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SPECIES OF THE FAMILY EIMERIIDAE (COCCIDIA, APICOMPLEXA) PARASITIC IN CATTLE AT DAIRY FARMS IN KYIV AND ZHYTOMYR REGIONS OF UKRAINE

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Species of the Family Eimeriidae (Coccidia, Apicomplexa) Parasitic in Cattle at Dairy Farms in Kyiv and Zhytomyr Regions of Ukraine. Slobodian, R. O., Kychyliuk, Yu. V., Soroka, N. M. — The results of identification of *Eimeria* spp. oocysts based on fecal examination of cattle of the first year of life from 7 farms of Zhytomyr and Kyiv regions of Ukraine are presented in article. Nine species of *Eimeria*, namely, *Eimeria zuernii* (Rivolta, 1878) Martin, 1909; *E. bovis* (Zublin, 1908) Fiebiger, 1912; *E. ellipsoidalis* Becker and Frye, 1929; *E. bukidnonensis* Tubangui, 1931; *E. cylindrica* Wilson, 1931; *E. canadensis* Bruce, 1921; *E. auburnensis* Christensen and Porter, 1939; *E. brasiliensis* Torres and Ramos, 1939; *E. wyomingensis* Huizinga and Winger, 1942 were identified. Species of *E. canadensis*, *E. auburnensis*, *E. brasiliensis* and *E. wyomingensis* were found in calves for the first time in Ukraine.
Key words: Eimeriidae, protozoa, oocysts, calves, cattle, Ukraine.

Introduction

The protozoan phylum Apicomplexa Levine, 1970 comprises a large and heterogeneous assemblage of obligate intracellular parasites; a number of them are of medical and veterinary significance. The largest subgroup in this phylum is the suborder Eimeriorina Leger, 1911, which contains organisms collectively referred to as the coccidia. Predominantly intestinal parasites, coccidia infect all classes of vertebrates and most invertebrates. At present, the Eimeriorina includes 10 families, at least 42 genera, and over 2,000 nominal species. Unfortunately, little is known about the majority of these species and few have been reported since their original descriptions (Duszynski et al., 1997, 2001).

Our subject of interest and research are the species of *Eimeria* Schneider, 1875 (family Eimeriidae Minchin, 1903) in cattle.

Nowadays, 22 species of *Eimeria* and one species of *Isospora* Schneider, 1881 are known to parasitize cattle (Krylov, 1996). Some of these species are highly pathogenic, dangerous, and can cause the acute clinical disease in young cattle with great losses. In addition to acute diarrhea, affected animals display muscular tremors, convulsions, opisthotonus, nystagmus, blindness, and mortality rate is from 50 up to 100 % (Isler et al., 1987).

However, according to many scientists, validity of some *Eimeria* species is doubtful, since their diagnoses are based only on the description of oocysts, whereas morphology of parasites at different stages of their development, sporulation period and location has not been taken into account. This opinion is supported by the majority of scientists who have been studying of *Eimeria*. They emphasize that these parasites belong to the species which should be characterized, above all, by the specific morphological characters at all stages of their development.

In Ukraine, during the last 30 years Eimeriidae in cattle have been investigated to some extent by Manzhos (1983–1989), Ponomarenko (1993–1998) and others. Thus, the interest to eimeriosis disease has increased in last century in 80–90's years. It was reported on 9 species of *Eimeria* in cattle in Ukraine, mostly *E. bovis*, *E. zuernii*, *E. ellipsoidalis*, and *E. cylindrica* in livestock farms (Slobodian et al., 2015). However, despite the considerable period of study, eimeriosis of cattle does not lose its relevance, and this, in turn, is still drawing more attention to it.

An analysis of published data shows that before 2006 seven species of the genus: *E. zuernii*, *E. bovis*, *E. ellipsoidalis*, *E. bukidnonensis*, *E. cylindrica*, *E. smithi*, and *E. zurnabadensis* have been recorded in cattle in Ukraine.

In the present study, we collected and identified *Eimeria* spp. from cattle in Kyiv and Zhytomyr regions of Ukraine. Results of morphological studies of the collected species, as well as information on their taxonomy, biology, distribution and specificity, are presented herein.

Material and methods

The studies were carried out in 2005–2015 in a scientific laboratory of the Department of Parasitology and Tropical Veterinary Faculty of Veterinary Medicine of National University Life and Environmental Sciences of Ukraine.

