

Caryospora peneireiroi n. sp. (Apicomplexa: Eimeriidae) in the common kestrel, *Falco tinnunculus* (Falconiformes: Falconidae), in mainland Portugal

Caryospora peneireiroi n. sp. (Apicomplexa: Eimeriidae) no peneireiro, *Falco tinnunculus*
(Falconiformes: Falconidae), em Portugal Continental

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Abstract

The common kestrel *Falco tinnunculus* Linnaeus, 1758, is a widespread raptor, native in Europe, Asia and Africa, and vagrant in the Americas. In the current work, 27 fecal samples were collected from common kestrels kept in the Lisbon Center for Wild Animal Recovery, located at Monsanto Forest Park, Lisbon, Portugal. Five (19%) of them were found to be passing an undescribed species of *Caryospora* in their feces. The oocysts of *Caryospora peneireiroi* n. sp. were ellipsoidal with a bilayered wall and measured $47.1 \times 37.6 \mu\text{m}$ with a shape index of 1.25. No micropyle, oocyst residuum or polar granule was present. The sporocysts were subspherical, measuring $25.1 \times 24.3 \mu\text{m}$. Stieda, sub-Stieda and para-Stieda bodies were absent. The sporocyst residuum was composed of many homogenous globules scattered throughout the periphery of the sporocyst. This is the fourth caryosporan species reported from *F. tinnunculus*.

Keywords: Coccidia, oocysts, morphology, taxonomy, conservation, raptors.

Resumo

O peneireiro *Falco tinnunculus* Linnaeus, 1758, é uma ave de rapina com vasta distribuição geográfica, nativa da Europa, Ásia e África, e errante nas Américas. No presente trabalho, 27 amostras de fezes foram coletadas de peneireiros mantidos no Centro de Recuperação de Animais Silvestres de Lisboa, localizado no Parque Florestal de Monsanto, Lisboa, Portugal. Cinco (19%) deles eliminaram uma espécie não descrita de *Caryospora* em suas fezes. Os oocistos de *Caryospora peneireiroi* n. sp. foram elipsoides, com parede de dupla camada, medindo $47,1 \times 37,6 \mu\text{m}$, e índice morfológico de 1,25. A micrópila, resíduo do oocisto e grânulo polar não foram evidenciados. Os esporocistos foram subsféricos, medindo $25,1 \times 24,3 \mu\text{m}$. Corpos de Stieda, substieda e parastieda não se manifestaram. Resíduo do esporocisto foi composto de muitos glóbulos homogêneos espalhados por toda a periferia do esporocisto. Essa é a quarta espécie *Caryospora* descrita de *F. tinnunculus*.

Palavras-chave: Coccidia, oocistos, morfologia, taxonomia, conservação, aves de rapina.

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Introduction

The common kestrel *Falco tinnunculus* Linnaeus, 1758, is a raptor observed in several environments, easily recognizable through its ability to hover while searching for its prey. In Portugal, this species was one of the most abundant in the 1940s; however, it suffered a sharp decline over the subsequent decades. Nowadays, although the population trend appears to be still decreasing, it is recognized that the population size is still extremely large (PALMA, 1985; Birdlife International, 2015).

Genus *Caryospora* Leger, 1904, is occasionally reported in raptors and reptiles, which act as its definitive hosts, and in rodents, which act as its intermediate hosts (UPTON et al., 1990; BERTO et al., 2014). *Caryospora* is the third largest genus in the family Eimeriidae. *Caryospora* spp. have now been reported worldwide, especially in raptors kept in captivity (UPTON et al., 1992; PAPAZHARIADOU et al., 2001; MCALLISTER et al., 2013a, b). However, little is known about the distribution and importance of species of the genus *Caryospora* in free-living birds (YANG et al., 2014). The current work describes a new species of *Caryospora* from the common kestrels *F. tinnunculus* that were being kept for rehabilitation and reintroduction into the wild at the Lisbon Center for Wild Animal Recovery (Centro de Recuperação de Animais Silvestres de Lisboa, LxCRAS), Monsanto Forest Park, Lisbon, Portugal.

