



# A New Species of *Eimeria* Schneider, 1875 from the Saffron Finch, *Sicalis flaveola* (Aves: Passeriformes) in Brazil

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## Abstract

**Purpose** The present study describes a new species of *Eimeria* found in free-living *S. flaveola* that inhabit the city of Eugenópolis in the state of Minas Gerais, Brazil.

**Methods** Fecal samples from all captured birds were filtered through double gauze, mixed with 2.5% potassium dichromate ( $K_2Cr_2O_7$ ), placed in a Petri dish and incubated at 23–28 °C until 70% of the oocysts were sporulated.

**Results** *Eimeria flaveola* n. sp. from the saffron finch, *Sicalis flaveola* (Aves: Passeriformes), was described in Brazil. Sporulated oocysts are subspherical;  $22.67 \pm 1.57$  (18.47–26.48)  $\times$   $21.19 \pm 1.42$  (16.69–24.91)  $\mu$ m; with a shape-index of  $1.07 \pm 0.05$  (1.00–1.25)  $\mu$ m and a smooth, bilayered wall,  $\sim 1.09$   $\mu$ m. A micropyle and an oocyst residuum are absent, but one polar granule is present. Sporocysts are ovoidal,  $14.24 \pm 1.71$  (9.02–19.33)  $\times$   $9.98 \pm 1.02$  (6.80–12.87)  $\mu$ m; with a shape-index of  $1.43 \pm 0.16$  (0.74–2.11). The Stieda body is button-shaped; sub-Stieda body and para-Stieda absent. The sporocyst residuum is formed by a compact rounded mass of granules. The sporozoite is claviform, 11.53  $\mu$ m in length and 2.84  $\mu$ m in width, with a refractile body and a nucleus.

**Conclusions** Based on its morphological and morphometric characteristics, we consider *E. flaveola* a newly identified species.

**Keywords** *Eimeria flaveola* · Passeriformes · Saffron finch · Coccidian

## Introduction

The saffron finch *Sicalis flaveola* is one of the many birds belonging to the order Passeriformes and the suborder Oscine, measuring between 11 and 15 cm and showing marked sexual dimorphism [1]. *Sicalis flaveola* inhabit open fields and forage near the ground [2]. They are found throughout South America in open areas with trees, including pastures, plantations and farms [3].

There are few reports of coccidia of the genus *Eimeria* in passerines; however, since 1893, this genus has parasitized

passerines in the Old World [4, 5]. In the Americas, passerine infection with coccidia of this genus has been more recently reported [6, 7]. In the *Sicalis flaveola*, oocysts of *Eimeria* have not yet been reported, but there are reports that birds of the family Emberizidae have been infected with *Eimeria atlapetesi* [8]. The present study describes a new species of *Eimeria* found in free-living *S. flaveola* that inhabit the city of Eugenópolis in the state of Minas Gerais, Brazil.

