Study of fecal elimination parasites and associated risk factors in sheep

Estudo de parasitas de eliminação fecal e fatores de risco associados em ovinos

Estudio de parásitos de eliminación fecal y factores de riesgo asociados en ovinos

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ABSTRACT
This study aimed to investigate some fecal elimination parasites and the effect of certain risk factors on parasitism rate in sheep from the Laghouat region in Southern Algeria. Coproscopy using various qualitative methods (direct examination, flotation and sedimentation, Zeihel Nelson staining) and quantitative methods (Mac Master) were conducted over a period of 4 months, on a total of 170 sheep. The results revealed an overall infestation rate of 82.9%. This study identified the presence of the following parasites: Cryptosporidium sp. (57.1%), Eimeria sp. (52.9%); Nematodirus sp. (24.7%), Strongyloides sp. (17%), Cooperia sp. (1.2%); and finally, Teladorsagia sp., Trichostrongylus sp., Fasciola hepatica, Dircocoelium lanceolatum, and Paramphistomum sp. at 0.6%. Statistical analysis revealed no significant influence of the factors studied on the parasitic infestation rate of the examined sheep. Regarding the Mac Master, the highest parasite load was observed for Eimeria sp. with a rate of 1153 OPG (Egg per gram of fecal matter).

Keywords: sheep, infestation rate, risk factors, Mac Master, Laghouat.
1 INTRODUCTION

In Algeria, sheep breeding occupies by its numerical and socio-economic importance, a crucial place in breeding systems. It is concentrated mainly in the steppe and constitutes an important animal resource for the country (Bennadji et al., 2023; Taherti et al., 2023). The primary purpose of the steppes is extensive sheep and goat farming, supplemented by nomadic cereal cultivation (Saidi et al., 2009; Benattia et al., 2024).

Sheep farming is sensitive to numerous problems, including climatic, health, and economic issues that hinder lamb production. Among diseases, parasitism is the most significant agent due to the use of pastures infested by free forms of parasites evolving during favorable climatic periods. These parasites are responsible for considerable decreases affecting milk and meat production and can cause mortality in sheep and goat farms (Chartier and Hoste, 1994). Furthermore, they also have a great impact on public health. Therefore, controlling this type of parasitism is currently considered an essential element of herd health management (Benlarbi et al., 2023).

In Algeria, the internal parasites of domestic ruminants identified macroscopically are mainly shared among nematodes (22 genera), cestodes (9 genera), and trematodes (3 genera) (Saidi et al., 2009), although, there is a lack of deep studies regarding parasitic infestations in ruminants, which can lead to significant economic consequences. In this context, the objective of our work is based on the search for some fecal elimination parasites in the sheep population of the Laghouat region. This is aimed at assessing their prevalences and studying the risk factors associated with the parasitic infestation.

2 MATERIALS AND METHODS

Study area

Our study was conducted in five sites located within the territory of the Laghouat region. This zone is situated 400 km South of the capital city, Algiers, covering a total area of 27,561.6 km². It is bordered to the North by Tiaret, to the East by Djelfa, to the South by Ghardaïa, and to the West by El Bayadh. The Laghouat province is a steppe zone predominantly used for sheep, goat, cattle, and camel farming. It experiences a semi-arid climate. The collection of samples was carried out over a period of 4 months from January to April 2017 in the Laghouat region.

Climatic Factors

Climate plays a fundamental role in the distribution and life of living beings, depending on numerous factors such as temperature, precipitation, humidity, and wind.
Resulting from the relief, the climate exhibits precipitation ranging from 300 to 400 mm, with snowfall and white frosts. In the high plateau region, the climate is of Saharan and arid type. Precipitation varies between 150 mm in the center and 50 mm in the south. Winters are characterized by white frosts, and summers by intense heat accompanied by sandstorms.

The average temperature of the coldest month in the Laghouat region is 8.4°C in January, while the hottest month is July with an average temperature of 32.19°C. For the Laghouat region, the rainiest month is October and the driest is July, with an annual average of 140,091 mm. Humidity varies from month to month; the wettest month is December with a humidity of 65.4, and the least humid is July with a humidity of 27.4.

In Laghouat, soil is characterized by three types of soils (texture): sandy-clayey, silty-sandy, and silty-clayey (Marouani, 2011).

