

Ciliated Protozoa in the Rumen of Turkish Domestic Cattle (*Bos taurus* L.)

BAYRAM GÖÇMEN,^a BURK A. DEHORITY^b and SAMIYE RASTGELDI^a

^aDepartment of Biology and Protozoology-Parasitology Research Laboratory, Ege University, 35100 Bornova-Izmir, Turkey, and

^bDepartment of Animal Sciences, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster, Ohio 44691, USA

ABSTRACT. Rumen contents obtained from 28 domesticated cattle (*Bos taurus* L.) slaughtered at abatoirs near Izmir, Turkey were surveyed for ciliate protozoa. Protozoa are known to make an appreciable contribution to ruminant fiber digestion in many different geographical areas; however, little if any information is available on their occurrence in Turkish cattle. As a result of our survey, 13 genera including 52 species were identified. Nine of the species were further divided into 36 forma. The average ciliate density in our cattle ($52.44 \times 10^4/\text{ml}$) was higher than that of Turkish domestic sheep and other domestic cattle reported previously from different geographical areas. *Entodinium basoglui*, *Entodinium williamsi* f. *williamsi*, *E. williamsi* f. *turcicum*, *E. dalli* f. *rudidorsospinatum*, *Entodinium imai*, *Entodinium oektemae*, *Eudiplodinium dehorityi*, *Epidinium graini*, *Ophryoscolex purkynjei* f. *bifidobincinctus*, and *Ophryoscolex purkynjei* f. *bifidoquadrincinctus* have previously been reported from Turkey and appear to be endemic. All of the remaining species represent a new host record for domestic Turkish cattle. This study also reports for the second time the presence of *Entodinium constrictum* in herbivorous mammals, and is the first record of its occurrence in domesticated cattle.

Key Words. Ciliate protozoa, fauna, microorganisms, Turkey.

RUMEN protozoa, which can play an important role by contributing nutrients to the host animal (Hungate 1955; Ogimoto, and Imai 1981), also play a role in the digestion of carbohydrate and protein-containing feedstuffs by secreting saccharolytic and proteolytic enzymes (Coleman and Laurie 1974; Nagasawa, Uchida, and Onodera 1992; Shinchu, and Abe 1987a, b; Shinchu et al. 1986; Williams 1979). Although investigations have been conducted in various geographical areas on the ciliate population occurring in ruminants, our knowledge about the overall distribution of protozoa in different animal hosts in different countries around the world is limited. There have been several studies on the rumen fauna of domestic cattle and sheep in Turkey (Göçmen 1993, 1999a, b, c; Göçmen and Öktem 1996; Göçmen, Falakali-Mutaf, and Tosunoglu 2001; Göçmen, Torun, and Öktem 1999; Göçmen Tosunoglu, and Falakali 2001; Öktem and Göçmen 1996; Öktem, Göçmen, and Torun 1997). However, no compilation has been published on the protozoal populations occurring in Turkish domestic cattle. The purpose of the present study was to determine the rumen ciliates in a larger number of Turkish domestic cattle and to compare this information with data from previous studies conducted both in Turkey and other geographical areas.

MATERIALS AND METHODS

Samples of rumen contents were obtained from 28 domestic cattle (*Bos taurus* L.) at the slaughterhouses around Izmir, Turkey (Manavkuyu, Buca, and Kemalpaşa), between March 21, 1990 and July 10, 1995. The animals were fed twice a day (0800 h and 1600 h) with about 4 kg of oat straw, clover, and sugar beet rubble. The animals were generally slaughtered 1–2 h after feeding time and samples taken immediately thereafter.

Collection, fixation, storage, and counting of samples have been described in previous publications (Göçmen 1993, 1999a, b; Göçmen and Budak 2000; Göçmen et al. 2001). Specimens were examined with a Jena “NF-binocular” microscope and “MF” photomicrography accessory.

