non-treated groups (Yvoré et al., 1980b). In kids, a superimposed infection with trichostrongyles leads to an increased and longer lasting excretion of *Eimeria* spp. oocysts (De La Fuente et al., 1993). On the contrary, Catchpole and Harris (1989) did not indicate any influence of an superimposed infection with *Nematodirus battus* on the excretion of coccidia oocysts. Otherwise, the excretion of strongyles eggs is increased when the animals also harbour coccidia: during an experimental infection by *Haemonchus contortus*, goats infected 60 days earlier by 500,000 *Eimeria* sp. oocysts excreted more nematode eggs and showed a more pronounced retarded growth (Rahman, 1994).

4. Pathogenesis

4.1. Symptoms

The majority of the studies carried out in temperate or tropical zones show the importance of age in the excretion of coccidia: the prevalence and the intensity of excretion are highest in young animals of less than 4–6 months. In Great Britain, typical coccidiosis is seen in 4–8-week-old unweaned lambs (Taylor, 2009). Similarly, clinical coccidiosis in goats is usually recorded 2–4 weeks after weaning.

The main symptom is diarrhoea which can be haemorrhagic in sheep but less frequently than in cattle (Foreyt, 1990). In contrast, the diarrhoea is never haemorrhagic in kids. The faeces are watery with clumps of mucus and colour changes from brown to yellow or dark tarry (Koudela and Bokova, 1998). There is weight loss and dehydration. The general condition of the animal is worsened because of decreased appetite. In certain conditions, coccidiosis can be characterised by sudden mortality without preceding digestive signs, in particular amongst young animals between 2 and 4 months old (Chartier, 2009).

4.2. Subclinical form

Impairment of growth is the main sign of subclinical coccidiosis and is most often revealed during systematic treatment in comparison with control groups. In small ruminants, numerous studies have shown the importance of anticoccidial treatments on the growth of animals around the time of weaning and afterwards (Foreyt, 1990). For example, in French conditions, the prophylactic administration of diclazuril in weaned lambs may reduce the mean fattening period by 5–8 days and increase the feed conversion rate by 7–16% (Alzieu et al., 1999). Moreover the level of oocyst excretion at 3 months old is inversely correlated to growth until the age of 6 months in kids (Chartier et al., 1992). Similarly, there is an inverse relationship between mean or maximum oocyst counts and body weight in lambs (Reeg et al., 2005).

4.3. Lesions

In sheep, the lesions due to *E. ovinoidalis* affect above all the caecum although the colon and the small intestine can also be affected. The general pathological picture in small ruminants is that of a catarrhal enteritis (jejunum, ileum, caecum, possibly proximal colon) which is congestive and more or less haemorrhagic with mucus and fibrin (Khodakaram Tafti and Mansourian, 2008; Koudela and Bokova, 1998). An important oedema can also be noticed in the mucosa and sub-mucosa. Small greyish-white lesions ("nodules") of 1–2 mm in diameter speckling the mucosa are characteristic (Fig. 4) (Koudela and Bokova, 1998). They are a coalescence of the different stages of the parasite (macroschizonts, gametocytes, oocysts). Sometimes more prolific lesions can be observed in small ruminants (notably with *E. bakuensis* infection in sheep) i.e. large nodules in the intestinal lumen and whose pathogenic role has not been confirmed.

The histopathological lesions, at least with *E. ovinoidalis* or *E. crandallis* in lambs, showed loss of surface epithelial cells and villous atrophy associated with first generation schizonts, and crypt destruction or hyperplasia associated with gamonts (Gregory and Catchpole, 1987; Taylor et al., 2003).

4.4. Diagnosis

Coccidiosis is suspected when there are digestive troubles in young animals bred under poor hygienic conditions and/or intensive breeding. In small ruminants, sudden mortality around the weaning period should also suggest coccidiosis. All the stress factors mentioned previously should be looked for. A poor growth rate in an appropriate epidemiological setting should suggest a diagnosis of subclinical coccidiosis.

During the necropsy, examination of the gut allows display of possible lesions which are almost pathognonomic of coccidiosis.