**Presentation of Study Sites**

Our work was carried out in five communes of Laghouat: El Assafia (1), El Kheneg (2), Laghouat (Ksar Faroug) (3), Sidi Makhlouf (4), Tadjemout (5).

The selection of these sites was related to the availability of breeders, the number of individuals within the sheep flocks, and our ability to travel.

Sample analysis was conducted at the parasitology laboratory of the Department of Biology at "Amar Teledji" University in Laghouat.

**Characteristics of Examined Animals**

To conduct our study, we visited 17 sheep farms located in five communes in the Laghouat region.

A total of 170 sheep were included in this investigation aimed at researching fecal elimination parasites in the Laghouat region.

Among the sheep studied, 127 were females and 43 were males; 107 were classified as adults (> one year) and 63 as young (≤ one year). The characteristics of these animals are presented in the following table.
Table 1: Characteristics of the sheep collected.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Variables</th>
<th>El Assafia</th>
<th>El Kheneg</th>
<th>Laghouat</th>
<th>Sidi makhlouf</th>
<th>Tadjemout</th>
<th>Total Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Female</td>
<td>5</td>
<td>42</td>
<td>14</td>
<td>47</td>
<td>19</td>
<td>127</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>2</td>
<td>23</td>
<td>0</td>
<td>14</td>
<td>4</td>
<td>43</td>
<td>25</td>
</tr>
<tr>
<td>Breed</td>
<td>Local</td>
<td>0</td>
<td>65</td>
<td>14</td>
<td>61</td>
<td>10</td>
<td>150</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Exotic</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>Age</td>
<td>Adult</td>
<td>5</td>
<td>35</td>
<td>13</td>
<td>40</td>
<td>15</td>
<td>107</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Young</td>
<td>2</td>
<td>30</td>
<td>1</td>
<td>21</td>
<td>8</td>
<td>63</td>
<td>37</td>
</tr>
<tr>
<td>Clinical health</td>
<td>Healthy</td>
<td>6</td>
<td>59</td>
<td>14</td>
<td>54</td>
<td>21</td>
<td>154</td>
<td>91</td>
</tr>
<tr>
<td>State</td>
<td>Sick</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>16</td>
<td>9</td>
</tr>
</tbody>
</table>

Information Sheet

From the selected sites, we randomly chose several sheep farms to conduct our sampling. To obtain a clear picture regarding the characteristics of the visited farms, we filled out a technical sheet for each breeder.

Simultaneously, a clinical examination was conducted for each sampled animal, noting all relevant information, including the breed, sex, and age of the animal in the information sheets.

Methods

General examination of animals

After restraining the animal, we carried out a general examination: Observation of the color of the mucous membranes; Taking temperature; Check for the presence or absence of skin lesions or other abnormalities.

Technique for collecting and storing samples

Feces

The experiments required a certain quantity of feces for each animal (3 g) for each coproscopic diagnostic technique, therefore a minimum of 6 g. The feces were collected directly from the rectum by stimulating the anal orifice of sheep using gloves or immediately after their emission to avoid contamination in the external environment by free nematodes, which may be present in tail soiling. Fecal samples were collected in tightly sealed sterile pots and labeled (Figure 9). The samples were then kept cool in a cooler and transported to the laboratory, where they were either stored in the refrigerator at (+4°C) or directly examined. The identification keys of Dang and Beugnet (2000) were used for the research for endoparasites.
Macroscopic examination of feces

The first step was the macroscopic examination which consists of observing the feces with the naked eye, noting the colour, the appearance of stools, presence of blood, pus or mucus and the presence of adult forms of certain parasites (Ascaris, Pinworm, Taenia rings).

Microscopic examination of stools

The second step was microscopic analysis. It included qualitative and quantitative methods:

Qualitative Methods

Direct Examination

This method is very simple to use and very quick as it requires very little manipulation. However, it is rarely used because it has two major drawbacks: the small volume of the sample examined and the abundance of food debris, both of which limit the sensitivity of the technique (Dang and Beugnet, 2000).

Flotation Techniques (Willis 1921) (The Dense Solution)

The principle of this method is to dilute the sample in a solution of high density (the flotation liquid) in order to concentrate the parasitic elements of lower density at the surface of the liquid (Dang and Beugnet, 2000).