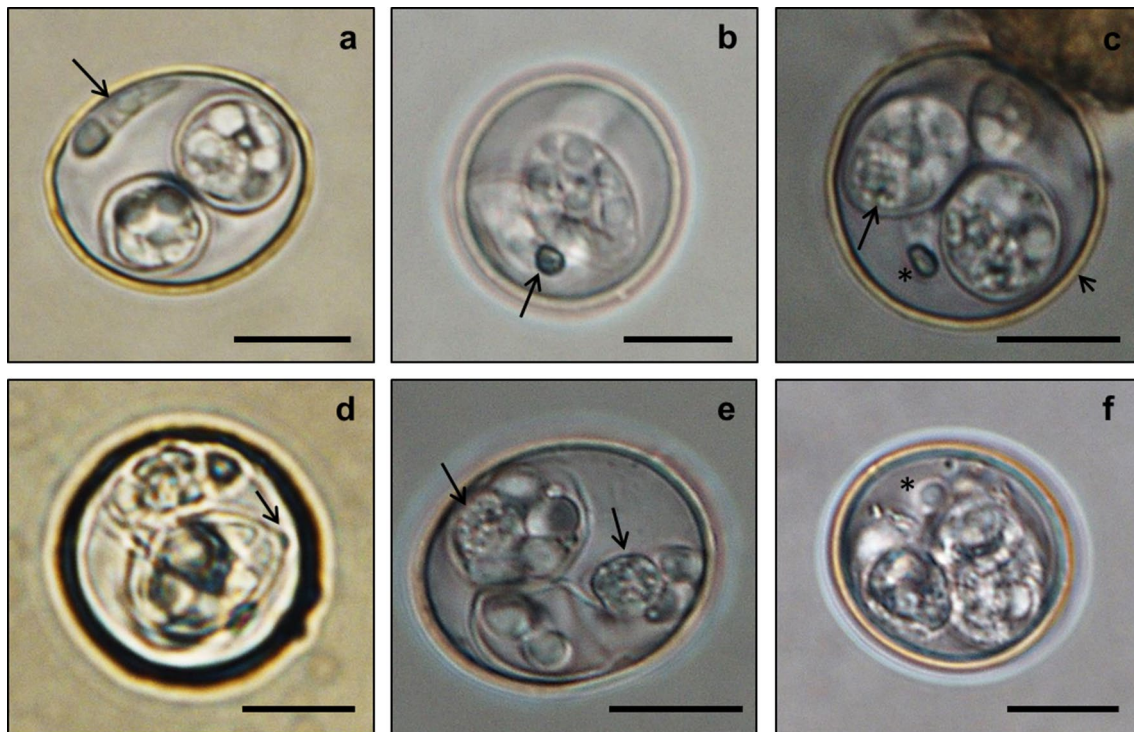
## Materials and Methods

Thirty *S. flaveola* were captured in an ornithological mist net in the municipality of Eugenópolis (21°05'56" S and 42°11'13" W) in Minas Gerais, Brazil. After capture, the birds were housed for 24 h in cages with water and food ad libitum. The feces found at the bottom of the cage were placed in 15 mL tubes, identified, placed in an isothermal box with ice and immediately transported to the Center for Advanced Research in Parasitology (NUPAP) of the

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**Fig. 1** Photomicrographs of *Eimeria flaveola* n. sp. found in the saffron finch *Sicalis flaveola*. a Sporozoite (arrow); b polar granule (arrow); c sporocyst residuum (arrow), polar granule (asterisk) and

oocyst double wall (arrowhead); d stieda body (arrow); e sporocyst residuums (arrows) and f polar granule (asterisk). Scales: 10  $\mu$ m

Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF). Fecal samples from all captured birds were filtered through double gauze, mixed with 2.5% potassium dichromate ( $K_2Cr_2O_7$ ), placed in a Petri dish and incubated at 23–28 °C until 70% of the oocysts were sporulated. Oocysts were retrieved by the flotation method with Sheather's sugar solution and examined microscopically using the method described by Duszynski and Wilber (1997) [9].

Morphological observations and measurements, given in micrometers, were made using an Eclipse i80 optical microscope (Nikon, Japan). Photomicrographs were taken using a Coolpix 5700 digital camera (Nikon, Japan), and the drawings were made by superimposing images at different focuses using CorelDRAW software version 2020. Size ranges are given in parentheses, followed by the mean, standard deviation, and shape-index (length/width).

## Results

Two of the thirty free-living saffron finches examined shed *Eimeria* sp. in the feces and the count of oocysts per gram of feces (OoPG) was 1364 and 1252. Initially, the oocysts were not sporulated, but approximately 70% of the oocysts sporulated by the third day, and it was found that on the

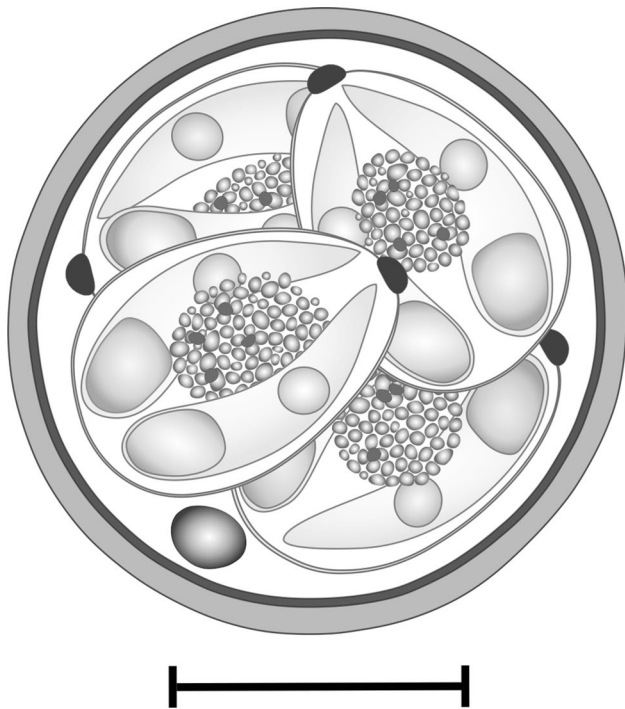
fourth day, more than 80% of these oocysts had complete sporulation under the conditions used in this study.