Materials and Methods

Twenty-seven fecal samples were collected from common kestrels that were being kept in individual cages on the premises of the Lisbon Center for Wild Animal Recovery (LxCRAS), located in Monsanto Forest Park, Lisbon, Portugal. The samples were collected immediately after defecation and were placed in plastic

vials containing 2.5% potassium dichromate ($K_2Cr_2O_7$) solution at 1:6 (v/v). In the laboratory, the samples were incubated at room temperature for 10 days or until day three when around 70% of the oocysts had sporulated. The oocysts were recovered by means of flotation in Sheather's sugar solution (specific gravity: 1.20). Morphological observations, line drawings, photomicrographs and measurements were made using an Olympus BX40 microscope equipped with a digital camera (Olympus DP10). The line drawings were edited using two software applications from CorelDRAW® (Corel Draw Graphics Suite, Version 11.0, Corel Corporation, Canada), specifically Corel DRAW and Corel PHOTO-PAINT. All measurements were made in micrometers and are given as the range followed by the mean in parentheses. The descriptions of oocysts and sporocysts followed the guidelines of Duszynski & Wilber (1997) and Berto et al. (2014), as follows: oocyst (O) length (L) and width (W) and their ranges and ratios (L/W); micropyle (M), oocyst residuum (OR), polar granule (PG) and sporocyst (SP) length (L) and width (W) and their ranges and ratios (L/W); and Stieda body (SB), sub-Stieda body (SSB), para-Stieda body (PSB), sporocyst residuum (SR), sporozoite (SZ), refractile body (RB) and nucleus (N).

Results

Caryospora peneireiroi n. sp.

(Figures 1a, b)

Description of sporulated oocyst: Oocyst shape: ellipsoidal; oocyst wall: bilayered, ~2.0 thick; outer layer smooth; L × W (n = 20) 47.1 × 37.6 (42-49 × 34-40); L/W 1.25 (1.2-1.4). M, OR, PG: all absent. Distinctive features of oocysts: large oocyst ellipsoidal lacking M, OR, and PG.

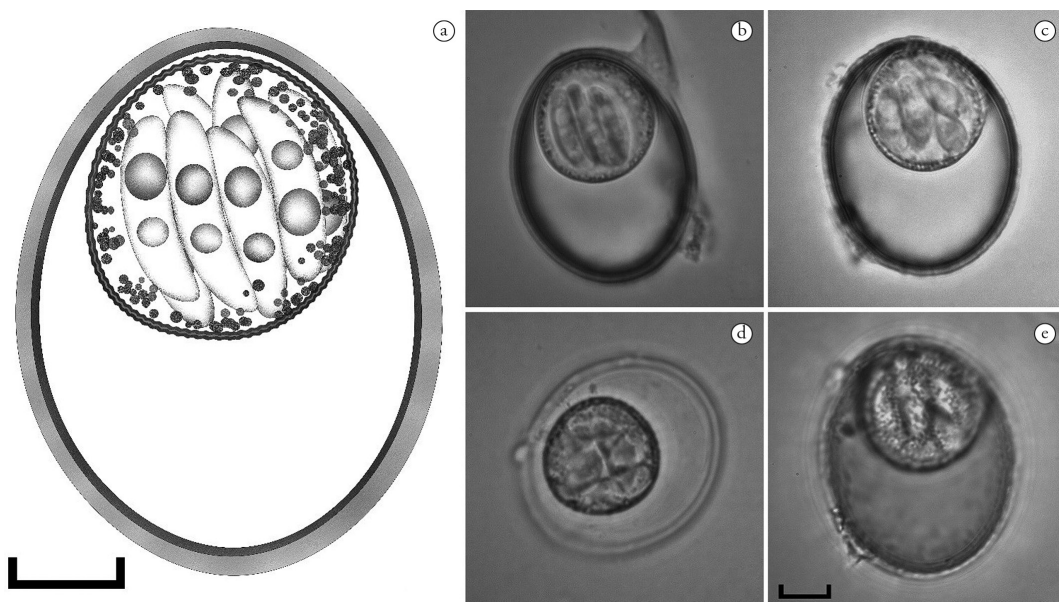


Figure 1. Oocysts of *Caryospora peneireiroi*, a new coccidium species recovered from the common kestrel *Falco tinnunculus*. (a) Composite line drawing; (b-e) Photomicrographs. Bars=10 µm.

Description of sporocyst and sporozoites: Sporocyst shape: subspherical; sporocyst wall: single-layered, ~0.8 thick, slightly rough to wrinkled; L × W (n = 20) 25.1 × 24.3 (24–27 × 24–25); L/W 1.03 (1.0–1.1); SB, SSB, PSB: all absent; SR: present; SR characteristics: composed of many homogenous globules scattered throughout the periphery of the SP. SZ: stout, L × W (n = 5) 17.0 × 4.2 (15–18 × 3–5) in situ, arranged parallel to one another in SP. Each SZ without striations discernible, but with one medium-sized spherical PRB, 3.0 (2–4) wide; single N in midpoint of body. Distinctive features of sporocyst: large size, presence of globules scattered throughout the periphery of the SP, and large SZ.

