Turkish Journal of Zoology

Volume 38 | Number 2 Article 3

1-1-2014

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TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2014) 38: 136-143
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doi:10.3906/zoo-1303-21

Rumen ciliate fauna (Ciliophora, Protista) of Turkish domestic goats living in İzmir, Turkey

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Received: 17.03.2013 • **Accepted:** 14.10.2013 • **Published Online:** 17.01.2014 • **Printed:** 14.02.2014

Abstract: Species composition and distribution of rumen ciliates were investigated in the rumen contents of 15 domestic goats living in İzmir, Turkey. Nineteen species and 10 morphotypes belonging to 7 genera were identified. The mean number of ciliates was (94.3 ± 33.4) × 10^4 cells mL^{-1} rumen contents, which is higher than that of other goat hosts reported from Turkey and the world. The mean number of ciliate species per host was 9.2 ± 3.4. *Entodinium semahatae*, *E. rostratum*, and *Ophryoscolex purkynjei* m. bifidoquadricinctus are new host records for goats. This is only the second reported occurrence of *E. semahatae* in herbivorous mammals. *E. nanellum* was found to be the dominant species occurring in all animals.

Key words: *Capra*, ciliate, goat, İzmir, Trichostomatia, Protista, rumen, Turkey

1. Introduction

The only previous reports from Turkey on rumen ciliate protozoa in domestic goats were from animals living in the southeastern section of Turkey (Göçmen and Atatür, 2002; Göçmen et al., 2002, 2005; Göçmen and Rastgeldi, 2004; Göçmen and Karaoğlu, 2005). Comparative investigations of the rumen ciliate populations of various hosts in different areas should provide information on phylogenetic connections between the rumen ciliates and the host ruminants. Some species could possibly be host-specific (Dogiel, 1927; Dehority, 1978; Imai, 1988; Ito and Imai, 1990; Ito et al., 1995; Göçmen and Öktem, 1996). Faunation of young ruminants or transfaunation between adult ruminants occurs only as a result of direct contact between animals. A mother can transfer ciliate protozoa to her young by grooming, in which case the protozoa present in her mouth from rumination are passed in the saliva. In addition, a ruminant can salivate on feed or forage plants in the field, infecting a second animal when these feeds are ingested (Dehority, 2003).

There have been several investigations on the rumen ciliated protozoan fauna of domestic cattle and sheep living in the vicinity of İzmir, Turkey (Göçmen and Öktem, 1996; Öktem et al., 1997; Göçmen et al., 1999, 2001, 2003); however, no studies have been published on the ciliate fauna of domestic goats living in this area. The aim of this investigation is to identify the rumen ciliate fauna in domestic goats living in İzmir, Turkey, and to compare this information with studies from goats in other regions of Turkey and the world.

2. Materials and methods

Samples of rumen contents were obtained from 15 domestic goats (*Capra hircus*) at a slaughterhouse near İzmir, Turkey, between July 2012 and October 2012. The rumen wall was cut with a knife and a sample was obtained by inserting a ladle into the rumen. A well-mixed sample of the rumen content was fixed with 18.5% formalin immediately (Dehority, 1984). A portion of each sample was also immediately added to methyl green formalin saline (MFS) solution for total and differential counts (Ogimoto and Imai, 1981; Göçmen and Gürelli, 2009). The MFS was used as a nuclear stain, and Lugol's iodine was used to indicate skeletal plates (Gürelli and Göçmen, 2012).

Ciliate densities were calculated with a Neubauer hemocytometer counting chamber. A total of 700–1200 cells in each sample were used for estimation of percentage composition of each species (Göçmen and Gürelli, 2009).

The identification and classification of species was based on descriptions from studies by Dogiel (1927), Ogimoto and Imai (1981), Öktem et al. (1997), and Lynn (2008).

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3. Results

The mean number (±SD) of ciliates in rumen contents from the 15 Turkish domestic goats was (94.3 ± 33.4) × 10^4 cells per mL (SE = 18.6). Values ranged from 52.5 × 10^4 to 150.0 × 10^4 (Table 1). Nineteen species and 10 morphotypes in 7 genera were identified. The majority of ciliates present in all 15 animals were *Entodinium* species, which constituted from 10.0% to 99.9% of the total protozoa. All Turkish domestic goats harbored *E. nanellum*. Of the other species, frequency of appearance of individual species ranged from 6.7% for *Enoploplastron triloricatum* up to 93.3% for *Entodinium minimum* (Table 2). For individual animals, the total number of species ranged from 4 to 15, with an average of 9.2 ± 3.4.

