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A new species of *Eimeria* Schneider, 1885 (Apicomplexa: Eimeriidae) from the eastern gray squirrel, *Sciurus carolinensis* (Rodentia: Sciuridae: Sciurinae: Sciurini) from Oklahoma, USA

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Abstract

A new species of *Eimeria* Schneider, 1885 is described from an eastern gray squirrel (*Sciurus carolinensis*) from McCurtain County, Oklahoma, USA. Oöcysts of *Eimeria lukfataensis* n. sp. are ellipsoidal with a rough pitted bi-layered wall, measure $23.8 \times 14.9 \mu\text{m}$, and have a length/width (L/W) ratio of 1.6; a micropyle is absent but an oöcyst residuum and polar granule(s) are present. Sporocysts are ellipsoidal and measure $12.5 \times 6.1 \mu\text{m}$, L/W 2.0; Stieda and sub-Stieda bodies are present, but para-Stieda body is absent. The sporocyst residuum is composed of small indistinct granules along the edge or in the center of the sporocyst. This is the first species of coccidian reported from *S. carolinensis* from Oklahoma and only the fourth species from the sciurid tribe Sciurini with oöcysts possessing an oöcyst residuum.

Introduction

The eastern gray squirrel, *Sciurus carolinensis* Gmelin is a medium-sized tree squirrel that ranges throughout most of the eastern United States, from the southern provinces of central and eastern Canada, southward to Florida and west to the central Gulf Coast of Texas; introduced populations occur in various parts (Ireland, England, Italy and South Africa) of

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Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All applicable institutional, national and international guidelines for the care and use of animals were followed. Scientific Collecting Permits were provided to CTM by the Oklahoma Department of Wildlife Conservation (permit number 7297).

the Old World (Koprowski, 1994; Reid, 2016). In Oklahoma, *S. carolinensis* occurs in the timbered eastern half of the state (Caire et al., 1989).

There is a moderate amount of information on the coccidian parasites of *S. carolinensis*, including populations from Arkansas (McAllister & Kessler, 2002), Florida (Parker et al., 1972; Forrester et al., 1977), Massachusetts (Joseph 1969, 1972; Duncan, 1973), the southern USA (Davidson, 1976), Texas (McAllister & Kessler, 2002), and Ontario, Canada (Lee & Dorney, 1971). In addition, coccidia have been reported from invasive (alien) *S. carolinensis* from England (Ball et al., 2014) and Italy (Hofmannová et al., 2016).

Here, we provide a description of a new species of *Eimeria* Schneider, 1885, from an eastern gray squirrel from Oklahoma, USA.

Materials and methods

Between June 2012 and September 2014, 3 *S. carolinensis* were collected from Lukfata (n = 2) and Sweethome Community (n = 1), McCurtain County, Oklahoma, USA. Fresh fecal specimens or intestinal contents were preserved in individual vials containing 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$). Samples were examined for coccidia using an Olympus BX53 light microscope after flotation in Sheather's sugar solution (specific gravity = 1.30). Sporulated oöcysts from all infected hosts were examined using Olympus® cellSens 1.14 digital software and all measurements are reported in micrometers (μm) with the ranges followed by the means in parentheses. Photographs were taken using Nomarski interference-contrast optics at 1,000× magnification. Oöcysts were *c.* 215 days-old when measured and photographed. Descriptions of oöcysts and sporocysts follow the standard guidelines of Wilber et al. (1998) including: oöcyst length (L) and width (W), their ranges and ratios (L/W), micropyle (M), oöcyst residuum (OR), polar granule(s) (PG), sporocyst length (L) and width (W), their ranges and ratio (L/W), sporocyst (SP), Stieda body (SB), sub-Stieda body (SSB), para-Stieda body (PSB), sporocyst residuum (SR), sporozoites (SZ) anterior (ARB) and posterior (PRB) refractile bodies, and nucleus (N).

A host photovoucher was accessioned into the Henderson State University (HSU) Mammal Collection, Arkadelphia, Arkansas, USA. Photosyntypes of sporulated oöcysts were accessioned into the Harold W. Manter Laboratory of Parasitology (HWML), Lincoln, Nebraska, USA.

Results

One of 3 (33%) *S. carolinensis* were found to be passing coccidian oöcysts of an eimerian that we describe here as new.

Eimeria lukfataensis n. sp.

Syn. *Eimeria* sp. of Lee & Dorney (1971)

Type-host: Eastern gray squirrel, *Sciurus carolinensis* Gmelin, 1788 (Mammalia, Rodentia, Sciuridae), adult (not measured) collected 12.xi.2012.

Type-locality: Lukfata (34°02'53.00"W, 94°49'15.44"W), McCurtain County, Oklahoma, USA.

Type-material: Photosyntypes of sporulated oöcysts are deposited as HWML 139993.

Prevalence: In 1 of 3 (33%) overall; in 1 of 2 (50%) Lukfata; 0 of 1 (0%) Sweethome Community.

Sporulation time: Unknown; oöcysts were sporulated when examined.

Site of infection: Unknown; oöcysts recovered from faeces.

Etymology: The specific epithet is derived from the type locality. In Choctaw language, it is from the “lukfi hata” meaning chalk or white clay.

Description (Figs. 1, 2 A–F)

Sporulated oöcyst—Oöcyst ($n = 50$) ellipsoidal; $19\text{--}32 \times 13\text{--}18$ (23.8×14.9), length/width (L/W) ratio $1.4\text{--}1.9$ (1.6). Wall moderately rough and pitted, thick, bi-layered, $c. 0.6\text{--}1.6$ (1.0), light brown. Micropyle absent but spheroidal granulated oöcyst residuum located between and around the sporocysts, and 1 (rarely 2) polar granule(s) present.