The feces of cattle (1–12 months old) naturally infected by *Eimeria* spp. were investigated at 7 farms of Narodychi district of Zhytomyr Region, and Fastiv, Borodianka, Vasylkiv districts of Kyiv Region in the Northwest of Ukraine. In total, 1361 samples of feces were examined by Scherbovych's flotation technique and combined original author's' technique; 398 of those were positive for *Eimeria* oocysts. We calculated the total number of *Eimeria* oocysts in 1 g of feces (OPG), and in 20 fields of view of the microscope according to the Orlov's technique (Orlov, 1956).

The diversity of *Eimeria* species have been studied by cultivation by the Arnastauskene's technique (Arnastauskene, 1985) and by Mironenko's technique (Mironenko, 2007) in thermostat at 24–30 °C. Accumulation of culture of coccidian oocysts was performed according to Yakimoff's (1931) method. The material with oocysts was treated with 2.5 % potassium dichromate solution (Yatusevich, 2006) for protection of coccidian oocysts against development of microorganisms and mold, before the cultivation.

Sporulation process was controlled under a light microscope (x10 eyepiece, x20 objective). Each *Eimeria* species was studied and described based on each specimen, which contained 100 ± 2.32 oocysts at three stages of their exogenous development. For species identification, we used the determinants proposed by Kolabsky and Pashkin (1974), Pellerdy (1974), Swanbaiev (1977), Levine (1985), and Krylov (1996), particularly, shape of oocysts and sporocysts, their color, size (length and width), features of the outer membrane and such morphological structures as micropile, polar cap, polar granules, and the residual body of oocysts. Also, the sporulation time of the oocysts was taken into consideration.

Measurements of the oocysts were performed using the light microscope MBI–3 with binocular device AU–12 under x40 to x60 magnification. The digital camera Canon PowerShot A1100IS with 4 to 6 optical and digital zoom mounted on the MBI–3 microscope was used for illustrations.

Results and discussion

At separate farms, the prevalence of infection varied from 8.5 % to 78.7 % (table 1). The highest intensity of infection estimated by microscope scanning was observed in 2- to 4-months-old calves, from 89.1 ± 1.38 to 133.3 ± 5.06 oocysts. The lowest intensity of infection was in calves of 5–6 months of age, from 17.45 ± 1.03 to 22.91 ± 1.98 oocysts.

The most abundant species in calves at all examined dairy farms were *E. bovis* and *E. ellipsoidalis* with 48 % of incidence; *E. auburnensis* with 44 %; *E. zuernii* with 32 %; *E. wyomingensis* with 24 %; and *E. bukidnonensis* with 20 % of incidence, respectively. Other species were found are less often.

The highest intensity of infection was registered in cases of associated infection of 2 or 3 species of *Eimeria*, such as *E. bovis*, *E. zuernii* and *E. auburnensis*; *E. bovis* and *E. bucidnonensis*; *E. bovis*, *E. ellipsoidalis* and *E. wyomingensis*. This association of *Eimeria* has caused the acute clinical eimeriosis in animals. Similar observations

Table 1. The prevalence and infection intensity of *Eimeria* species of calves at farms of Kyiv and Zhytomyr regions of Ukraine, M ± m

Farm	No. of hosts examined	No. of host infected	Prevalence of infection, %	Infection intensity, OPF*	*Eimeria* species found
1	225	106	47.1	17 ± 1.03	*E. bovis, E. cylindrica, E. auburnensis, E. canadensis*
2	145	61	42.1	22.9 ± 1.98	*E. bovis, E. wyomingensis, E. brasiliensis, E. auburnensis*
3	47	37	78.7	101 ± 8.32	*E. bovis, E. wyomingensis, E. auburnensis, E. brasiliensis*
4	282	24	8.5	52.08 ± 2.4	*E. bovis, E. zuernii, E. ellipsoidalis,E. bucidnonensis*
5	64	25	39.1	82.12 ± 1.58	*E. zuernii, E. bovis, E. cylindrica, E. auburnensis, E. canadensis*
6	80	30	37.5	89.1 ± 1.38	*E. bovis, E. ellipsoidalis, E. zuernii, E. bucidnonensis*
7	114	30	26.2	133.3 ± 5.06	*E. bovis, E. cylindrica, E. zuernii, E. ellipsoidalis, E. auburnensis, E. bucidnonensis, E. wyomingensis*

Note. $p < 0.05$; * OPF — oocysts per field of microscope scanning area.

were reported in Kuwahara's (2016) parasitological analyses of *Eimeria* infections in domestic animals and the development of molecular methods for species discrimination in Japan; *E. bovis* and *E. zuernii* were highly pathogenic since they usually caused bloody stool (Kawahara, 2016).