Classification and identification of species were based on previously published species descriptions and taxonomic lists (Dehority 1986a, b; Dogiel 1927; Göçmen 1999a, b, c; Göçmen, Falakali-Mutaf, and Tosunoglu 2001; Göçmen, Tosunoglu, and Falakali 2001; Göçmen et al. 2001; Grain 1994; Hsiung 1932; Imai 1981, 1984; Kofoid and MacLennan 1930, 1932, 1933;

Latteur 1966; Levine et al. 1980; Lubinsky 1957, 1958; Ogimoto and Imai 1981; Williams and Coleman 1992).

RESULTS AND DISCUSSION

The mean number (\pm SD) of ciliates in rumen contents from the 28 Turkish cattle examined was $52.44 \pm 20.73 \times 10^4$ per ml (CV = 39.52%) (Table 1). The geometric mean is 47.49×10^4 cells per ml. Values ranged from 16.00×10^4 to 87.50×10^4 . When compared with ciliate surveys from cattle in other countries (Imai 1986, 1988; Ito and Imai 1990; Imai and Ogimoto 1984; Ito, Imai, and Ogimoto 1994; Imai et al. 1989), the overall mean concentration of ciliates in Turkish domestic cattle was considerably higher, with the exception of Japan (40.3×10^4) (Table 1). The concentration of ciliates found in Turkish domestic cattle is almost identical with the number previously reported from Turkish domestic sheep (53.90×10^4), suggesting that differences between the number of rumen ciliates from different locations may be related with the kind and type of nutrition and geographical location. Thirteen genera; *Charonina*, *Isotricha*, *Dasytricha*, *Entodinium*, *Diplodinium*, *Eodinium*, *Eudiplodinium*, *Metadinium*, *Ostracodinium*, *Polyplastron*, *Enoploplastron*, *Epidinium*, and *Ophryoscolex* were observed (Table 2). The number of species included in these genera was 53, with a total of 36 forma observed in nine of the species.

The number of species and formae living in the rumen of Turkish cattle is similar to those in Japanese cattle (Ito and Imai 1990; Ito, Imai, and Ogimoto 1994). However, *Oligoisotricha* and *Microcetus* were not detected in this study. It is unclear at this time as to why the genus *Oligoisotricha* has been detected in Russia (Dogiel 1927), the Far East (Imai 1985; Ito and Imai 1990; Ito, Imai, and Ogimoto 1994), and USA (Dehority, Dameron, and McLaren 1983), but not in Europe.

Entodinium constrictum, originally described from Alaskan Dall mountain sheep (*Ovis dalli*) (Dehority 1974), and not subsequently observed, was detected in the rumen of Turkish cattle. This study is the first report of the occurrence of *E. constrictum* in the rumen of cattle. Another species also originally described from Alaskan Dall sheep, *Entodinium dalli*, was also observed, but had previously been reported from Turkish cattle (*Bos taurus*) (Göçmen and Öktem 1996).

Almost all of the species detected in this survey represent the first report for their occurrence in Turkey, excluding several species that were observed previously: *Entodinium basoglui*, *E. williamsi* f. *williamsi*, *E. williamsi* f. *turcicum*, *E. dalli* f. *rud-*

Corresponding Author: B. Dehority—Telephone number: 330-263-3909; FAX number: 330-263-3949; E-mail: dehority.1@osu.edu

Table 1. Total ciliate concentrations and distribution of the total number of genera, species, and forms of the ciliates in rumen contents of cattle at various locations around the world.

Locality ^a	Total ciliates × 10 ⁴ ml ⁻¹	Range × 10 ⁴ m ⁻¹	Total no. of genera	Total no. of species	Total no. of formae	References ^b
Japan	40.3 ± 1.9 ^c	6.5–172.5	15	48	25	1
Kenya	15.1 ^d	6.3–39.8	13	51	19	2
Canada	6.9 ^d	2.5–12.6	12	28	— ^d	3
Sri Lanka	2.9 ± 4.9	.08–31.6	16	53	19	4
Mexico	8.3 ^d	.07–21.9	13	38	15	5
Thailand	7.1 ± 2.8	0.6–31.6	17	56	19	6
Brazil	26.4 ± 17.7	9.0–51.2	14	55	4	7
Turkey	52.4 ± 20.7	16.0–87.5	13	52	36	Present study