Taxonomic summary

Type host: common kestrel *Falco tinnunculus* Linnaeus, 1758 (Aves: Falconiformes: Falconidae).

Other hosts: None.

Type specimens: Phototypes and line drawings are deposited and available (<http://r1.ufrrj.br/lcc>) in the Parasitology Collection of the Coccidia and Coccidiosis Laboratory, at the Federal Rural University of Rio de Janeiro (UFRRJ), located in Seropédica, State of Rio de Janeiro, Brazil. Photographs of the type-host specimens (syntypes) are deposited in the same collection. The repository number is P-63/2015.

Type locality: Lisbon Center for Wild Animal Recovery (LxCRAS), Lisbon, Portugal (38°44'22.9" N, 9°11'02.3" W).

Prevalence: Five out of 27 (19%).

Sporulation: Exogenous. All oocysts were passed in the feces unsporulated and were fully sporulated by day 7 in K₂Cr₂O₇ solution at room temperature.

Prepatent and patent periods: Unknown.

Site of infection, definitive host: Unknown. Oocysts recovered from feces.

Site of infection, secondary host: Unknown.

Endogenous stages, definitive host: Unknown.

Endogenous stages, secondary host: Unknown.

Cross-transmission: None to date.

Pathology, definitive host: Unknown.

Pathology, secondary host: Unknown.

Etymology: The specific epithet is derived from the common local name for the host, which is 'peneireiro'.

Remarks

Table 1 and Table 2 show some characteristic features of *Caryospora* spp. described from Accipitriformes and Falconiformes respectively. Of *Caryospora* species listed in Table 1, only *Caryospora aquilae* Volf, Koudela and Modrý, 2000, *Caryospora petersoni* McAllister, Duszynski and McKown, 2013, and *Caryospora hanebrinki* McAllister, Duszynski and McKown, 2013, have oocyst measurements similar to those of *C. peneireiroi*. However, *C. aquilae* can be distinguished through the smooth surface of the SP and smaller SZ, which has N not discernible. *Caryospora petersoni* and *C. hanebrinki*, in turn, can easily be distinguished through the smooth surface of the SP, SR forming a compact mass and SZ with striations. Of the species of *Caryospora* described from Falconiformes (Table 2), only *Caryospora megafalconis* Klüh, 1994, and *Caryospora biarmicusis* Alyousif, Alfaleh and Al-Shawa, 2011, have oocyst measurements similar to those of *C. peneireiroi*. However, *C. megafalconis* can be distinguished through the smooth surface of the SP and SR forming a compact mass. *Caryospora biarmicusis* can be distinguished through the presence of OR and smaller SP with smooth surface.

Discussion

The family Falconidae comprises 66 species of raptors distributed in 11 genera. The genus *Falco* comprises 39 species worldwide, while other genera are exclusively Neotropical (Birdlife International, 2015). The common kestrel *F. tinnunculus* Linnaeus, 1758, is a widespread kestrel species, found throughout Europe, Asia and Africa. In Europe, *F. tinnunculus* is migratory in winter, heading for southern Europe and sub-Saharan Africa (VILLAGE, 1990; Birdlife International, 2015).

Table 1. Comparative data of *Caryospora* spp. described from Accipitridae (Accipitriformes).

Species	Host	Locality	Reference	Oocyst		Sporocyst	
				Shape	Size (µm)	Shape	Size (µm)
<i>C. arcayae</i>	<i>Buteo magnirostris</i> ; <i>Buteo platypterus</i>	Venezuela; USA	Upton et al. (1990)	subspherical	32.9 × 29.4	subspherical	21.9 × 21.8
<i>C. uptoni</i>	<i>Buteo jamaicensis</i>	USA	Lindsay & Blagburn (1986, 1989)	subspherical	28.1 × 26.4	subspherical	18.2 × 17.9
<i>C. kansasensis</i>	<i>Buteo swainsoni</i>	USA	Upton et al. (1990)	ovoid	37.2 × 32.6	spherical	22.5
<i>C. lindsayi</i>	<i>B. jamaicensis</i>	USA	Upton et al. (1990)	subspherical	33.7 × 31.6	subspherical	19.2–22.0
<i>C. aquilae</i>	<i>Aquila chrysaetos</i>	Czech Republic	Volf et al. (2000)	subspherical to ellipsoidal	43.0 × 37.5	subspherical	23.8 × 23.3
<i>C. cirsi</i>	<i>Circus aeruginosus</i>	Czech Republic	Volf et al. (2000)	ovoid	24.5 × 21.8	subspherical	16.2 × 15.6
<i>C. hanebrinki</i>	<i>Haliaeetus</i> <i>leucocephalus</i>	USA	McAllister et al. (2013a)	ellipsoidal to ovoidal	48.1 × 42.1	spherical	24.8
<i>C. petersoni</i>	<i>Accipiter striatus</i>	USA	McAllister et al. (2013b)	subspherical	43.1 × 39.8	subspherical to spherical	23.4 × 23.3