## Description

### *Eimeria flaveola* n. sp. (Figs. 1 and 2)

**Sporulated oocyst** Subspherical oocysts ( $n = 150$ ),  $22.67 \pm 1.57$  (18.47–26.48)  $\times$   $21.19 \pm 1.42$  (16.69–24.91), with a shape-index of  $1.07 \pm 0.05$  (1.00–1.25). Double wall,  $1.09 \pm 0.14$  (0.77–1.59) thick ( $n = 90$ ), smooth outer surface representing 2/3 of the total thickness. Micropyle and oocyst residuum absent; 1 spherical to subspherical polar granule present ( $n = 71$ ),  $2.94 \pm 0.44$  (1.83–3.96)  $\times$   $2.13 \pm 0.55$  (1.20–3.68).

**Sporocyst and sporozoites** Four ovoid sporocysts ( $n = 104$ ),  $14.24 \pm 1.71$  (9.02–19.33)  $\times$   $9.98 \pm 1.02$  (6.80–12.87) with shape-index of  $1.43 \pm 0.16$  (0.74–2.11) with rounded end; Stieda body ( $n = 3$ ) knob-like,  $1.40 \pm 0.26$  (1.19–1.77) wide  $\times$   $0.59 \pm 0.12$  (0.5–0.76) deep. Sub-Stieda and para-Stieda bodies absent. Sporocyst residuum ( $n = 4$ ) forms a compact mass of granules,  $5.98 \pm 0.66$  (5.12–6.82)  $\times$   $5.67 \pm 0.47$  (5.15–6.20). Claviform sporozoite 11.53 in length and 2.84 in width, with a refractile body ( $n = 2$ ) of  $3.66 \pm 0.5$  (3.16–4.15) by  $3.14 \pm 0.72$  (2.42–3.85) and a nucleus measuring 2.04 by 1.91.



**Fig. 2** Schematic drawing of *Eimeria flaveola* n. sp. found in the saffron finch *Sicalis flaveola*. Bar: 10  $\mu\text{m}$

## Taxonomic Summary

*Type-host* *Sicalis flaveola* Linnaeus (Aves: Passeriformes: Emberizidae).

*Type locality* Eugenópolis (21°05'56" S and 42°11'13" W), Minas Gerais, Brazil.

*Type material* Photosyntypes and linear drawings of sporulated oocysts are deposited and available (<http://r1.ufrj.br/labicoc/colecao.html>) in the Parasitology Collection of the Laboratório de Biologia de Coccídios, at Universidade Federal Rural do Rio de Janeiro, located in Seropédica, Rio de Janeiro, Brazil. Photographs of the host specimens (symbiotypes) are deposited in the same collection. The repository number is P-125/2021.

*Prevalence* 2/30 (6.7%).

*Sporulation time* 3–4 days at a temperature of 23–28 °C.

*Site of infection* Unknown. Oocysts were collected from faecal specimens.

*Etymology* The specific name is derived from the species name of the type host.

## Discussion

Descriptions of the genus *Eimeria* in the order Passeriformes are scarce. According to Duszynski and Wilber (1997) [9], a new coccidian species needs to be compared

in detail with coccidian species that have similar characteristics and belong to the same host family. Twelve species of *Eimeria* spp. have been described with morphological and morphometric characteristics in the order Passeriformes [6, 8–13]. In addition, *Eimeria grallinida* was found in the bird Magpie-lark *Grallina cyanoleuca* Latham, 1802 in Victoria, Australia, by Reece (1989) [14], who reported only stages of liver development. The sporulated oocysts had an average size of 15  $\times$  10  $\mu\text{m}$ , but morphological data were not provided.

