2019). Gaseous or liquid distension of the intestines is observed, associated with congestion of the mucosa, enteritis and colitis in some cases (Ananthakrishnan & Xavier, 2020). Histologically, the main lesions are moderate to severe atrophy of the villi, hyperplasia of the crypts and focal areas of necrosis, the lamina propria is infiltrated by mononuclear cells and neutrophilic granulocytes (Nichols, 1992; Foster, 2012; Pal & Chetty, 2020).

However, the parasite is sometimes found in unusual locations, such as the digestive tract and its associated lands, as well as the uterus, respiratory tract, heart and conjunctiva (Fayer, 2007; McDougald et al., 2020). Our observations are in agreement with those reported by Bourgouin (1996) and Baroudi et al. (2011), in their work on calves where noted atrophied, abraded and fused intestinal villi. Hyperplasia of the crypts or Liberkuhun gland associated with villous atrophy was reported by Naciri & Yvore (1989) in their work on lambs. Cellular infiltration within the chorion of the villi is represented particularly by macrophages and lymphocytes and to a lesser extent eosinophilic and neutrophilic granulocytes (Khelef et al., 2002).

4 Conclusion

Cryptosporidiosis is a disease caused by a protozoan parasite of the genus Cryptosporidium, which affects a large number of animal species, including humans. It is generally responsible for gastroenteritis, which can be fatal in immunologically immature or immunosuppressed individuals. Once considered an opportunistic infection, Cryptosporidium is now considered a major pathogen in livestock farming due to its incidence, economic importance and zoonotic potential. The severity of the disease depends on the individual's immune status. It affects young animals at the end of the first week of life, mainly through diarrhoea, which can rapidly affect all the young. Associated mortality can be very high in some farms (>80%). This parasite multiplies in the intestine. During diarrhoea, a sick animal emits eggs called oocysts, which are highly resistant to the external environment. Oocysts can survive for several years in bedding and on equipment. Young animals

with diarrhoea excrete large quantities of oocysts, which are immediately pathogenic for other animals in the group. Young animals are probably contaminated during the first few hours or days of life. This is why particular care must be taken with hygiene around this period. Economic losses can be direct, due to the high mortality rate that can occur on some farms, but can also be indirect, due to the costs incurred (feed, medication, stunted growth, etc.). The disinfection measures cited in the literature are difficult to apply. Sanitary prophylaxis seems to be the best solution for limiting contamination and the spread of the disease.

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