4. Discussion

The average ciliate density in rumen contents of domestic goats living in İzmir, Turkey, at (94.3 ± 33.4) × 10^4 cells mL^{-1}, was considerably higher than that of Turkish domestic goats living in southeastern Turkey [(33.2 ± 11.5) × 10^4 cells mL^{-1}; Göçmen et al., 2005], Tokara native goats in Japan (43.2 × 10^4 cells mL^{-1}; Ito et al., 1995), and Alaskan goats (53.7 × 10^4 cells mL^{-1}; Dehority, 1975). This variation may be the result of differences in feed, species, or geographical location, or a combination of these factors.

Table 1. Ciliate density in the rumen contents of 15 domestic goats.

Goat no.	Ciliate density (×10^4 cells mL^{-1})
1	70.5
2	68.5
3	59.5
4	100.0
5	148.0
6	103.5
7	63.0
8	150.0
9	78.0
10	117.5
11	69.5
12	76.5
13	52.5
14	117.5
15	139.5
	Mean ± SD = 94.3 ± 33.4

İzmir is located in the western region of Turkey, where vegetation is more nutritious than in the southeast. This may explain the higher ciliate density for goats in İzmir as compared to that of domestic goats living in southeastern Turkey.

In general, the fauna of almost all 15 Turkish domestic goats was primarily composed *Entodinium* species (mean: 82.7%; range: 10.0%–99.9%). *Entodinium nanellum* was found in all 15 goats. Eating habits vary between browsing and grazing animals with subsequent differences in their fauna (Dehority and Odenyo, 2003). Many of the browsers possess an all-*Entodinium* fauna, and, in some cases, only a single species of *Entodinium* (Dehority, 1990, 1994). Goats are intermediate feeders (or opportunistic feeders). They do not tolerate high fiber levels and are forced to consume less fibrous parts of plants and alter their feeding behavior according to seasonal changes in diet availability (Cannas and Pulina, 2008). A diet of browse tends to lack fiber and consequently is rapidly fermented by the rumen bacteria, with a subsequent lowering of rumen pH. The establishment of a fauna composed of entodinia alone has been attributed to the low pH in the rumen (Eadie, 1962; Hungate, 1966; Wilkinson and Van Hoven, 1976; Nakamura et al., 1988; Gürelli et al., 2012). As stated by Ito et al. (1993), the rumen of intermediate-type feeders may have environmental factors more advantageous for the growth of entodinia than those of the true browser or true grazer.

In Turkish domestic goats, the density of *Entodinium* morphotypes without caudal spines was higher than that of the morphotypes with caudal spines. This suggests that the feeding habits and species composition of animals belonging to the genus *Capra* might favor the growth of morphotypes without caudal spines (Ito et al., 1995). Lubinsky (1957) suggested that when animals are fed a diet with low starch value, ciliates without caudal spines are predominant. The selection of particular foods and the quantities eaten by different ruminant species are important factors in establishing fauna composition (Dehority, 1974; Ito et al., 1993; Gürelli et al., 2012). In hosts consuming high-concentrate diets, both the percentage of entodiniid species and their total density became higher (Hungate, 1966; Ito et al., 1994). It has mostly been accepted, but not proven, that the *Entodinium*-only fauna is the result of an either an extremely low pH, a rapid rate of passage of fluid and particulate matter through the rumen, ingestion of specific toxic or inhibitory substances, or a combination of all these factors (Hungate, 1966; Wilkinson and Van Hoven, 1976; Dehority 1990, 1995). Coleman et al. (1977) considered that the caudal spines of *Entodinium* served to protect against engulfment by larger carnivorous ciliates such as *Entodinium bursa* and *Polyplastron multivesiculatum*. At this time, the exact reason for spine development is not known.

Table 2. Frequency of appearance and percentage composition of rumen ciliates in the rumen contents of 15 domestic goats.