In 2019, McAllister and Hnida [13], in Oklahoma, United States, described oocysts and sporocysts of *Eimeria hochatownensis* in barn swallow *Hirundo rustica* Linnaeus (see Table 1), 1758 of the family Hirundinidae as ellipsoids. The mean smaller diameter (15.2  $\mu\text{m}$ ) of the oocysts is lower than that reported in the present study, which justifies its shape. Likewise, the mean of the smallest diameter of the sporocyst (6.5  $\mu\text{m}$ ) is half of the mean of the largest diameter (12.8  $\mu\text{m}$ ), which characterizes its ellipsoid shape, different from that reported in *E. flaveola*. It has 1–3 bilobed granules, differing from the present species that has a single simple polar granule. Other features that distinguish this species are the mamilliform Stieda body and sporozoite lacking a nucleus.

Only one species was described in the family Emberizidae (see Table 1), where *S. flaveola* was found [8, 12]. *Eimeria atlapetesi* Soriano-Vargas *et al.*, 2017 was described in rufous-capped brush finch *Atlapetes pileatus* Wagler, 1831 in Mexico; its oocysts (16.5  $\times$  14.1  $\mu\text{m}$ ) and sporocysts (9.0  $\times$  5.4  $\mu\text{m}$ ) were ellipsoid and smaller than those described in our research. It has a Stieda body that varies from flat to half-moon shape and has a sub-Stieda body, which was not described in this work. Furthermore, the sporozoite lacks a nucleus, though a nucleus is present in *E. flaveola*.

The other two *Eimeria* species described in New World birds belong to the Tyrannidae family (see Table 1). *Eimeria divinolimai* was found in rufous casinornis, *Casinornis rufus* Vieillot, 1816 in Minas Gerais, Brazil [6], but its oocyst is different from the one described in this work, because it is smaller (17.84  $\times$  15.90  $\mu\text{m}$ ), its double wall is thicker (2.13  $\mu\text{m}$ ), the Stieda body is prominent and the sporocyst residuum is granular but diffuse. In addition, the sporozoite has no nucleus. *Eimeria sicki* was described in short-crested flycatcher *Myiarchus ferox* Gmelin, 1789 in Rio de Janeiro, Brazil [7] but differs from *E. flaveola*, because it has much larger oocysts (30.3  $\times$  28.5  $\mu\text{m}$ ) and does not have polar granules. Although the smaller diameter of the sporocyst has the same average size (10  $\mu\text{m}$ ) as those found in the present study, the larger diameter has a higher average size (18.4  $\mu\text{m}$ ), which characterizes the ellipsoid shape of the sporocyst, in contrast to *E. flaveola*, which is ovoid. *Eimeria sicki* also differs from *E. flaveola* as it has a flattened