A high prevalence of infection depended from age and constituted 39.1 % in calves of 2–4 months of age, with a maximum is 2.5 to 5 months of age in 51.9 %, and with decreasing up to 5–6 months of age in 3.3 %, respectively.

It should be noted, that the fecal samples of most young cattle with high intensity of eimeriosis infection contained only *Eimeria* spp. oocysts. At the same time, clinical eimeriosis in calves with a low intensity of infection was not observed. All young cattle were apparently healthy and in good condition.

In the studied samples, in addition to the oocysts of *Eimeria* spp., we found the eggs of cestodes and nematodes, as well as the cysts of ciliates: *Moniezia benedeni* eggs in 22.6 % of samples, gastrointestinal nematodes of the superfamily Trichostrongyloidea eggs in 11.5 %, *Trichuris bovis* eggs in 6.7 %, *Balantidium* spp. cysts in 6 %, *Neoascaris vitulorum* eggs in 4.8 %, and *Capillaria bovis* eggs in 3.3 %, respectively.

Descriptions of particular species of *Eimeria* in livestock farms of Ukraine collected and identified in the present study are given below. We supplement the original descriptions with the information on biology and distribution of each species.

Family EIMERIIDAE Minchin, 1903
Genus *Eimeria* Schneider, 1875
Eimeria zuernii (Rivolta, 1878) Martin, 1909 (figs 1, 2)

Syn.: *Cytospermium zurnii* Rivolta, 1878; *Eimeria bovis* (Zublin, 1908) Fiebiger, 1912 pro parte; *Eimeria canadensis* Bruce, 1921 pro parte.

Oocysts are round, spherical, sub-spherical to oval in shape. Their size is 16 to 20 by 15 to 18 μm. Oocysts are light gray in color, or transparent, without micropyle. External wall is smooth, single layered, yellowish in color.

According to our data, sporulation takes 2–3 days at 20 °C; it lasts 9–10 days at 12 °C, and 23–24 hours at 30–32 °C. The prepatent period is 15 to 17 days; the patent period is about 11 days.

This species belongs to the most pathogenic ones among the bovine coccidians (Krylov, 1996; Slobodian et al., 2015). It parasitizes the large intestine, caecum, colon and rectum of young cattle (Levine, 1961).

Hosts and distribution: cattle (*Bos taurus taurus* Linnaeus, 1758), zebu (*Bos taurus indicus* Linnaeus, 1758), water buffalo (*Bubalus bubalis* Linnaeus, 1758); worldwide in distribution (Duszynski et al., 2001).

The first report on coccidiosis in cattle was that of Zurn (Zurn, 1878). At that time, the author assigned this microorganism to the gregarins. Rivolta (1878) noted that the species is similar to protozoans, which had been found by Eimer in rabbits in 1870. He named it

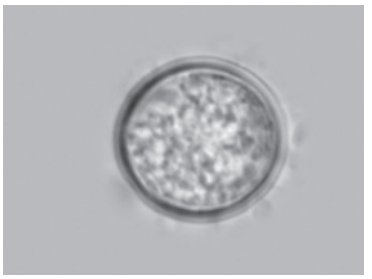

Fig.1. *Eimeria zuernii*, unsporulated oocyst (one-cell stage).

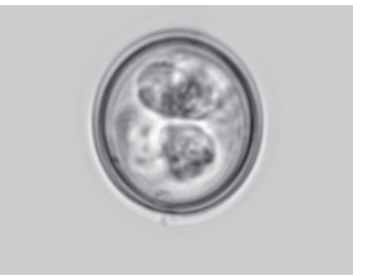

Fig. 2. *E. zuernii*, sporulated oocyst (x800) containing four sporocysts, each of which contains two sporozoites (right).

Cytospermium zurnii (syn. *Eimeria zuernii*). The modern name this species is *Eimeria zuernii* (Rivolta, 1878) Martin, 1909.

Round oocysts with the size of 30 to 35 by 20 μm were described by Zublin in 1908 as *Coccidium bovis* (syn. *Eimeria bovis*). At the same time, Smith and Graybill (1918) by exploring the dysentery of cattle in the United States described oocysts of two distinct species. Those had round oocysts, 18.6 to14.8 μm (*Eimeria zuernii*), and ovoid oocysts 29.9 to 19.9 μm in size (*Eimeria bovis*).