The coproscopical examinations should be quantitative and allow, if possible, the diagnosis of the most pathogenic species of *Eimeria* found in faecal matter (McMaster's technique with NaCl or $MgSO_4$ for example with an additional flotation cover glass) (Yvoré et al., 1987). Identification of *Eimeria* species has to be made on the basis of the morphological criteria of the oocysts, most often after sporulation (faecal matter at room temperature for 2 or 3 days, or after dilution in 2% bichromate potassium and incubation at 25 °C). The criteria for diagnosis of the oocyst include the size, the shape and the presence of characteristic elements (polar cap, micropyle, colour, aspect of the oocyst wall, oocystal and sporocystal residues, etc.) (Eckert et al., 1995). There are large variations in excretion between individual animals and according to the species of coccidia. Furthermore, at individual level, diarrhoea may precede oocyst shedding and oocyst output may be high without any clinical signs as well (Wright and Coop, 2007). As a group, between 7 and 10 individual samples are needed in order to obtain a correct estimation of the average excretion of a group of animals. Otherwise, a sampling of fresh faecal matter on the ground (about 50 small samples brought together in one homogenous mass from which 5 analyses can be made), allows for the average level of excretion to be evaluated (Chartier, 1991). Despite the general relationship between clinical coccidiosis and high excretion of oocysts, a clear-cut threshold for coproscopical values is difficult to assess. According to Yvoré et al. (1987), the threshold value indicating a clinical coccidiosis in small ruminants could be

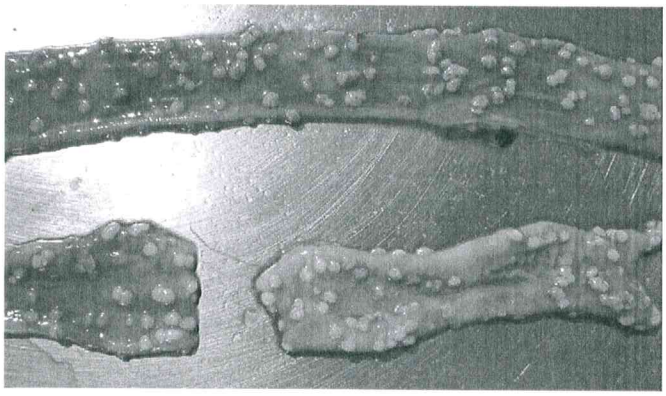

Fig. 4. Small intestine of a kid heavily infected by coccidia: whitish nodules in the mucosa (photo C. Chartier).

around 50,000–100,000 opg whatever the *Eimeria* species involved. However, the determination of percentages for the species which are the most pathogenic for each host is a crucial information as some less pathogenic species can be excreted in relatively large numbers without causing any overt clinical effect (Yvoré et al., 1985).

5. Control

The successful and economical control of coccidiosis can be achieved once detailed knowledge about management characteristics and time course of infection in a given flock is collected. Systematic blanket medication is thus not relevant.

5.1. Treatment

Treatment must be done as early as possible and concern the whole group of animals (age, paddock) as animals showing no obvious signs may contaminate the environment. Treatment has to be associated with a move of the animals to a cleaner environment. Anticoccidial products belong to a number of chemical families with different modes of action on the endogenous phase of the life cycle. Sulfonamides have an activity on the last stages of the cycle whereas amprolium and the ionophores (monensin, lasalocide) have an effect on the earlier stages. Decoquinate and more recently toltrazuril and diclazuril are molecules which act on the whole cycle of the coccidia (Taylor et al., 2003) and this allows both a curative and a preventative effect. In a curative way, amprolium and sulfonamides must be distributed for a period of 3–5 days whereas triazinones (toltrazuril, diclazuril) have to be given only once. For these last two molecules the dose rate to be administered for goats should be doubled (in one shot) compared to the dose rate for cattle or sheep (Chartier et al., 1992; Chartier and Pors, 2000). This off-licence use involves the "cascade principle" with specific meat withdrawal periods to be applied. On the field, the administration of a single treatment around early weaning of lamb may be sufficient to control oocyst excretion and to improve weight gain and animal health as it has been demonstrated with diclazuril (Platzer et al., 2005). A recent comparison between toltrazuril and diclazuril in lambs has shown a higher efficacy of the former in terms of duration and amount of oocyst excretion (Mundt et al., 2009; Le Sueur et al., 2009). These diverse molecules are not available in all countries nor are they licenced for all species of animals or for all uses.

As an alternative to conventional drugs, the effect of condensed tannin-containing plants (pine needles, oak leaves) was assessed in goat through a decrease of oocyst counts of 85–93% 10 days after the start of administration (Hur et al., 2005).