Sedimentation Technique (low density solution)

For stools rich in fat, it is possible to use the so-called Telemann-Rivas sedimentation method. Its principle is to dilute the sample in a solvent of reduced density in order to concentrate the parasitic elements (Giardia cysts), of higher density, in the base of the test tube (Zajac and Conboy, 1992).

Modified Ziehl-Neelsen Staining

This staining allows for the visualization of Cryptosporidium oocysts in bright red or pink, containing four sporozoites arranged around a rounded residual body. It is essential for highlighting Cryptosporidium oocysts (Henriksen and Pohlenz, 1981).

Quantitative Mac Master Method

It is a quantitative technique based on the principle of flotation. It involves counting the number of parasitic elements contained in 0.5 ml of a suspension of fecal matter diluted to 1/15 and requires the use of a Mac Master slide (Dang and Beugnet, 2000).
Each cell has a known volume of 0.15 ml, so, since the solution is diluted by a fifteenth, the number of eggs counted is that contained in one hundredth of a gram of feces. To obtain the number of eggs per gram, multiply the result obtained during counting in one compartment by a factor of 100. It is recommended to count both compartments, so the multiplication factor will be 50. Conclusion: EPG = number of eggs in both compartments x 50.

**Prevalence**

It is the percentage ratio $P(\%)$ of the number of hosts infested by a given species of parasite $HP$ on the total number of hosts examined $HE$. $P(\%) = \frac{HP}{HE} \times 100$

In this study, we calculated the prevalence of sheep parasitism for each parasite type.

**Statistical analysis**

The statistical analysis was carried out using the SPSS version 20 software. Chi-square test was used to compare between the data. The difference was considered significant at 5% risk of error.

**3 RESULTS**

**Endoparasites**

**Microscopic observation**

Parasitological examination of stools revealed 10 species of parasites.

Two intestinal coccidia: *Eimeria sp.* and *Cryptosporidium sp.*, and five types of Nematodes namely: *Cooperia sp.*, *Nematodirus sp.*, *Strongyloides sp.*, *Teladorsagia sp. Trichostrongylus sp.*, and three types of Trematodes: *Fasciola hepatica.*, *Dicrocoelium lanceolatum.*, *Paramphistomum sp.* (Figure 1).
Figure 1. Endoparasites observed in sheep under an optical microscope.

A: *Eimeria sp.* (Not sporulated). Oocysts ovoid, round embryo with finely granular contents with cytoplasm appearing slightly pink, shell smooth, thin and colorless (GX400).

B: Oocysts of *Cryptosporidium sp.* Les oocystes sont colorés en rose sur un fond vert, Ovoïde à sphéroïde. The oocysts are colored pink on a green background, ovoid to spheroid (GX1000).

C: Egg of *Strongyloides sp.* Ovaless, contiennent une larve pleinement développée. Oval, contain a fully developed larva (GX400).

D: Egg of *Nematodirus sp.* Ovoïde, à coque mince et lisse renfermant une morula à nombreuses petites cellules. Ovoid, with a thin, smooth shell containing a morula with numerous small cells (GX400).

E: *Teladorsagia sp.* Ovaless, with a thin, smooth shell containing a morula with numerous small cells (GX400).

F: *Trichostrongylus sp.* Medium sized egg. Unequal poles but not very wide, one of the poles more rounded than the other. Thin wall, multicellular embryo (GX400).

G: *Cooperia sp.* Ovaless, with a thin, smooth shell containing a morula with numerous small cells (GX400).

H: *Fasciola hepatica.* Medium sized egg. Unequal poles but not very wide, one of the poles more rounded than the other. Thin walled, multicellular embryo pale brown in color (GX400).

I: *Dicrocoelium lanceolatum.* Trematode egg, small, brownish, capped, very lightly, symmetrical (GX400).

J: *Paramphistomum sp.* Ovoid trematode egg, without polar spine, with unequal poles, non-uniform distribution (GX400).
The Mac Master Results

Fecal egg shedding is measured as the number of parasite eggs per gram of feces (OPG). For this, we utilized the Mac Master quantitative method. The results obtained revealed the presence of eggs of *Eimeria* sp., *Nematodirus* sp., *Strongyloides* sp., and *Fasciola hepatica*. Individual OPG values of *Eimeria* sp. in sheep ranged from 50 to 16,000, for strongyles the figures ranged from 50 to 850, and for *Nematodirus* sp. from 50 to 100. The number of *Fasciola hepatica* eggs was 50 (Table 2, 3).