^a Number of animals and breed: Japan (125 Holstein-Friesian cattle); Kenya (13 Boran Zebu cattle); Canada (11 Holstein cattle); Sri Lanka (20 “Sinhala” Zebu cattle); Mexico (10 Hereford cattle); Thailand (46 Zebu cattle); Brazil (4 Zebu cattle); Turkey (28 *Bos taurus* domestic cattle).

^b (1) Ito, Imai, and Ogimoto 1994; (2) Imai 1988; (3) Imai et al. 1989; (4) Imai 1986; (5) Imai and Kinoshita 1997; (6) Imai and Ogimoto, 1984; (7) Dehority 1986a.

^c Mean ± SD.

^d Data not reported.

idorsospinatum, *E. imai*, *E. oektemae*, *Eudiplodinium dehorityi*, *Epidinium graini*, *Ophryoscolex purkynjei* f. *bifidobicinctus* and *O. purkynjei* f. *bifidoquadricinctus*. These species appear to be endemic in Turkish rumen ciliate faunas.

It is of interest that *Isotricha* was present in all the Turkish cattle studied, while it was less frequent in Japanese cattle (83.2%). Frequency of appearance of *Polyplastron*, *Epidinium* and *Ophryoscolex* was also higher in Turkish domesticated cattle, i.e. 60.7% vs. 34.4%; 50.0% vs. 29.6%; and 25.0% vs. 9.6%, respectively.

Although *Entodinium* spp. and the “holotrichs” are generally present in the rumen contents of domesticated sheep, cattle, and goats under normal farm conditions, some entodiniomorphid protozoa are peculiar to given populations because of both predatory activity and antagonism. Rumen ciliate populations have been divided into four types, A, B, K, and O, all of which contain *Entodinium* spp. and the “holotrichs” (Eadie 1956, 1962; Imai, Katsuno, and Ogimoto 1978, 1979; Ogimoto and Imai 1981; Williams and Coleman 1992). A type A population specifically includes *Polyplastron multivesiculatum* and usually but not always, *Metadinium affine*; a type B population is characterized by *Epidinium* spp., *Eudiplodinium maggii* or both; a type K population is characterized by *Elytroplastron bubali*; while type O contains none of the type A, B, or K species. Nine of the 28 cattle (32.14%) were type A, eight were type B (28.57%), two were type K (7.14%) and one was type O (3.57%). The remaining eight cattle (28.57%) included some or all of the ciliates belonging to type A and B populations together. Ogimoto and Imai (1981) and Imai, Katsuno, and Ogimoto (1979) reported that the type A population was dominant in cattle from Japan and other far eastern countries (44.1% type A, 28.4% type B, and 4.9% type K). Similarly, the type A population is a little more frequent in Turkish cattle. When we consider that *Eudiplodinium* and/or *Epidinium* are generally eliminated by the predatory activity of *Polyplastron multivesiculatum*, animals with a mixed A and B fauna type are probably in a transitory stage, i.e. predation and removal of *Eudiplodinium* and/or *Epidinium* species was not complete. All cattle that have a mixed A and B type population will probably form a type A population and on that basis, the type A population can be considered to be the dominant one, 60.71% (32.14% + 28.57%).

ACKNOWLEDGMENTS

We would like to express our appreciation to Prof. Dr. Nimet Öktem and Mr. Saim Torun (Ege University, Izmir, Turkey) who kindly assisted in our studies and also to the Ege University Research Fund which supported this study in two projects (No. 1996-FEN-022 & 1998-FEN-041).