5.2. Prevention

This relies on the control of hygienic conditions, the reduction of stressors, an adequate nutrition and the use of anticoccidial drugs (Foreyt, 1990). Hygienic measures are essential to prevent the appearance of the clinical form of coccidiosis: clean dry buildings (drinking and eating troughs at the appropriate height, dry and clean litters), breeding on duckboard, improvement of "kraals" and of feeding and drinking areas, limiting the numbers of animals, etc. As written in professional journals, coccidiosis control requires "showel, wheelbarrow and strong back". The cleaning and disinfecting of the buildings must be done with boiling water under pressure and gaseous ammonia when possible. Long kidding/lambing seasons predispose to a progressive heavy contaminated environment and to mixing of different age groups that is very favourable to clinical coccidiosis (Catchpole et al., 1993). In this situation, the main objective is to raise later-born lambs or kids on different paddocks/pastures from early animals in order to avoid highly contaminated areas. On the other hand, Gregory et al. (1989a) have shown that lambs born in "used" pens gained 20 per cent more than those born in clean pens and these authors suggest that some level of faecal contamination could boost immunity to further challenge without being detrimental. Finally, the true objective is the prevention of "excessive" environmental contamination (Wright and Coop, 2007).

Moreover, all the stress factors must be limited as far as possible; nutrition of dam and litter, in particular, is a very important factor and it has been shown that coccidiosis is more common in twin or triplet lambs (Taylor, 2009).

Even if some of the anticoccidial drugs mentioned previously can be used as a means of prevention by prolonging

or repeating the periods of administration, the "true" preventive anticoccidial drugs in ruminants are coccidiostatic substances distributed in small doses in foodstuffs over a sufficiently long period: monensin, lasalocide and decoquinate. Some encouraging trials were also performed with intra-ruminal bolus of sulfamethazine (Gutiérrez-Blanco et al., 2006). The continued use of coccidiostats lessen the number of oocysts passed in the faeces over time but may also lead to selection for resistance and thus a regular monitoring of the treated animals is needed (Foreyt, 1990). The medication of feed for ewes may reduce the output of oocysts but may not prevent infection in lambs (Wright and Coop, 2007) and thus seems not advisable.

Conflict of interest

None.

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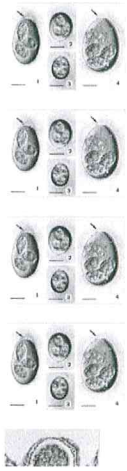

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Coccidiosis in goats in the Czech Republic

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Abstract

An observational study was conducted to determine coccidial infections in goats of 13 farms in the Czech Republic. The prevalence of oocysts of *Eimeria* species in kids (less than 3 months old), weaned but not served goats (from 3 months to 1 year), and adult goats (1 year or more) was determined. Nine *Eimeria* species were identified in fecal samples by Sheather's sugar flotation technique. The overall prevalence of *Eimeria* oocysts in fecal specimens was 92.2%. *Eimeria arloingi* was the most common species with an overall prevalence of 84%, followed by *E. hirci* (63%) and *E. ninakohlyakimovae* (56%). Other species present were *E. christenseni* (55%), *E. alijevi* (36%), *E. caprina* (25%), *E. aspheronica* (12%), *E. capriovina* (6%) and *E. jolchijevi* (2%). Two or more *Eimeria* species were detected in 88% of the samples. The most prevalent species in kids was *E. arloingi*, while in weaned but not served and adult goats *E. ninakohlyakimovae* was the most frequently found. The number of oocysts excreted was generally lower in adult goats (2567.3±12 678 OPG), whereas higher number oocyst per gram of feces (OPG) were found in kids (18 565±24 888 OPG). Clinical coccidiosis was detected in two farms, and *E. arloingi* and *E. ninakohlyakimovae* were implicated as its cause. Disease was observed in kids 2 to 4 weeks after weaning and watery feces with clumps of mucus, and color changes from brown to yellow or dark tarry, weight loss, and dehydration were the most conspicuous clinical signs. At necropsy, macroscopic changes included mucosal hemorrhages and whitish nodular polyps in the jejunum were found. Histopathological changes were characterized by local hypertrophy and hyperplasia of intestinal villi, villus blunting and inflammatory infiltration in the lamina propria. Numerous developmental stages of the parasites were observed in enterocytes and lacteals of intestinal villi.