<table>
<thead>
<tr>
<th>The species</th>
<th>Low</th>
<th>Average</th>
<th>Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eimeria</em> sp.</td>
<td>100-1000 OPG</td>
<td>1000-5000 OPG</td>
<td>&gt; 5000</td>
</tr>
<tr>
<td><em>Fasciola</em> sp.</td>
<td>The presence alone is important and deserves attention.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Nematodirus</em> sp.</td>
<td>&lt; 50</td>
<td>50-100</td>
<td>&gt; 100</td>
</tr>
<tr>
<td><em>Strongyloides</em> sp.</td>
<td>&lt; 300</td>
<td>300-1000</td>
<td>&gt; 1000</td>
</tr>
</tbody>
</table>

OPG: Egg per gram of fecal matter (Duquesnel, 2016).

<table>
<thead>
<tr>
<th>Parasite</th>
<th>Result</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eimeria</em> sp.</td>
<td>Not infested</td>
<td>82</td>
<td>48.2</td>
</tr>
<tr>
<td></td>
<td>Low infestation</td>
<td>75</td>
<td>44.1</td>
</tr>
<tr>
<td></td>
<td>Medium infestation</td>
<td>13</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>170</td>
<td>100</td>
</tr>
<tr>
<td><em>Fasciola</em> sp.</td>
<td>Not infested</td>
<td>169</td>
<td>99.6</td>
</tr>
<tr>
<td></td>
<td>Medium infestation</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>170</td>
<td>100</td>
</tr>
<tr>
<td><em>Nematodirus</em> sp.</td>
<td>Not infested</td>
<td>156</td>
<td>91.8</td>
</tr>
<tr>
<td></td>
<td>Low infestation</td>
<td>11</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Medium infestation</td>
<td>3</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>170</td>
<td>100</td>
</tr>
<tr>
<td><em>Strongyloides</em> sp.</td>
<td>Not infested</td>
<td>142</td>
<td>83.5</td>
</tr>
<tr>
<td></td>
<td>Low infestation</td>
<td>13</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Medium infestation</td>
<td>15</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>170</td>
<td>100.0</td>
</tr>
</tbody>
</table>

After identifying the classification and morphology of helminth eggs present in these samples, we counted them. Table 4 presents the quantitative results of the analyses conducted based on the parasitic species found.
Table 4: Results of the average number of eggs counted for the parasitic species found.

<table>
<thead>
<tr>
<th>Parasitic species</th>
<th>Average number of eggs found</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eimeria sp.</em></td>
<td>1153 eggs/g</td>
</tr>
<tr>
<td><em>Fasciola hepatica</em></td>
<td>50 eggs/g</td>
</tr>
<tr>
<td><em>Nematodirus sp.</em></td>
<td>68 eggs/g</td>
</tr>
<tr>
<td><em>Strongyloides sp.</em></td>
<td>150 eggs/g</td>
</tr>
</tbody>
</table>

The parasite load of *Eimeria sp.* was the most important than those of other species.

**Parasite index**

**Total prevalence of parasitism**

Among 170 samples examined, 141 were infested by endoparasites with a total prevalence of 82.9% (Figure 2).

**Endoparasites prevalence**

Out of 170 fecal samples examined, 141 were positive (82.9%). The highest prevalence was that of *Cryptosporidium sp.* (57.1%), followed by *Eimeria sp.* (52.9%); then by *Nematodirus sp.* (24.7%), *Strongyloides sp.* (17%), *Cooperia sp.* (1.2%); and finally, by *Trichostrongylus sp.*, *Fasciola hepatica*, *Teladorsagia sp.*, *Dicrocoelium lanceolatum* and *Paramphistomum sp.* with 0.6% each (Figure 3).
Percentage of parasite association

The following table reveals the notion of poly parasitism and mono parasitism.

Table 5: Number of parasites present in the same animal.

<table>
<thead>
<tr>
<th>Number of parasites encountered in the same animal</th>
<th>Infected sheep</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56</td>
<td>33%</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>27%</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>18%</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>5%</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>1%</td>
</tr>
<tr>
<td>Total</td>
<td>142</td>
<td>84%</td>
</tr>
</tbody>
</table>

Association of a parasite

Table 6 shows that the association of Cryptosporidium sp. in sheep was the most common with a rate of 19%.