Sporocyst and sporozoite—Sporocysts ($n = 50$) 4, ellipsoidal $10\text{--}17 \times 5\text{--}8$ (12.5×6.1); L/W ratio $1.6\text{--}2.5$ (2.0); wall smooth, thin and uni-layered, light brown, $c. 0.2$ thick. Pointed Stieda body and sub-Stieda bodies present; para-Stieda body absent; sporocyst residuum small granules along edge or in centre of sporocyst. Sporozoites (2, not measured), elongate; with spheroidal anterior and ellipsoidal posterior refractile bodies, nucleus difficult to discern.

Remarks

We limit the comparison of our new taxon only to those few eimerian species with oöcysts possessing an oöcyst residuum (OR) from squirrels of the tribe Sciurini G. Fischer (see McKenna & Bell, 1997) (see Table 1). In addition, no species of *Tamiasciurus* Trouessart (Sciurini) possess oöcysts with an oöcyst residuum (Hill & Duszynski, 1986). No coccidians have been reported, to date, from other members of the Sciurini, including dwarf squirrels, *Microsciurus* spp. Allen, tufted ground squirrel, *Rheithrosciurus macrotis* (Gray), or Bang's mountain squirrel, *Syntheosciurus brochus* Bangs. Even if we make comparisons to ten eimerians with oöcysts possessing an oöcyst residuum from related marmotine rodents (see Hnida, 2019), none are remotely similar to the new species.

Lee & Dorney (1971) reported an *Eimeria* sp. from *S. carolinensis* from Ontario, Canada, with morphological and morphometric features consistent with the new species; a photomicrograph was included but a line drawing was not presented. The only differences between the two are lack of a polar granule, an insignificantly greater mean L/W ratio of the oöcysts (1.7 vs. 1.6), and no mention of a sub-Stieda body in the *Eimeria* sp. (see figure 5 in Lee & Dorney, 1971). These differences are considered negligible and we therefore suggest the new species is the same unnamed eimerian reported by Lee & Dorney (1971). Based on

the differences in morphological and morphometric characteristics noted above, *E. lukfataensis* is considered a species new to science.

Discussion

There is a great diversity of coccidians known from sciurid rodents. There are 285 species within the family Sciuridae Fischer de Waldheim (Wilson & Reeder, 2005) and many have yet to be surveyed for these parasites. Incorporation of molecular techniques will invariably add to our knowledge of these coccidians as well as description of new species. Here, we document the first coccidian reported from *S. carolinensis* from Oklahoma and only the fourth species from squirrels of the tribe Sciurini to have oöcysts that possess an oöcyst residuum.

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Fig. 1.
Composite line drawing of sporulated oöcyst of *Eimeria lukfataensis* n. sp. *Scale-bar:* 10 μ m

Fig. 2. A–F, Nomarski-interference contrast microscopy of sporulated oocysts of *Eimeria lukfataensis* n. sp. from *Sciurus carolinensis*. *Abbreviations:* OR, oocyst residuum; OW, oocyst wall; PG, polar granule; PRB, posterior refractile body; SR, sporocyst residuum; SB, Stieda body. *Scale-bars:* 10 µm

Table 1

Comparison of the sporulated oöcysts of *Eimeria* spp. from squirrels of the Tribe Sciurini possessing an oöcyst residuum

	Type-host (current name) Type-locality	Oöcyst shape, size, features ^{a,b}	Sporocyst shape, size, features ^{a,b}
<i>Eimeria</i> sp.	<i>Sciurus carolinensis</i> Gmelin Ontario, Canada	Ellipsoidal 24.9 14.4; L/W 1.7 15–34 9–20 M, PG: both –	Ellipsoidal to ovoidal 13.6 6.4; L/W 2.0 9–18 4–9 SB, SR: both + SSB, PSB: both –
<i>E. kniplingi</i> Levine & Ivens, 1965	<i>Sciurus niger</i> Linnaeus Iowa, USA	Ellipsoidal to cylindroida 24.2 14.2; L/W 1.7 16–34 11–19 M, PG: both –	Ellipsoidal 13.1 6.7; L/W 2.0 SB, SR: both + SSB:?, PSB: –
<i>E. luisieri</i> (Galli-Valerio, 1935) Reichenow, 1953	<i>Sciurus vulgaris</i> Linnaeus Switzerland	Ovoidal 33 24; L/W 1.4 M +, PG?	Subspheroidal 9 7.5; L/W 1.2 ?
<i>E. lukfataensis</i> n. sp.	<i>S. carolinensis</i> Oklahoma, USA	Ellipsoidal 23.8 14.9; L/W 1.6 19–32 13–18 M: – PG: +	Ellipsoidal 12.5 6.1; L/W 2.0 10–17 5–8 SB, SSB, SR: all + PSB: –

^aMeasurements in µm;

^bDescriptions of oöcysts and sporocysts follow guidelines of Wilber et al. (1998) as follows: oöcyst length (L) and width (W), their ranges and ratios (L/W), micropyle (M), polar granule(s) (PG), sporocyst (SP) length (L) and width (W), their ratio (L/W), Stieda body (SB), sub-Stieda body (SSB), para-Stieda body (PSB), and sporocyst residuum (SR). Key: +, present; –, absent