Eimeria bovis (Zublin, 1908) Fiebiger, 1912 **(**figs 3, 4)

Syn.*: Coccidium bovis* Zublin, 1908; *Eimeria canadensis* Bruce, 1921 *pro parte; Eimeria smithi* Yakimoff and Galouso, 1927; *Globidium fusiformis* Hassan, 1935; *Eimeria aareyi* Rao and Bhatavdakar, 1959; *Eimeria yunnanensis* Zuo and Chen, 1984.

Oocysts are ovoid or oval-shaped, 26 to 32 μm long and 18 to 21 μm wide. The form index is 1.41 ± 0.038 (Patent, 2011; Mironenko et al., 2014).The outer wall is smooth, double–contoured, yellow, with brown shade. Micropyle is located on the narrow end of oocyst. The residual body is absent.

According to our studies, the sporulation takes 2 to 4 days. The prepatent period is 18 to 20 days; the patent period is 6 to 8 days (Krylov, 1996). Parasite is one of the most pathogenic and common species in cattle. Merogony takes place in the small intestine. Gametogony is in the terminal part of the ileum, and in the blind and caecum (Hammond, 1969).

Hosts and distribution: cattle, zebu, American bison (*Bison bison* Linnaeus, 1758), European bison (*Bison bonasus* Linnaeus, 1758), water buffalo; worldwide in distribution (Soulsby, 1978; Duszynski et al., 2001).

In our opinion, the nominal species *E. smithi*, *E. zurnabadensis*, *E. azerbaidschanica*, and *E. orlovi* are likely the synonyms of the previously described *E. bovis*. A similar view is held by Krylov (1996). On the other hand, some authors consider *E. azerbaidschanica* (Yakimoff, 1933) as valid species. This subject apparently needs further investigations.

In 1921, small, cylindrical oocysts of *E. canadensis* were described by Bruce. Later, in the Soviet Union by Yakimoff and Galuzo (1927) distinguished two types of oocysts in feces: *E. zuernii* and *E. smithi*. It should be noted that the existence of such species as *E. smithi* Yakimoff and Galouzo, 1927 is still disputable. Orlov (1956), Petrov, Nikonov (1964), Kolabsky (1974) and Arnasthauskene (1985) are determined *E. smithi* as a separate species. At the same time, Krylov (1996) identified it as *E. bovis.* The latter point of view is supported by Pellerdy and Levine (Pellerdy, 1974; Levine, 1985).

Our investigations coincide with results of Polish scientists confirming that *Eimeria spp.* are very common pathogens in farmed cattle. In Poland, the highly

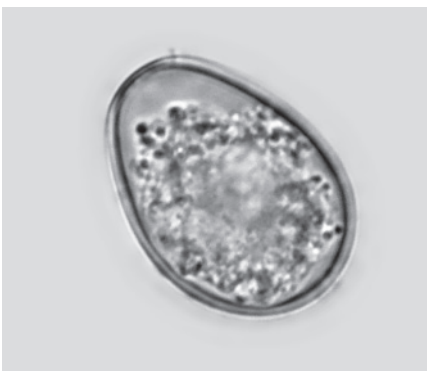

Fig. 3. *Eimeria bovis*, unsporulated oocyst.

Fig. 4. *E. bovis*, sporulated oocyst (x1000) with four sporocysts, each of which contains two sporozoites (right).

pathogenic species (*E. bovis* and *E. zuernii*) were found in 88.4 % of the investigated farms. The highly pathogenic *Eimeria* occurred more frequently in big rather than in small farms were found more frequently in bigger farms (92.3 %) compared to smaller ones (85.1 %). However, the intensity of *E. bovis* as well as *E. zuernii* infection remained, in most cases, low — 75.4 and 79.8 %, or moderate — 21.3 and 18.5 %, respectively. The intensity of the infections was, respectively, 3.1 and 1.9 times higher in big farms (Klockiewicz et al., 2007).

Eimeria ellipsoidalis Becker and Frye, 1929 (figs 5, 6)

Oocysts are ellipsoidal, 18–26 x 3–18 μm in size. The form index is 1.42 ± 0.034 (Patent, 2011; Mironenko et al., 2014). External wall is smooth, thin, single-layered, light pink or yellow in color. The micropyle is absent. Residual body is in the sporocyst.

According to our data, sporulation takes 2 to 3 days. The prepatent period is 8 to 13 (10) days; the patent period is 4 to16 days (Krylov, 1996). The species belongs to pathogenic parasites (Arnastauskene, 1985). Merogony and gametogony stages are in the small intestine of the hosts (Hobzem, 1972).

Hosts and distribution: cattle, zebu, European bison and water buffalo; North America, Europe (Soulsby, 1978; Duszynski et al., 2001), and Ukraine.