Genus/species/morphotype	Frequency appearance (%)	Percentage composition (%)	
		Mean ± SD	Range
Entodinium	100.0	82.7 ± 23.1	10.0–99.9
E. rostratum Fiorentini, 1889	20.0	2.1 ± 4.4	0–12.4
E. exiguum Dogiel, 1925	80.0	9.5 ± 6.0	0–22.4
E. longinucleatum Dogiel, 1925	66.7	6.6 ± 6.5	0–23.2
E. nanellum Dogiel, 1923	100.0	17.5 ± 4.3	10.2–24.8
E. minimum Schuberg, 1888	93.3	10.8 ± 4.9	0–22.9
E. dilobum (Dogiel, 1927)	53.3	2.5 ± 3.0	0–10.1
E. parvum Buisson, 1923	40.0	1.9 ± 2.7	0–8.2
E. ellipsoideum (Kofoid and MacLennan, 1930)	60.0	6.3 ± 6.1	0–15.2
E. semahatae Öktem et al., 1997	13.3	0.4 ± 1.1	0–4.2
E. bursa Stein, 1858	13.3	2.2 ± 5.9	0–20.3
E. caudatum Stein, 1858	33.4	5.7 ± 9.5	0–31.8
m. dubardi Lubinsky, 1957	26.7	4.2 ± 7.8	0–24.1
m. caudatum Stein, 1858	13.3	1.5 ± 4.2	0–14.7
E. rectangulatum Kofoid and MacLennan, 1930	20	3.2 ± 8.5	0–28.7
m. lobospinosum Lubinsky, 1957	6.7	0.5 ± 1.9	0–7.3
m. dubardi Lubinsky, 1957	6.7	4.2 ± 7.8	0–24.1
m. rectangulatum Kofoid and MacLennan, 1930	20	1.8 ± 5.0	0–18.6
E. simulans Lubinsky, 1957	86.7	23.7 ± 17.2	0–64.5
m. dubardi Lubinsky, 1957	33.3	6.8 ± 13.0	0–47.7
m. lobospinosum Lubinsky, 1957	20	1.5 ± 3.3	0–9.8
m. caudatum Lubinsky, 1957	86.7	14.9 ± 13.0	0–47.7
Isotricha	46.7	2.0 ± 4.4	0–17.1
I. prostoma Stein, 1858	46.7	2.0 ± 4.4	0–17.1
Dasytricha	40	1.8 ± 2.9	0–9.7
D. ruminantium Schuberg, 1888	40	1.8 ± 2.9	0–9.7
Polyplastron	80	3.4 ± 3.2	0–8.3
P. multivesiculatum (Dogiel and Fedorowa, 1925)	80	3.4 ± 3.2	0–8.3
Metadinium	40	3.4 ± 6.0	0–20.7
M. affine (Dogiel and Fedorowa, 1925)	40	3.4 ± 6.0	0–20.7
Ophryoscolex	26.7	0.8 ± 1.8	0–6.8
O. purkynjei Stein, 1858	26.7	0.8 ± 1.8	0–6.8
m. purkynjei Stein 1858	13.3	0.5 ± 1.8	0–6.8
m. bifidoquadricinctus Göçmen, 1999	13.3	0.3 ± 0.7	0–2.0
Enoploplastron	6.7	0.4 ± 1.6	0–6.4
E. triloricatum (Dogiel, 1925)	6.7	0.4 ± 1.6	0–6.4

Total species, morphotypes, and genera number: 19, 10, and 7.

Rumen ciliate populations have been classified into 4 main groups: A, B, K, and O (Eadie, 1957, 1962; Imai et al., 1978, 1979; Ogimoto and Imai, 1981; Williams and Coleman, 1992; Göçmen et al., 2005). All 4 groups include the genera *Isotricha*, *Dasytricha*, and *Entodinium*, but are differentiated from each other based on the presence or absence of specific species. Type A populations are defined as those that specifically contain *Polyplastron multivesiculatum* and usually, but not always, *Metadinium affine*. Type B populations contain *Epidinium* sp., *Eudiplodinium maggii*, or both. Type K populations are normally limited to cattle populations, specifically containing *Elytroplastron bubali*. Type O populations contain only *Isotricha*, *Dasytricha*, and *Entodinium*. It is generally assumed that Type A populations are predominant since the predatory activity of *P. multivesiculatum* can eliminate *Epidinium* sp., *Eudiplodinium maggii*, and other species of Ophryoscolecidae. Twelve of the 15 Turkish goats (80%) were Type A; the remaining 3 animals (20%) were Type O.