**Table 1** Comparative morphology and morphometry of *Eimeria* spp. reported in New World passerines

Species	<i>Eimeria flaveola</i>	<i>Eimeria hochatownensis</i>	<i>Eimeria atlapetesi</i> *	<i>Eimeria divinolimai</i>	<i>Eimeria sicki</i>
Host (Family)	<i>Sicalis flaveola</i> (Emberizidae)	<i>Hirundo rustica</i> (Hirundinidae)	<i>Atlapetes pileatus</i> (Emberizidae)	<i>Casiornis rufus</i> (Tyrannidae)	<i>Myiarchus ferrox</i> (Tyrannidae)
Reference	Present research	McAllister and Hnida [13]	Soriano-Vargas <i>et al.</i> [8, 12]	Berto <i>et al.</i> [6]	Berto <i>et al.</i> [7]
Sporulation time	3–4 days	–	4 days	10 days	7 days
Oocyst					
Shape	Subspheroidal	Ellipsoidal	Ellipsoidal	Subspheroidal	Spheroidal to Subspheroidal
Larger diameter	22.67 ± 1.57 (18.47–26.48)	25.5 (20–30)	16.5 (15–20)	17.84 ± 1.52 (15.61–20.00)	30.3 (29–32)
Smaller diameter	21.19 ± 1.42 (16.69–24.91)	15.2 (12–17)	14.1 (13–15)	15.90 ± 0.99 (14.15–17.80)	28.5 (26–30)
Shape-index	1.07 ± 0.05 (1.00–1.25)	1.7 (1.5–2.0)	1.17 (1.1–1.3)	1.12 ± 0.05 (1.01–1.20)	1.1 (1.0–1.2)
Wall	Double 1.09 ± 0.14 (0.77–1.59)	Double 1.0 (0.8–1.5)	Double 1.0 (0.9–1.1)	Double 2.13 ± 0.16 (2.00–2.38)	Double 1.3 (1–2)
Micropyle	Absent	Absent	Absent	Absent	Absent
Polar granule	Present (spherical to subspherical)	Bilobed (1–3)	Present (1 or 2)	Present (subspherical)	Absent
Oocyst residuum	Absent	Absent	Absent	Absent	Absent
Sporocyst					
Shape	Ovoid	Ellipsoid	Ellipsoid	Ovoid	Ellipsoid
Larger diameter	14.24 ± 1.71 (9.02–19.33)	12.8 (10.0–16.0)	9.0 (8–9)	14.98 ± 0.85 (13.81–16.19)	18.4 (18–19)
Smaller diameter	9.98 ± 1.02 (6.80–12.87)	6.5 (5.0–8.0)	5.4 (5.0–6.0)	7.50 ± 0.44 (6.76–8.09)	10 (9–11)
Shape-index	1.43 ± 0.16 (0.74–2.11)	2.0 (1.6–2.3)	1.67 (1.5–1.9)	–	1.8 (1.7–2)
Stieda body (Width x Height)	Knob-like (1.40 × 0.59)	Mamiliform (1.1 × 2.2)	Flattened to half-moon shape (0.5 × 1.5)	Prominent	Flattened (0.5 × 2.8)
Sub-stieda body (Width x Height)	Absent	Absent	Rectangular to rounded (1.0 × 2.0)	Absent	Prominent (2.4 × 3.0)
Sporocyst residuum	Granular Compact	Granular Compact or Irregular	Granular Compact	Granular Diffuse	Granular Diffuse
Sporozoite					
Larger diameter	11.53	–	–	–	–
Smaller diameter	2.84	–	–	–	–
Refractile body	1	1	1	1	1
Nucleus	Present	Absent	Absent	Absent	Absent

\*Originally described as *Eimeria pileata* (see Soriano-Vargas *et al.* 2015) [8]; replacement name above (see Soriano-Vargas *et al.* 2017)

and wider Stieda body (2.8 µm), a prominent sub-Stieda body, diffuse sporocyst residuum and the sporozoite lacks a nucleus.

Due to the scarcity of descriptions of Eimerian parasites in the Emberizidae family and in the New World, *E. flaveola* was also compared with *Eimeria balozeti* Yakimoff and Gouseffé (1938), *Eimeria anili* Haldar *et al.* (1982), *Eimeria malaccae* Chakravart and Kar (1944), *Eimeria depuytoraci* Cerná (1976), *Eimeria paradisaeai* Varghese (1977),

*Eimeria saubenovae* Dzerzhinskii and Kairullaev (1989), *Eimeria lucknowensis* Misra (1946) and *Eimeria roscoviensis* Labbé (1893a, b; 1896) from passerine birds belonging to different families in the Old World (see Table 2).

*Eimeria balozeti* was found in Russia in European starling *Sturnus vulgaris* Linnaeus, 1758 of the Sturnidae family [15]; its oocyst is oval and has no polar granules. Furthermore, the sporocyst lacks a Stieda body and residuum, and the sporozoite lacks a nucleus.