Table 6: Number of associations of a parasitic genus in the sheep examined.

<table>
<thead>
<tr>
<th>Association of a parasite</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eimeria sp.</td>
<td>19</td>
<td>11%</td>
</tr>
<tr>
<td>Cryptosporidium sp.</td>
<td>32</td>
<td>19%</td>
</tr>
<tr>
<td>Nematodirus sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Strongyloides sp.</td>
<td>2</td>
<td>2%</td>
</tr>
</tbody>
</table>

Association of two parasites

Data show that the association of Cryptosporidium sp. + Eimeria sp. in sheep was the most common with a rate of 15%. Other associations were also be noted (Table 7).

Table 7: Number of associations of two parasitic genera in the sheep examined.

<table>
<thead>
<tr>
<th>Association of two parasites</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eimeria sp. + Nematodirus sp.</td>
<td>4</td>
<td>2%</td>
</tr>
<tr>
<td>Eimeria sp. + Strongyloides sp.</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>Eimeria sp. + Paramphistomum sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Cryptosporidium sp. + Eimeria sp.</td>
<td>27</td>
<td>15%</td>
</tr>
<tr>
<td>Cryptosporidium sp. + Nematodirus sp.</td>
<td>6</td>
<td>3%</td>
</tr>
<tr>
<td>Cryptosporidium sp. + Strongyloides sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Dicrocoelium lanceolatum + Strongyloides sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Nematodirus sp. + Strongyloides sp.</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>Nematodirus sp. + Teladorsagia sp.</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>

Association of three parasites

According to our results, the association of Eimeria sp., Cryptosporidium sp. and Nematodirus sp. in sheep was the most common with a rate of 6% (Table 8).
Table 8: Number of associations of three parasitic genera in the sheep examined.

<table>
<thead>
<tr>
<th>Association of three parasites</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Nematodirus</em> sp.</td>
<td>12</td>
<td>6%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Strongyloides</em> sp.</td>
<td>6</td>
<td>3%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Teladorsagia</em> sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Trichostrongylus</em> sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Nematodirus</em> sp. + <em>Cooperia</em> sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Nematodirus</em> sp. + <em>Strongyloides</em> sp.</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td><em>Cryptosporidium</em> sp. + <em>Nematodirus</em> sp. + <em>Strongyloides</em> sp.</td>
<td>6</td>
<td>3%</td>
</tr>
<tr>
<td><em>Cryptosporidium</em> sp. + <em>Teladorsagia</em> sp. + <em>Strongyloides</em> sp.</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>

Association of four parasites

Data show that the association of *Eimeria* sp., *Cryptosporidium* sp., *Nematodirus* sp. and *Strongyloides* sp. in sheep is the most common with a rate of 4% (Table 9).

Table 9: Number of associations of four parasitic genera in the sheep examined.

<table>
<thead>
<tr>
<th>Association of four parasites</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Nematodirus</em> sp. + <em>Cooperia</em> sp.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Nematodirus</em> sp. + <em>Strongyloides</em> sp.</td>
<td>7</td>
<td>4%</td>
</tr>
</tbody>
</table>

Association of five parasites

Table 10 shows that the two associations of five parasites in sheep had the same frequency with a rate of 1%.

Table 10: Number of associations of five parasitic genera in the sheep examined.

<table>
<thead>
<tr>
<th>Association of five parasites</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Nematodirus</em> sp. + <em>Teladorsagia</em> sp. + <em>Fasciola hepatica</em></td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td><em>Eimeria</em> sp. + <em>Cryptosporidium</em> sp. + <em>Nematodirus</em> sp. + <em>Cooperia</em> sp. + <em>Strongyloides</em> sp.</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>

Influence of Certain Risk Factors on Parasitism in Sheep

Parameters such as age, sex, breed, clinical status, and study site were subjected to statistical analysis to determine their real influence on the incidence of encountered parasitic infections.

Influence of Age

Parasite infestation among adults (85.7%) is higher than that found in young sheep (81.3%). However, statistical analysis showed that this difference was not significant (p = 0.54, > 0.05) (Figure 4).
Influence of Sex

Parasitic infection among females (83.5%) is higher than that among males (81.4%). However, the influence of sex on parasitism is statistically non-significant (p = 0.96, > 0.05) (Figure 5).