LITERATURE CITED

- Coleman, G. S. & Laurie, J. I. 1974. The metabolism of starch, glucose, amino acids, purines, pyrimidines and bacteria by three *Epidinium* spp. isolated from the rumen. *J. Gen. Microbiol.*, **85**:244–256.
- Dehority, B. A. 1974. Rumen ciliate fauna of Alaskan moose (*Alces americana*), musk-ox (*Ovibos moschatus*) and Dall mountain sheep (*Ovis dalli*). *J. Protozool.*, **21**:26–32.
- Dehority, B. A. 1986a. Rumen ciliate fauna of some Brazilian cattle: occurrence of several ciliates new to the rumen, including the Cycloposthid *Parentodinium africanum*. *J. Protozool.*, **33**:416–421.
- Dehority, B. A., 1986b. Protozoa of the digestive tract of herbivorous mammals. *Insect Sci. Applic.*, **7**:279–296.
- Dehority, B. A., Damron, W. S. & McLaren, J. B. 1983. Occurrence of the rumen ciliate *Oligoisotricha bubali* in domestic cattle (*Bos taurus*). *Appl. Environ. Microbiol.*, **45**:1394–1397.
- Dogiel, V. A. 1927. Monographie der Familie Ophryoscolecidae. *Arch. Protistenkd.*, **59**:1–288.
- Eadie, J. M. 1956. The mid-winter rumen microfauna of the seaweed-eating sheep of North Ronaldshay. *Proc. Roy. Soc. Edinburgh Sect. B*, **66**:276–287.
- Eadie, J. M. 1962. Interrelationships between certain rumen ciliate protozoa. *J. Gen. Microbiol.*, **29**:579–588.
- Göçmen, B. 1993. Sigir Iskembesinde Endosimbiyont Yasayan *Isotricha* spp. Stein, 1859 (Isotrichidae, Trichostomatida) Üzerine Isik Mikroskobu Düzeyinde Morfolojik ve Sitolojik Gözlemler. *Doga-Tr. J. Zool.*, **17**:289–301.
- Göçmen, B. 1999a. *Ophryoscolex* Stein, 1858 (Protozoa: Ciliophora: Entodiniomorpha) Cinsi Hakkında Morfolojik ve Taksonomik Arastirmalar. *Doga-Tr. J. Zool.*, **23**(Turk. Suppl. 2):397–427.
- Göçmen, B. 1999b. *Epidinium* Crawley, 1923 (Protozoa: Ciliophora: Entodiniomorpha) Cinsi Hakkında Morfolojik ve Taksonomik Arastirmalar. *Doga-Tr. J. Zool.*, **23**(Turk. Suppl. 2):429–463.
- Göçmen, B. 1999c. New rumen ciliates from Turkish domestic cattle (*Bos taurus* L.): II. *Epidinium graini* n. sp. (Ophryoscolecidae, Entodiniomorpha). *Turk. J. Zool.*, **24**:23–31.
- Göçmen, B. & Budak, A. 2000. Iskembe Siliyatlarının (Protozoa: Ciliophora) Siniflandırılmasında Kaudal Çikintilerin Önemi ve Forma, Grup, Seri Taksonlarının Kullanımı. *T. Parazitol. Derg.*, **24**:214–216.

Table 2. Percentage distribution and frequency of occurrence of rumen ciliate protozoa in rumen contents from 28 Turkish domesticated cattle.