**Table 2** Comparative morphology and morphometry of *Eimeria* spp. reported in Old World passerines

Species	<i>Eimeria flavicola</i>	<i>Eimeria balozeti</i>	<i>Eimeria anili</i>	<i>Eimeria malaccae</i>	<i>Eimeria depuytoraci</i>	<i>Eimeria paradisaeci</i>	<i>Eimeria saubhenovae</i>	<i>Eimeria luc-knowensis</i>	<i>Eimeria roscovienensis</i>
Host (Family)	<i>Sicalis flaveola</i> (Emberizidae)	<i>Sturnus vulgaris</i> (Sturnidae)	<i>Sturnus contra</i> (Sturnidae)	<i>Lonchura malacca</i> (Estrilidae)	<i>Sylvia curruca</i> (Sylviidae)	<i>Paradisaea ragiana</i> (Paradisaeidae)	<i>Lanius collurio</i> (Laniidae)	<i>Motacilla alba</i> (Motacillidae)	<i>Motacilla alba</i> (Motacillidae)
Reference	Present research	Yakimoff and Gouseffe [15]	Haldar et al. [16]	Chakravarty and Kar [17]	Cerná [18]	Varghese [19]	Dzerzhinskii and Kairullaev [20]	Misra [21]	Labbé [4, 5, 10]
Sporulation time	3–4 days	–	3 days	–	–	5 days	–	3–4 days	–
Oocyst									
Shape	Subspheroidal	Oval	Oval	Oval	Spheroidal or oval	Oval	Spheroidal	Oval	Pitiform
Larger diameter	22.67 ± 1.57 (18.47–26.48)	19.52–30.60	15.7 (14.1–17.4)	26.8–30.9	Spheroidal: 13–14 Oval: 17–19	30.0 (28.0–31.0)	10.1	21.4–24.5	16.0–18.0
Smaller diameter	21.19 ± 1.42 (16.69–24.91)	17.08–26.60	12.8 (12.3–13.3)	16.4–18.5	Oval: 12–17	26 (24–28)	10.1	17.4–18.8	14.0–16.0
Shape-index	1.07 ± 0.05 (1.00–1.25)	1 (0.70–0.87)	–	–	–	1–1.1	–	–	–
Wall	Double	Double	Double	Double	Double	Double	Simple 0.5	Double	Double
	1.09 ± 0.14 (0.77–1.59)								
Micropyle	Absent	Absent	Present	Present	Absent	Absent	Absent	Absent	Pseudomicropyle
Polar granule	Present (spherical to subspherical)	Absent	Absent	Absent	Present (1 or 2)	Present	Present	Absent	Present 2
Oocyst residuum	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Sporocyst									
Shape	Ovoid	Ovoid	Ovoid	Ovoid	Ovoid	Ovoid	Ovoid	Ovoid	Pitiform
Larger diameter	14.24 ± 1.71 (9.02–19.33)	12.20–14.40	8.2 (7.3–9.1)	12.4	8.0–9.0	17.0 (14.0–18.0)	5.8	8.5	–
Smaller diameter	9.98 ± 1.02 (6.80–12.87)	7.20–8.54	5.2 (5.0–5.5)	10.3	–	6.0	2.9	6.0	–
Shape-index	1.43 ± 0.16 (0.74–2.11)	–	1.2	–	–	–	–	–	–
Stieda body (Width × Height)	Knob-like (1.40 × 0.59)	Absent	Present	Pointed	Indistinct	Distinct	Absent	Absent	Knob-like
sub-Stieda body (Width × Height)	Absent	Absent	Absent	Knob-like	Absent	Absent	Absent	Absent	Absent
Sporocyst residuum	Granular Compact	Absent	Granular Compact	Granular Diffuse	Granular Compact	Granular Compact	Absent	Granular Compact	Granular Compact

Table 2 (continued)

Species	<i>Eimeria flaveola</i>	<i>Eimeria balozeti</i>	<i>Eimeria anili</i>	<i>Eimeria malaccae</i>	<i>Eimeria deputytoraci</i>	<i>Eimeria paradisaeai</i>	<i>Eimeria saubenovae</i>	<i>Eimeria lucknowensis</i>	<i>Eimeria roscoviensis</i>
Host (Family)	<i>Sicalis flaveola</i> (Emberizidae)	<i>Sturnus vulgaris</i> (Sturnidae)	<i>Sturnus contra</i> (Sturnidae)	<i>Lonchura malacca</i> (Estrildidae)	<i>Sylvia curruca</i> (Sylviidae)	<i>Paradisaea raggiana</i> (Paradisaeidae)	<i>Lanius collurio</i> (Laniidae)	<i>Motacilla alba</i> (Motacillidae)	<i>Motacilla alba</i> (Motacillidae)
Reference	Present research	Yakimoff and Gouseffe [15]	Haldar et al. [16]	Chakravarty and Kar [17]	Cerná [18]	Varghese [19]	Dzerzhinskii and Kairullaev [20]	Misra [21]	Labbé [4, 5, 10]
Sporozoite									
Larger diameter	11.53	–	7.0 (6.7–7.3)	8.3	–	–	2.9	7.0	–
Smaller diameter	2.84	–	1.7 (1.7–1.7)	2.1	–	–	1.45	–	–
Refractile body	1	1	1	Absent	Absent	1	–	Absent	–
Nucleus	Present	Absent	Absent	Present	Absent	Absent	–	Present	–