Parasitism Frequency Based on Clinical state

The relationship between parasite infestation and the clinical status of the examined individuals shows that sheep in good general condition are less parasitized (81.88%) than sick ones (90.48%). However, the difference is not statistically significant (P = 0.96, > 0.05) (Figure 6).
Influence of Sheep Breed

Parasite infestation among the local breed (85.3%) appears to be higher than that of the crossbred breed (65%). Statistical analysis revealed that the difference is not significant (P >0.05) (Figure 7).

Figure 7: Distribution of the parasitic infestation rate between the different sheep breeds.

Influence of Study Site

Parasitic infestation is more significant in the commune of Tadjemout and Sidi Makhlouf with prevalence rates of 87% and 86.9%, respectively, followed by the communes of Laghouat and El Kheneg (85.7% and 81.5%, respectively). The commune of El Assafia is less exposed to parasitism, with a prevalence rate of 42.9%. Following statistical analysis, no significant difference was noticed in parasitism among these different sites (P>0.03) (Figure 8).

Figure 8: Parasite infestation rate according to the study site.

Influence of Sheep Rectal Temperature

Parasite infestation in sheep with normal rectal temperature (82.6%) appears to be less than in sheep with low (hypothermia) (100%) and high (hyperthermia) temperatures (100%). However, statistical analysis revealed that the difference is not significant (P = 0.62) (Figure 9).
Total prevalence of parasitism by Mac Master method

Out of 170 fecal samples examined, 25 tested positive, resulting in a prevalence rate of 15%. The highest prevalence was observed for *Eimeria sp.*, followed by *Strongyloides sp.*, and then by *Nematodirus sp.* and *Fasciola hepatica*. Statistical analysis revealed that the difference is not significant (p = 0.65, > 0.05) (Figure 10).

4 DISCUSSION

Our study aimed to investigate the main fecal elimination parasites in sheep raised in the Laghouat region. The choice of the animal species is justified by its economic and social importance. Several methods were used to search for fecal elimination parasites in sheep. These methods are well-known and standardized: qualitative methods include direct examination for protozoa (Guillaume, 2007); flotation method (Urquhart et al., 1996); sedimentation method; and the quantitative Mac Master method, which was used for the first time in the Laghouat region, for
endoparasites such as nematodes, cestodes, and trematodes. For the detection of Cryptosporidium, we used the Ziehl-Neelsen staining method (Dang and Beugnet, 2000).

Data revealed that our samples were parasitized with at least one type of parasite. The prevalence of endoparasites was 82.9%. This value is higher than those recorded in Ain d'Hab by Saidi et al. (2009) (54%), in Iran by Naem and Gorgani (2011) (70%), and in Cameroon by Ntonifor et al. (2013) (73.1%). It is rather close to that found in Tiaret (78.9%) by Boulkaboul and Moulaye (2006). Recording 10 types of parasites among the 170 examined sheep, the parasites found were: Cryptosporidium sp. (57.1%), followed by Eimeria sp. (52.9%); then by Nematodirus sp. (24.7%), Strongyloides sp. (17%), Cooperia sp. (1.2%); and finally, by Teladorsagia sp, Trichostrongylus sp, Fasciola hepatica, Dircocoelium lanceolatum and Paramphistomum sp with 0.6%.

The rate of infestation by Cryptosporidium sp. is higher compared to other genera. Cryptosporidia are presented with a total prevalence of 60%. This rate is significantly greater than that found in Algiers (Baroudi et al., 2011) (46.44%) and in Iran (Gharekhani et al., 2013) (11.3%). However, it is lower than that recorded in the United States (77.4%) (Santin et al., 2007). Often, the initiation of the infection is due to colibacillus infection in the 1st week, which complicates into cryptosporidiosis in the 2nd week. Once present in a few animals, infestation quickly becomes widespread (Chartier and Hoste, 1994). Cryptosporidium oocysts are directly infective with a high capacity for resistance in the environment. Moreover, the oocysts of these coccidia are known for their extremely frequent self-infection capability, which justifies this rate.