The ellipsoid oocysts of *E. ellipsoidalis* were first described by Becker and Fry (1929) in the United States.

Fig. 5. *Eimeria ellipsoidalis*, unsporulated oocyst.

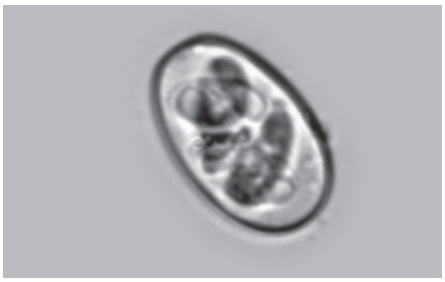

Fig. 6. *E. ellipsoidalis*, sporulated oocyst (x1000).

Eimeria cylindrica Wilson, 1931 (figs 7, 8)

Oocysts are cylindrical, transparent, without micropyle and residual body, 16–27 x 12–15 μm in size (figs 7, 8). The form index is 1.75 ± 0.024 (Patent, 2011; Mironenko et al., 2014).

Fig. 7. *Eimeria cylindrica*, unsporulated oocyst.

Fig. 8. *E. cylindrica*, sporulated oocyst (x1000).

Sporulation takes 2 to 3 days. The prepatent period is 11 to 20 days; the patent period is 10 days (Krylov, 1996). The species belongs to moderately pathogenic parasites (Arnastauskene, 1985). Merogony and gametogony stages are in the small intestine of the host (Levine, 1961).

Hosts and distribution: cattle and zebu; North America, India, Europe (Soulsby,1978; Duszynski et al., 2001), Belarus, and Ukraine.

The cylindrical oocysts of *E. cylindrica* were first described by Wilson in the United States (1931).

Eimeria auburnensis Christensen and Porter, 1939 (figs 9, 10)

Syn.: *Eimeria ildefonsoi* Torres and Ramos, 1939; *Eimeria khurodensis* Rao and Hiregaudar, 1954.

E. auburnensis is the most common species in cattle. Oocysts are egg-shaped (figs 9, 10), with smooth-surfaced wall, transparent, thin, and yellowish-brown in color. Their size is 23–38 x 20–25 μm. The form index is 1.61 ± 0.030 (Patent, 2011; Mironenko et al., 2014). Micropyle appears as a pale area at narrow end. Sporogony takes 3–4 days. The prepatent period is 18 to 20 days; the patent period is 2 to 8 days (Krylov, 1996). In the host, parasites are localized in the small intestine (Hammond, 1969).

Hosts and distribution: domestic cattle; wide-spread in the world (Soulsby, 1978; Duszynski et al., 2001).

We found *E. auburnensis* during chronic eimeriosis or low intensity of infection in calves. It was present in 20 % of positive tests.

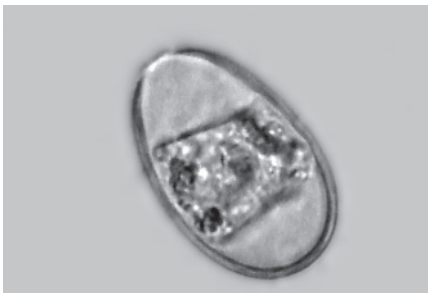

Fig. 9. *Eimeria auburnensis*, unsporulated oocyst.

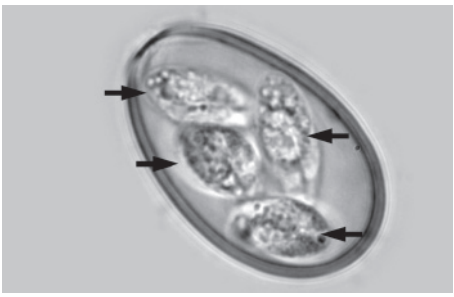

Fig. 10. *E. auburnensis*, sporulated oocyst (x800) four sporocysts (arrows), each of which contains two sporozoites.

Eimeria bukidnonensis Tubangui, 1931 (fig. 11)

Fig. 11. *Eimeria bukidnonensis*, unsporulated oocyst (x1000).

Oocysts are large, pear-shaped to oval. Their size is 48–50 x 33–37 μm, the color is yellowish-brown to dark brown. Micropyle could be seen on the narrower end of the oocyst. External wall is thickened, shows radial striation. The form index is 1.38 ± 0.061 (Patent, 2011; Mironenko et al., 2014). Sporogony lasts up to 17 days. The prepatent period is 9 to 25 days; the patent period is 7 to12 days (Krylov, 1996). *E. bukidnonensis* is localized in the small intestine of the hosts (Davis and Bawman, 2003). The pathogenicity of this species is unknown (Arnastauskene, 1985).