E. semahatae (Figures 1a and 1b) was first described from sheep living in the vicinity of İzmir, Turkey (Öktem et al., 1997), and it has now been found in goats living in the same area. It was not detected from goats living in southeastern Turkey (Göçmen et al., 2005). *E. salmani*, which was found in the rumen of goats living in southeastern Turkey, was not detected in goats living in İzmir. *E. nanellum* and *E. simplex* are distributed in many ruminants worldwide (Dogiel, 1927; Ogimoto and Imai, 1981); however, *E. simplex* was not present in the rumen of goats living in İzmir, Turkey. *Entodinium basoglui* was first detected from the rumen of cattle living in İzmir (Göçmen and Öktem, 1996) and was also detected from goats living in southeastern Turkey (Göçmen et al., 2005), but it was not observed in the rumen of goats living in İzmir.

E. semahatae resembles *E. dilobum* (Dogiel, 1927), having 2 lobes at the posterior end of the body and a similar location of the contractile vacuole and micronucleus. However, the posterior part of the body is wider than in *E. dilobum*. The width between the 2 posterior lobes of *E. semahatae* is greater than in *E. dilobum*, and the body shape is ellipsoidal as compared to the ovoid shape of *E. dilobum*.

Table 3 summarizes the frequency of occurrence of the different species and morphotypes reported from goats in various geographical locations. Nineteen species and 10 morphotypes in 7 genera were detected in Turkish domestic goats living in İzmir, Turkey. These numbers are greater than what has been reported for Indian (Das-Gupta, 1935) and Japanese (Imai et al., 1978; Ito et al., 1995) goats, but lower than the concentration in domestic goats living in southeastern Turkey (Göçmen et al., 2005). This is the first report of *E. rostratum* and *Ophryoscolex purkynjei* m. bifidoquadricinctus from goats.

In conclusion, the host animal species and its feeding habits, rumen pH, cross-inoculation, and antagonism

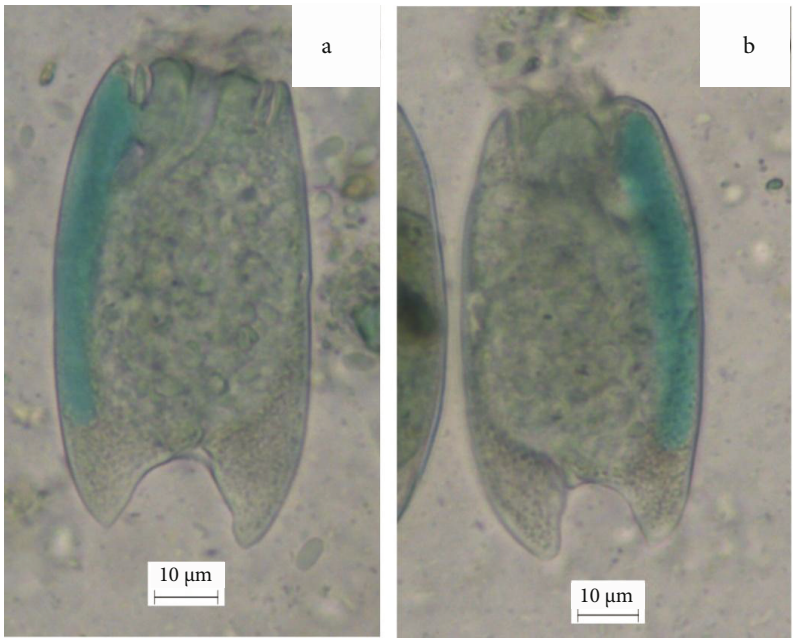

Figure 1. Photomicrographs of *E. semahatae*, fixed and stained with MFS. The cell is in the early stage of binary fission. **a)** From right side, **b)** from left side.

Table 3. Frequency of appearance of each ciliate species and morphotype detected in the rumen contents of goats from Turkey and several other countries [1. Das-Gupta (1935): India; 2. Imai et al. (1978): Japan; 3. Ito et al. (1995): Japan; 4: Göçmen et al. (2005): Turkey; 5. Present study: Turkey].