Our results regarding Eimeria sp. (32%) are close to those recorded in Togo (31%) (Bastiaensen et al., 2003), in Laghouat (30%) (Dib and Ben Aissa, 2015), and in Cameroon (28.8%) (Ntonifor et al., 2013). Controversially, the prevalence recorded by Cavalcante et al. (2012) in Brazil is higher (91.2%). Similarly, Ramisz et al. (2012) in Ukraine and Poland reported a rate of 74%. Other studies have noticed lower rates; of 10% in Iran (Yakhchali and Golami, 2008), and of 11.7% in Ethiopia (Ibrahim et al., 2014). On the other hand, an investigation in Tiaret (Boulkaboul and Moulaye, 2006) revealed a higher prevalence (44.5%).

The rate of this parasitic species encountered during our work could be explained by the fact that the parasite is widely spread in the surveyed farms, related to the observed lack of hygiene on one hand, and the mixing of ages and animal species (sheep, calves) on the other hand. This situation increases the chance of animal contamination (Guechtouli et al., 2022). Besides, Eimeria oocysts are directly infectious and can persist in the environment for very long periods without losing their infectivity (Medema et al., 2006). Furthermore, food and water can be factors in the dissemination of these coccidia (Lim et al., 2007).
For *Nematodirus sp.* rate, it is close to those reported in Tiaret (27%) (Boulkaboul and Moulaye, 2006) and in Laghouat (28%) (Dib and Ben Aissa, 2015) and is lower than that recorded in Tunisia (52.78%) (Akkari et al., 2012). However, it is higher compared to the prevalences observed in Iran (Naem and Gorgani, 2011), Pakistan (Razzaq et al., 2014), and in Congo (Bagalwa et al., 2012) (with 14%, 7.58%, and 0.6% respectively). *Nematodirus* infestation is common during spring and early summer, which coincides with the period of our field survey. It is due to a sudden infestation by large quantities of *Nematodirus* larvae. The eggs have particularly strong resistance to desiccation and freezing; they can survive for more than 2 years on pastures. Temperature can affect the survival and reproduction of these parasites, as well as animal exposure to infestation (Lakehal et al., 2021).

In our study, the infestation rate by *Strongyloides sp.* is close to that reported in Senegal (16%) ((Nadao et al., 1995), and in Ethiopia (20.1%) (Ibrahim et al., 2014). It is higher than that found in Pakistan (4.42%) (Razzaq et al., 2014), in Tiaret (5%) (Boulkaboul and Moulaye, 2006), and in Iran (6%) (Garedaghi et Bahavarnia, 2013). On the other hand, it is lower than the rates reported in Cameroon (25%) (Ntonifor et al., 2013) and in Tunisia (58.35%) (Akkari et al., 2012), and significantly lower than the prevalences recorded in Bangladesh (Hassan et al., 2011) and southern Benin (Salifou et al., 2004) with values of 51.74% and 30.47%, respectively.

Regarding *Trichostrongylus sp.*, the prevalence recorded in our study is low compared to those reported in Tiaret (15%) (Boulkaboul and Moulaye, 2006), in Iran (16%) (Naem and Gorgani, 2011), in Pakistan (18%) (AL-Shaibani et al., 2008), in Cameroon (28.8%) (Ntonifor et al., 2013), in Ethiopia (46.7%) (Kumsa et al., 2011), and in Tunisia (77.80%) (Akkari et al., 2012). It is close to that reported in Iran (Garedaghi et Bahavarnia, 2013) (12.3%).

According to Chartier and Hoste (1994), *Strongyloides*, *Trichostrongylus*, *Chabertia*, and *Ostertagia* are the most widespread helminths in ruminants. The reason for their rate in our study could be associated with several factors, including the presence of humidity and optimal temperature conditions during the rainy season, which favor the survival of infective larvae in pastures in rural areas of Laghouat. The phenomenon of hypobiosis should also be considered, as it represents one of the most useful mechanisms of adaptation of the life cycle of parasites to ensure their survival in the host or in the environment. This phenomenon appears to be widespread among nematodes (Naem and Gorgani, 2011).

Regarding *Teladorsagia sp.*, the prevalence noted in our research was only 2% as for *Cooperia sp.*; this prevalence is same to that recorded in Iran (Soraya and Tahmineh, 2011) and in Togo (Bastiaensen et al., 2003). It is lower compared to that reported in Senegal (Nadao M, 1994) (52%). The results for *Fasciola hepatica* are in agreement with those of Bastiaensen et al. (2003) in
Togo (1%) and lower than those reported in Kashmir (8.5%) (Sheikh et al., 2016). For *Dicrocoelium lanceolatum*, the rate is lower than that noted in Kashmir (26.79%) (Sheikh et al., 2016). For *Paramphistomum sp.*, the rate is lower than that reported in Togo (15%) (Bastiaensen et al., 2003).