*Eimeria anili* was described in India in Asian pied starling *Sturnus contra* Linnaeus, 1758 which belongs to the same family as *S. vulgaris* Linnaeus [16]. The oocyst is oval with a smaller mean size of oocyst ( $15.7 \times 12.8 \mu\text{m}$ ) and sporocyst ( $8.2 \times 5.2 \mu\text{m}$ ) than those reported in *E. flaveola*. It has a micropyle but no polar granules, and the sporozoite ( $7.0 \times 1.7 \mu\text{m}$ ) is smaller than that of the present study and has no nucleus.

In addition, in India, Chakravart and Kar (1944) described *Eimeria malaccae* in Black-headed Munia *Lonchura malacca* Linnaeus, 1766 of the family Estrildidae [17] as ovoid, with micropyles and no polar granules. The Stieda body is pointed, and the sub-Stieda body is button-shaped. The sporocyst residuum is diffuse, and the sporozoite, in addition to being smaller ( $8.3 \times 2.1 \mu\text{m}$ ) than that of the current study, does not have a refractile body.

*Eimeria deputytoraci* was found in the Czech Republic in Lesser Whitethroat *Sylvia curruca* Linnaeus, 1758 belonging to the family Sylviidae [18]. The dimensions of oocysts ( $17\text{--}19 \times 12\text{--}17 \mu\text{m}$ ) and sporocysts ( $8.0\text{--}9.0 \mu\text{m}$ ) are considerably smaller than those reported in *E. flaveola* n. sp. The Stieda body of the sporocyst was reported by the author as indistinct, as it was not possible to visualize in the schematic drawing. The sporozoites do not have a nucleus or a refractile body.

The following year in Papua New Guinea, Varghese (1977) described *Eimeria paradisaeai* in Raggiana bird-of-paradise *Paradisaea raggiana* Sclater, 1873 of the family Paradisaeidae [19] as having oval oocysts, with the diameters of both oocysts ( $30 \times 26 \mu\text{m}$ ) and sporocysts ( $17 \times 6 \mu\text{m}$ ) larger than those found in the present research. The Stieda body found in the sporocyst was reported to be distinct; however, in the schematic drawing, it resembles a flattened shape. The sporozoites do not have a nucleus.

*Eimeria saubenovae* of the family Laniidae was described in Red-backed Shrike *Lanius collurio* Linnaeus, 1758 in Kazakhstan by Dzerzhinskii and Kairullaev (1989) [20]. The oocysts, sporocysts and sporozoites of this species are very small and it also has only a single wall. It does not have a Stieda body or sporocyst residuum.

Two other species of the genus *Eimeria* were described in White Wagtail *Motacilla alba* Linnaeus, 1758 of the family Motacillidae. *Eimeria lucknowensis* was found by Misra (1946) [21] in India; it has an oval-shaped oocyst without a polar granule. The sporocysts are smaller ( $8.5 \times 6.0 \mu\text{m}$ ) than those found in *E. flaveola* and have no Stieda body. The sporozoite, in addition to being smaller ( $7 \mu\text{m}$ ), does not have a refractile body. *Eimeria roscoviensis* [4, 10] was reported in Russia; it has piriform-shaped oocysts and sporocysts. These oocysts ( $16\text{--}18 \times 14\text{--}16 \mu\text{m}$ ) are much smaller than those found in the present study, in addition to having a pseudomicropyle and two polar granules. The sporocyst

morphometric and sporozoite morphological data were not provided.

Based on its morphological and morphometric characteristics, we consider *E. flaveola* a newly identified species. It represents the fifth species described in passerine birds of the New World and the second species described in a bird of the Emberizidae family.

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## Declarations

**Conflict of Interest** The authors declare no competing interests.

**Ethical Approval** This study was approved by the Biodiversity Authorization and Information System (SISBIO) under protocol n° 78016–1.

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