Keywords

Eimeria spp.; Goat; Epidemiology-protozoa; Czech Republic

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Short communication

Eimeria species in dairy goats in Brazil ☆

Antônio César Rocha Cavalcante[a, 1], Marcel Teixeira[a,], Jomar Patrício Monteiro[a, 1], Carlos Wilson Gomes Lopes[b]

Show more

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Abstract

The focus of this work is to determine the distribution and identify species of *Eimeria* parasites of dairy goats in the livestock of the National Goat and Sheep Research Center in Sobral, State of Ceará, Northeast Brazil. Results showed the presence of multiple species in 196 of 215 analyzed samples (91.2%). Fifty five out of these were from kids (28%) and 141 from adult goats (72%). Eight different *Eimeria* species were identified and their prevalence in the herd was: *Eimeria alijevi* Musaev, 1970 (26.7%), *E. arloingi* (Marotel, 1905) Martin, 1909 (20.6%), *E. hirci* Chevalier, 1966 (18%), *E. ninakohlyakimovae* Yakimoff & Rastegaieff, 1930 (16.2%), *E. jolchijevi* Musaev, 1970 (8.7%), *E. christenseni* Levine, Ivens & Fritz, 1962 (6%), *E. caprovina* Lima, 1980 (2.8%) and *E. caprina* Lima, 1979 (1%). Moreover, *E. ninakohlyakimovae* showed higher prevalence in kids (97%), followed by *E. arloingi* and *E. alijevi* (88%). On the other hand, *E. alijevi* (77%) was more common in adult goats followed by *E. hirci* (74%) and *E. ninakohlyakimovae* (70%). The species *E. caprina* had low frequency in both kids (27%) and adult goats (13%). Data indicated that infection was relatively common among kids and adult goats. The implementation of a routine diagnostic strategy can be useful in maintaining *Eimeria* populations under monitoring and will enable the determination of its potential impact on dairy goat herds in Northeast Brazil.

Keywords

Coccidiosis; *Eimeria*; Diagnosis; Morphology; Goats

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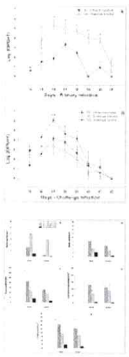

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Immunization with *Eimeria ninakohlyakimovae*-live attenuated oocysts protect goat kids from clinical coccidiosis

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Abstract

Caprine coccidiosis, affecting mainly young goat kids around the weaning period, is worldwide the most important disease in the goat industry. Control of caprine coccidiosis is increasingly hampered by resistances developed against coccidiostatic drugs leading to an enhanced need for anticoccidial vaccines. In the current study we conducted an oral immunization trial with live attenuated sporulated *Eimeria ninakohlyakimovae* oocysts. Sporulated *E. ninakohlyakimovae* oocysts were attenuated by X-irradiation technique. The experimental design included a total of 18 goat kids divided into the following groups: (i) animals immunized with attenuated *E. ninakohlyakimovae* oocysts at 5 weeks of age and challenged 3 weeks later with non-irradiated homologous oocysts (group 1); (ii) animals infected with non-attenuated *E. ninakohlyakimovae* oocysts at 5 weeks of age and challenged 3 weeks later with non-attenuated homologous oocysts (group 2); (iii) animals primary-infected with untreated *E. ninakohlyakimovae* oocysts at 8 weeks of age (control of the challenge infection, group 3); (iv) non-infected control animals (group 4). Goat kids immunized with live attenuated *E. ninakohlyakimovae* oocysts (group 1) excreted significantly less oocysts in the faeces (95.3% reduction) than kids infected with non-attenuated ones (group 2). Furthermore, immunization with live but attenuated oocysts resulted in ameliorated clinical coccidiosis compared to goat kids infected with untreated oocysts (group 2) and resulted in equally reduced signs of coccidiosis after challenge infection compared to acquired immunity driven by non-attenuated oocysts. Overall, the present study demonstrates for the first time that live attenuated *E. ninakohlyakimovae* oocysts orally administered showed almost no pathogenicity but enough immunogenicity in terms of immunoprotection. Importantly, vaccinated animals still shed low amounts of oocysts, guaranteeing environmental contamination and consecutive booster infections to sustain ongoing immunity.

Keywords

Eimeria ninakohlyakimovae; X-irradiation; Immunoprotection; Goats; Vaccine

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