After identifying helminth eggs present in our samples, we counted them. In fact, 10 species were identified, but the species most frequently discovered by the quantitative method (Mac Master) are those of the genera: *Eimeria*, *Fasciola*, *Nematodirus*, and *Strongyloides*. The maximum EPG was obtained in a male (16000 EPG). EPG values for *Nematodirus* and *Strongyloides* were always <500 EPG. These values are close to those reported in Tiaret (Boulkaboul and Moulaye, 2006) (<500 EPG). For *Eimeria*, the maximum EPG values (10600 EPG) were obtained in females. These rates are higher than those reported in Tiaret where the maximum EPG values in females were 7200 EPG in Tiaret (Boulkaboul and Moulaye, 2006). In the same context, Boulkaboul and Moulaye (2006) reported that the average egg excretion increases from 130 EPG to 1820 EPG during the rainy season. These values are similar to our data. The high excretion could be explained by the dominance of *Eimeria sp.*, a highly prolific coccidia.

In the current study, our results regarding the association between parasitic species are consistent with the work of Ntonifor et al. (2013) who found mixed infestation by several genera of nematodes along with coccidia in ruminants in Cameroon.

During our investigation, we encountered cases of polyparasitism (more than one parasitic species in the same individual) especially the case of two parasites than monoparasitism. This result is in disagreement with that of Cuervo et al. (2013) where they found more animals infested by a single parasite than those infested by more than one parasitic species. In this study, the authors also found the following parasitic associations: *Eimeria* + *Nematodirus* (15.38%) and *Fasciola hepatica* + *Eimeria* (11.01%). In our case, the associations found were: *Eimeria* + *Cryptosporidium* (15%) and *Eimeria* + *Cryptosporidium* + *Nematodirus* (6%). This difference in parasitic association could be explained by variations in several environmental factors that can positively or negatively influence the spatial distribution of parasites.

Regarding the relationship between infestation by different parasites found in our sheep and certain parameters such as breed and study site, statistical analysis revealed a significant difference. However, for age, sex, clinical status, and rectal temperature, statistical analysis did not show any significant difference.

The living conditions of sheep herds in the Laghouat region are well suited for the survival and transmission of parasites. Factors contributing to the high prevalence of endoparasites may be related to poor management of farms, including building structures, feeding methods, watering systems, and especially farm hygiene (Guechtouli et al., 2022). Additionally, the sheep included in
our survey lived in close proximity to goats, donkeys, poultry, as well as cats and dogs, which play an important role in the epidemiology of several parasitic diseases, explaining the polyparasitism noted in our study (Bennadji et al., 2022).

The relationship between the age and the parasitism rate showed that infestation in adults was not significantly higher compared to young animals. However, Rahmani et al. (2023) reported that young were more susceptible to parasitic infestation than adult due to their immature immune systems. Our data may be explained by a higher number of adult sheep sampled compared to young ones. Thus, it is crucial for animal owners to take necessary precautions considering the fact that infected animals are carriers for young (Aypak et al., 2013). Moreover, the immune status and physiological condition of the host significantly influence the degree of infestation. Our work showed that the positivity rate was more pronounced in the sites of Sidi Makhlouf and El Kheneg, respectively. This is related, on one hand, to the high number of farms visited in these sites, and on the other hand, to overpopulation and the importance of sheep cohabitation with other animal species.

5 CONCLUSIONS

This current work provided insight into the prevalence of parasites in sheep farms in a semi-arid region in Algeria. It indicated a high level of infestation, ranking the studied area among zones where conditions are more favorable for the development and evolution of parasites. According to our results, breed and study site had a significant influence on the infestation rate. It is important to note that this parasitism causes low production performances, consequently affecting the profitability of farming. It would be beneficial in the future to prospectively monitor parasitism in livestock over time and space to gain a clearer picture of the epidemiology of these parasitic diseases. The authors suggest in the future, more deep investigations among these, genetics to identify species for better confirmation, and inclusion of other further impactful parameters, particularly the ecological factors. For this purpose, collaboration among breeders, technicians, and veterinarians is crucial to effectively combat parasitic diseases and ensure the sustainability of sheep farming in semi-arid regions.
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