Table 2. Comparative data of *Caryospora* spp. described from Falconidae (Falconiformes).

Species	Host	Locality	Reference	Oocyst		Sporocyst	
				Shape	Size (µm)	Shape	Size (µm)
<i>C. falconis</i>	<i>Falco peregrinus</i> ; <i>Falco subbuteo</i> ; <i>Falco tinnunculus</i>	Europe	Upton et al. (1990); Alfaleh et al. (2013)	subspherical	29.5 × 36.5	subspherical	21.0 × 23.0
<i>C. kutzeri</i>	<i>Falco biarmicus</i> ; <i>Falco cherrug</i> ; <i>Falco jugger</i> ; <i>Falco mexicanus</i>	Europe	Upton et al. (1990); Alfaleh et al. (2013)	subspherical	38.7 × 34.1	ovoid	24.6 × 21.0
<i>C. neofalconis</i>	<i>F. biarmicus</i> ; <i>F. mexicanus</i> ; <i>F. subbuteo</i> ; <i>F. tinnunculus</i> ; <i>F. peregrinus</i>	Europe; Mexico	Upton et al. (1990); Alfaleh et al. (2013); Santana-Sánchez et al. (2015)	subspherical	27.0 × 23.8	ovoid	18.8 × 14.8
<i>C. boeri</i>	<i>F. tinnunculus</i>	Europe	Alfaleh et al. (2013)	subspherical	36.6 × 33.4	ovoid	27.8 × 19.6
<i>C. megafalconis</i>	<i>F. biarmicus</i> ; <i>F. mexicanus</i> ; <i>F. peregrinus</i> ; <i>F. subbuteo</i>	Europe	Alfaleh et al. (2013)	subspherical or ovoid	43.6 × 35.8	spherical	23.8
<i>C. biarmicis</i>	<i>F. biarmicus</i>	Saudi Arabia	Alyousif et al. (2011); Alfaleh et al. (2013)	ovoid	40.2 × 34.7	spherical	20.1
<i>C. cherrughi</i>	<i>F. cherrug</i>	Saudi Arabia	Alfaleh et al. (2013)	ovoid	32.1 × 29.3	ellipsoidal	24.1 × 19.6
<i>C. peneireiroi</i>	<i>F. tinnunculus</i>	Portugal	current work	ellipsoidal	47.1 × 37.6	subspherical	25.1 × 24.3

These geographical ranges and the reports of *Caryospora* spp. from *F. tinnunculus* and other *Falco* spp. emphasize the potential transmission and dispersion of these coccidians in Europe, Asia and Africa. Moreover, this coccidian dispersion may be worldwide if we consider that some specimens of *F. tinnunculus* are vagrant in the Americas and that some *Falco* spp. are native in both the New and the Old World, for example: *Falco columbarius* Linnaeus, 1758, *Falco peregrinus* Tunstall, 1771, and *Falco rusticolus* Linnaeus, 1758. This assumption of coccidian dispersion across species of *Falco* and subsequently of Falconidae is grounded in the concept of intra-familial specificity, which was suggested by Duszynski & Wilber (1997) and has been reaffirmed in several subsequent studies on coccidians in birds (BERTO et al., 2011).

In this regard, the species described in the current study was primarily compared with the *Caryospora* spp. described from Falconidae, which is the single family of Falconiformes. However, since falconids are close to accipitrids, and because earlier studies on *Caryospora* spp. in raptors compared coccidians through descriptions from these two families (UPTON et al., 1986, 1990), *C. peneireiroi* was also compared in the current work with *Caryospora* spp. described from Accipitridae.

Therefore, based on the morphological features described above, *C. peneireiroi* is considered to be new to science and to be the fourth caryosporan species reported from *F. tinnunculus*.

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