Hosts and distribution: domestic cattle, aurochs, ox, water buffalo, and zebu; originally in the Philippines, sub-

sequently in North and South America, Africa (Soulsby, 1978; Duszynski et al., 2001), Belarus, and Ukraine.

Our investigations have shown that *E. bukidnonensis* is associated with *E. bovis*; also *E. bovis* associates with *E. cylindrica* species. The associations of one or two highly pathogenic and non-pathogenic coccidians cause eimeriosis in calves with pronounced clinical signs.

Eimeria brasiliensis Torres and Ramos, 1939 (fig. 12)

Syn.: *Eimeria boehmi* Supperer, 1952; *Eimeria orlovi* Basanova, 1952; *Eimeria helenae* Donciu, 1961.

Fig. 12. *Eimeria brasiliensis*, unsporulated oocyst (x1000).

Oocysts are oval or ellipsoidal in shape (fig. 12), 38.4 ± 0.72 (34–42) long and 27.7 ± 0.76 (24–30) μm wide; length/width ratio is 1.39. The form index is 1.39 ± 0.071 (Patent, 2011; Mironenko et al., 2014).

External wall is smooth; double contoured; on the narrower end it contains polar caps and two polar granules in the form of two small grains located between protoplasmic layer and wall in the upper part of oocysts.

Sporogony lasts 12 to 14 days. There is no information about pathogenicity of this species. *E. Brasiliensis* is localized in the small intestine of the hosts (Arnastauskene, 1985).

Hosts and distribution: cattle, zebu, water buffalo; North and South America, Europe, Nigeria (Soulsby, 1978; Duszynski et al., 2001), Belarus, and Ukraine.

We found *E. brasiliensis* in association with *E. bovis* and *E. ellipsoidalis*, and with *E. bovis* and *E. auburnensis* during chronic eimeriosis of young cattle. We suppose that *E. brasiliensis* belongs to the non-pathogenic species in Ukraine, because this species has never been found separately at acute disease, neither in calves nor in cows.

Eimeria wyomingensis Huizinga and Winger, 1942 **(f**ig. 13)

Oocysts are oval or ovoid in shape (fig. 13). External wall is smooth, yellowish-brown to greenish-brown in color, slightly speckled. The size of oocyst is 37–45 by 36–31 μm. Micropyle is located at the narrower end of the oocyst.

Sporulation time is 5–7 days (Huizinga and Winger, 1942). The prepatent period is 13–15 days; the patent period is 1–7 (3–6) days (Krylov, 1996).

Hosts and distribution: cattle, zebu, water buffalo (Duszynski et al., 2001); Wyoming in the USA (Soulsby,1978), Ukraine.

In our investigations, we consider *E. wyomingensis* as low or non-pathogen species.

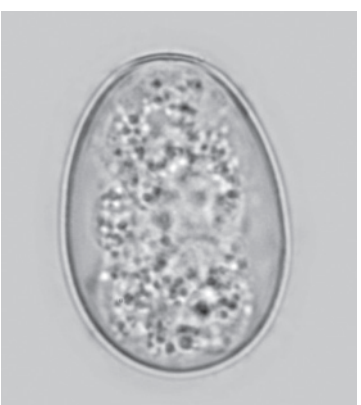

Fig. 13. *Eimeria wyomingensis*, unsporulated oocyst (x1000).

Eimeria canadensis Bruce, 1921

Syn.: *Eimeria zurnabadensis* Yakimoff, 1931, *Eimeria bombayannsis* Rao and Hiregaudar, 1954.

Oocysts are ellipsoidal or cylindrical in shape. Their size is 23–32 by 28–37 μm. Oocyst wall is smooth, transparent, slightly yellowish-brown in color, with micropyle. The form index is 1.41 ± 0.045 (Patent, 2011; Mironenko et al., 2014).

Sporogony takes 4–5 days. Information about pathogenicity of this species is unknown (Hobzem, 1972). According to our researches, *E. canadensis* is a low pathogenic species.

However, in association with other species of *Eimeria* (*E. zuernii*, *E. bovis* and *E. ellipsoidalis*), *E. canadensis* causes acute and subacute eimeriosis of calves. Endogenous stages of the parasite occur in the small intestine (Levine, 1961).

Hosts and distribution: cattle, zebu, American bison, European bison, water buffalo; bison, ox — type host; North America, Europe (Soulsby, 1978; Duszynski et al., 2001), Belarus, and Ukraine.