Species/morphotype	1 (n = 12)	2 (n = 10)	3 (n = 15)	4 (n = 8)	5 (n = 15)
Isotricha prostoma	100.0	70.0	53.3	87.5	46.7
I. intestinalis	-	40.0	60.0	62.5	-
Dasytricha ruminantium	100.0	50.0	86.7	75.0	40.0
Entodinium basoglui	-	-	-	12.5	-
Entodinium bovis	-	-	-	50.0	-
Entodinium bursa	-	-	-	25.0	13.3
E. caudatum m. caudatum	16.6	90.0	-	62.5	13.3
E. caudatum m. dubardi	-	-	-	75.0	26.7
E. caudatum m. lobosospinosum	-	-	-	50.0	-
E. dalli m. rudidorsospinatum	-	-	-	50.0	-
E. constrictum	-	-	-	62.50	-
E. dilobum	16.6	70.0	-	87.5	53.3
E. dubardi	83.3	10.0	-	87.5	-
E. ellipsoideum	-	-	-	37.5	60.0
E. exiguum	-	50.0	-	100.0	80.0
E. longinucleatum	25.0	90.0	-	100.0	66.7
E. minimum	-	70.0	-	75.0	93.3
E. rostratum	-	-	-	-	20.0
E. nanellum	8.3	100.0	100.0	100.0	100.0
E. ovinum	25.0	70.0	40.0	50.0	-
E. parvum	-	100.0	93.3	100.0	40.0
E. rectangulatum m. rectangulatum	16.6	-	66.7	75.0	20.0
E. rectangulatum m. lobosospinosum	-	-	86.7	50.0	6.7
E. rectangulatum m. dubardi	-	-	100.0	50.0	6.7
E. salmani m. salmani	-	-	-	12.5	-
E. salmani m. monospinosum	-	-	-	12.50	
E. salmani m. bispinosum	-	-	-	12.50	-
E. salmani m. trispinosum	-	-	-	12.50	-
E. simplex	100.0	100.0	100.0	100.0	-
E. simulans m. caudatum	-	-	-	75.0	86.7
E. simulans m. lobosospinosum	-	-	-	25.0	20.0
E. simulans m. dubardi	-	-	-	-	33.3

Table 3. (Continued).

Species/morphotype	1 (n = 12)	2 (n = 10)	3 (n = 15)	4 (n = 8)	5 (n = 15)
E. williamsi m. williamsi	-	-	-	75.0	-
E. williamsi m. turcicum	-	-	-	12.5	-
Diplodinium crista-galli	16.6	-	-	12.5	-
D. dentatum	33.3	30.0	-	25.0	-
D. flabellum m. flabellum	-	-	-	12.5	-
D. flabellum m. aspinatum	-	-	-	37.5	-
D. flabellum m. monospinatum	-	-	-	12.5	-
D. flabellum m. laterospinatum	-	-	-	12.5	-
Eudiplodinium bovis	-	-	-	12.5	-
Eudiplodinium maggii	33.3	50.0	-	37.5	-
Metadinium affine	8.3	-	46.7	25.0	40.0
M. banksi	-	-	-	12.5	-
Ostracodinium gracile	-	-	-	12.5	-
O. quadrivesiculatum	-	-	-	12.5	-
O. trivesiculatum	-	-	-	25.0	-
P. multivesiculatum	-	-	73.3	12.5	80.0
Elytroplastron bubali	33.3	-	-	37.5	-
Enoploplastron triloricatum	-	-	-	25.0	6.7
E. ecaudatum m. ecaudatum	16.6	50.0	-	37.5	-
E. ecaudatum m. caudatum	33.3	50.0	-	37.5	-
E. ecaudatum m. bicaudatum	-	-	-	12.5	-
E. ecaudatum m. tricaudatum	-	-	-	12.5	-
E. ecaudatum m. quadricaudatum	-	-	-	12.5	-
E. ecaudatum m. parvicaudatum	-	-	-	50.0	-
E. ecaudatum m. cattanei	33.3	-	-	50.0	-
Ophryoscolex purkynjei m. purkynjei	-	-	-	37.5	13.3
O. purkynjei m. bifidoquadricinctus	-	-	-	-	13.3
O. purkynjei m. tricoronatus	16.6	-	-	37.5	-
O. purkynjei m. bicoronatus	-	-		25.0	-
Total species number	17	16	10	39	19

among some species in the rumen are all important factors in establishing both the composition and concentration of the rumen ciliate protozoa fauna. Further studies of ruminants living in various countries will provide additional information about the fauna of different hosts and may possibly help explain the migration of these ciliates to different continents.

Acknowledgments

I would like to express my appreciation to Prof Dr Burk A Dehority for his kind help in checking the manuscript (Department of Animal Sciences, Ohio Agricultural Research and Development Center, Ohio State University, Columbus, OH, USA), and my father, Necati Gürelli, for his help in getting samples.

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