Remarks

We have studied the history of researches of *Eimeria* in cattle at livestock and farms conditions, and identified the species diversity of *Eimeria* in different geographic regions. More than 300 publications focused on different intensity of coccidiosis of cattle were analyzed.

Analysis of the publications on *Eimeria* species shows that more than 130 years have passed since the first discovery of bovine coccidia. However, the discussions about existence of some species of *Eimeria* are continuing to this day. This is probably due to the difficulty in determining the origin of some species of these parasites, their extremely wide spread, habitat and existence.

In the middle of the last century the extensive faunistic researches of the coccidia of cattle has started.

In the USSR, Orlov (1956) described 6 species of *eimeriids* in cattle: *E. zuernii*, *E. smithi*, *E. bukidnonensis*, *E. orlovi*, *E. thianethi*, and *I. aksaica.* At the same time, Petrov and Nikonov reported about the existence of 11 species of this group: E. *zuernii*, *E. smithi*, *E. bukidnonensis*, *E. orlovi*, *E. thianethi*, *E. ellipsoidalis*, *E. cylindrica*, *E. azerbaidjhanica*, *E. wyomingensis*, *E. alabamensis*, and *Isospora aksaica* (Petrov, Nikonov, 1964).

In Belarus Hobzem (1972) recorded 13 species of *Eimeria* in calves in his PhD thesis*:* *E. bovis*, *E. zuernii*, *E. ellipsoidalis*, *E. cylindrica*, *E. canadensis*, *E. subspherica*, *E. alabamensis*, *E. auburnensis*, *E. bukidnonensis*, *E. brasiliensis*, *E. smithi*, *E. pellita*, and *E. wyomingensis*.

Later, 9 species of protozoan parasites (*E. zuernii, E. smithi, E. zurnabadaensis, E. bovis*, *E.cylindrica*, *E. ellipsoidalis*, *E. bukidnonensis*, *E. auburnensis*, and *E. brasiliensis*) were found in cattle and described by Kolabsky and Pashkin (1974) in Russia.

Pellerdi (1974) in the monograph "Coccidia and Coccidioses" described 21 species of *Eimeria*. In Kazakhstan, Swanbaiev (1977) has found 6 species of bovine *Eimeria*: *E. pellita*, *E. bovis*, *E. bukidnonensis*, *E. alabamensis*, *E. auburnensis*, and *E. brasiliensis.* Three species of *Eimeria* were described in India: *E. bombayansis* Rao and Hiregaudar, 1954, *E. mundagari* Hiregaudar, 1956, and *E. gokaki* Rao and Bhatavdekar, 1959.

During 1960–1980's new species of *Eimeria* in cattle were described on different continents, such as *E. ovoidalis* Ray and Mandal, 1961 (now considered as *species inquirendae*)**,** and *E. bareillyi* Gill, Chhabra and Lall, 1963 in India; *E. illinoisensis* Levine and Ivens, 1967 in the USA; *E. ankarensis* Sayin, 1969 in Turkey, and *E. yunnanensis* Yangxian and Fuqiang, 1984 in China.

It was reported unable to transmit *E. ankarensis* to *Bos taurus* (Ox). However, only 50 oocysts were used in the attempt; that number is far below the levels that normally produce patent infections of other *Eimeria* **s**pp. in cattle. It is likely that this species was confused with either *Eimeria auburnensis* Christensen and Porter, 1939, or *E. pellita* Supperer, 1952 (Duszynski et al., 2001).

In the farms of Lithuania, Arnastauskene (1985) identified 10 species of *Eimeria* in cattle. Estonian researcher Karis (1987) reported about five coccidian species at dairy farms: *E. auburnensis*, *E. bovis*, *E. ellipsoidalis*, *E. zuernii*, and *E. subspherica*.

Krylov (1996) in his book "Identification of one-cellular parasites (in human, domestic animals and agricultural plants)" described about 22 species of *Eimeria* in cattle of different age: *E. zuernii*, *E. bovis*, *E. canadensis*, *E. ellipsoidalis*, *E. bukidnonensis*, *E. cylindrica*, *E. auburnensis*, *E. brasiliensis*, *E. alabamensis*, *E. subspherica*, *E. wyomingensis*, *E. pellita*, *E. bombayansis*, *E. mundaragi*, *E. illinoisensis*, *E. yunnanensis*, *E. azerbaidschanica*, *E. thianethi*, *E. gokaki*, *E. ovoidalis*, *E. ankarensis*, and *E. bareillyi*.

At conditions of Belarus livestock farms, Mironenko (2001) found11 species of *Eimeria* in cattle: *E. auburnensis*, *E. subspherica*, *E. bovis*, *E. zuernii*, *E. bukidnonensis*, *E. brasiliensis*, *E. cylindrica*, *E. ellipsoidalis*, *E. canadensis*, *E. wyomingensis*, and *E. alabamensis* (Mironenko, 2001; Yatusevich, 2006).

The study of the epidemiology of coccidiosis in Poland (Klockiewicz et al., 2007) showed the occurrence of disease with different association caused by one or a several 12 *Eimeria* species in infected calves.

In Russian Federation, Usarova is reported about parasitizing of 8 species of *Eimeria* in cattle in Dagestan (Usarova, 2008).

Nowadays, there are 11 species identified in Germany and Japan, and 13 species in the United States. Of these species, *Eimeria alabamensis, E. auburnensis, E. bovis, E. ellipsoidalis and E. zuernii* are recognized as pathogenic (Kawahara, 2016).

The most objective assessment of *Eimeria* species composition in cattle was given by Orlov (1956: p. 119) "Despite the numerous works that focus on the study of the coccidian fauna in cattle, the question of coccidia species composition in these animals can not be considered as solved. It still remains unclear and controversial".

In general, the most complete information about composition of *Eimeria* species parasitizing in cattle can be found in publications of Pellerdy (1974), Levine (1985), and Krylov (1996). Based on information from literature and results of our studies we consider 21 species of *Eimeria* from cattle as valid< namely: *E. zuernii***,** *E. bovis*, *E. ellipsoidalis*, *E. bukidnonensis*, *E. cylindrica*, *E. canadensis*, *E. auburnensis*, *E. brasiliensis*, *E. wyomingensis*, *E. subspherica, E. alabamensis*, *E. pellita* Supperer, 1952; *E. bombayansis* Rao and Hiregaudar, 1954; *E. mundagari* Hiregaudar, 1956; *E. illinoisensis* Levine and Ivens, 1967, *E. yunnanensis* Yangxian and Fuqiang, 1984; *E. thianethi* Gwelessiany, 1935; *E. gokaki* Rao and Bhatavdekar, 1959; *E. ovoidalis* Rao and Mandal, 1961; *E. bareillyi* Gill, Chhabra and Lall, 1963; *E. ankarensis* Sayin, 1969.

At the same time, the species *Isospora aksaica* is probably a transit parasite of birds, perhaps a pseudoparasite; it has never been found in cattle after 1980'th. Similar view was reported by Swanbaiev (1977). However, any further information about *I. aksaica* is absent in scientific publications.

Conclusions

1. Information about the *Eimeria* species in the dairy farm cattle of Ukraine was quite scattered and fragmental up to 2006. Up to this time, 7 species of *Eimeria* were recorded by different scientists.

2. Of the 22 species that constitute the world *Eimeria* fauna in *Bos taurus taurus* Linneus, 1758, 9 (40.9 %) were found in calves at livestock farms in Zhytomyr and Kyiv regions of Ukraine: *Eimeria zuernii* (Rivolta, 1878) Martin, 1909; *E. bovis* (Zublin, 1908) Fiebiger, 1912; *E. ellipsoidalis* Becker and Frye, 1929; *E. bukidnonensis* Tubangui, 1931; *E. cylindrica* Wilson, 1931; *E. canadensis* Bruce, 1921; *E. auburnensis* Christensen and Porter, 1939; *E. brasiliensis* Torres and Ramos, 1939; *E. wyomingensis* Huizinga and Winger, 1942. Five of those species (22.7 %) are the most abundant. Four species (18.2 %), namely, *E. canadensis*, *E. auburnensis*, *E. wyomingensis*, and *E. brasiliensis* were found in calves for the first time in Ukraine.

At the same time, we have not found any significant differences in the morphology of studied oocysts and those described in literature.

3. The highest intensity of infection was registered in calves of 2–4 months of age, 89.1 ± 1.38 to 133.3 ± 5.06 oocysts calculated by microscope scanning; the lowest was in calves of 5–6 months of age, 17.45 ± 1.03 to 22.91 ± 1.98 oocysts.

All these results confirm the fact, that *Eimeria* species occur mostly in young cattle, during the first year of life, and generally cause no clinical signs (chronic disease). However, reducing of immune resistance of milk period calves with different environmental factors may cause the development of disease with clinical signs, numerous oocysts and blood in diarrheal feces, and the mortality of hosts.

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