Genus/Species/Formae	Occurrence rate (%)		Frequency of occurrence (%)
	Mean \pm SD	Range	
<i>Isotricha prostoma</i>	12.68 \pm 15.21	0.45–52.94	100.00
<i>Isotricha intestinalis</i>	2.53 \pm 3.45	0–10.29	75.00
<i>Dasytricha ruminantium</i>	8.81 \pm 16.40	0–82.36	75.00
<i>Charonina ventriculi</i>	0.10 \pm 0.21	0–0.70	25.00
<i>Entodinium exiguum</i>	4.37 \pm 4.73	0–19.50	85.71
<i>Entodinium nanellum</i>	21.54 \pm 19.28	0–62.27	85.71
<i>Entodinium minimum</i>	0.22 \pm 0.41	0–1.40	32.14
<i>Entodinium parvum</i> f. <i>parvum</i>	1.08 \pm 1.42	0–6.08	57.14
<i>Entodinium simplex</i>	6.57 \pm 6.51	0–25.65	89.29
<i>Entodinium dubardi</i> f. <i>dubardi</i>	0.81 \pm 2.08	0–8.83	32.14
<i>Entodinium ovinum</i>	2.51 \pm 5.14	0–19.07	64.29
<i>Entodinium dilobum</i>	0.87 \pm 2.58	0–12.82	28.57
<i>Entodinium constrictum</i>	0.12 \pm 0.37	0–1.21	10.71
<i>Entodinium bimastis</i>	0.08 \pm 0.28	0–1.26	14.29
<i>Entodinium bovis</i>	4.34 \pm 17.58	0–93.44	53.57
<i>Entodinium bursa</i>	1.33 \pm 4.87	0–25.70	42.86
<i>Entodinium ellipsoideum</i>	1.38 \pm 3.68	0–14.39	25.00
<i>Entodinium rostratum</i>	0.41 \pm 0.74	0–2.10	32.14
<i>Entodinium anteroneucleatum</i> f. <i>laeve</i>	0.23 \pm 0.69	0–3.28	14.29
<i>Entodinium longinucleatum</i> f. <i>longinucleatum</i>	6.10 \pm 5.65	0–20.73	96.43
<i>Entodinium furca</i> f. <i>furca</i>	0.07 \pm 0.20	0–0.72	10.71
<i>Entodinium triacum</i> f. <i>dextrum</i>	0.87 \pm 2.61	0–13.10	32.14
<i>Entodinium caudatum</i> f. <i>caudatum</i>	6.07 \pm 7.20	0–28.9	82.14
<i>Entodinium caudatum</i> f. <i>lobosospinosum</i>	0.31 \pm 0.52	0–1.89	35.71
<i>Entodinium simulans</i> f. <i>caudatum</i>	0.16 \pm 0.76	0–0.56	7.14
<i>Entodinium rectangulatum</i> f. <i>rectangulatum</i>	0.06 \pm 0.18	0–0.72	10.71
<i>Entodinium rectangulatum</i> f. <i>lobosospinosum</i>	0.03 \pm 0.09	0–0.36	7.14
<i>Entodinium rectangulatum</i> f. <i>dubardi</i>	0.01 \pm 0.07	0–0.36	3.57
<i>Entodinium quadricuspis</i>	0.05 \pm 0.15	0–0.60	10.71
<i>Entodinium dalli</i> f. <i>rudidorsospinatum</i>	0.64 \pm 3.24	0–17.18	7.14
<i>Entodinium williamsi</i> f. <i>williamsi</i>	0.23 \pm 1.12	0–5.90	7.14
<i>Entodinium williamsi</i> f. <i>turcicum</i>	0.15 \pm 0.60	0–3.00	7.14
<i>Entodinium basoglui</i>	2.05 \pm 5.70	0–22.12	25.00
<i>Entodinium bifidum</i>	0.01 \pm 0.04	0–0.20	7.14
<i>Entodinium imaii</i>	0.10 \pm 0.24	0–1.08	21.43
<i>Entodinium oektemae</i>	0.43 \pm 2.25	0–11.90	7.14
<i>Diplodinium dentatum</i> f. <i>anacanthum</i>	0.27 \pm 0.99	0–5.17	17.86
<i>Diplodinium dentatum</i> f. <i>monacanthum</i>	0.01 \pm 0.04	0–0.23	7.14
<i>Diplodinium dentatum</i> f. <i>diacanthum</i>	0.01 \pm 0.04	0–0.20	7.14
<i>Diplodinium dentatum</i> f. <i>triacanthum</i>	0.01 \pm 0.08	0–0.40	7.14
<i>Diplodinium dentatum</i> f. <i>tetracanthum</i>	0.02 \pm 0.11	0–0.60	3.57
<i>Diplodinium dentatum</i> f. <i>pentacanthum</i>	0.08 \pm 0.28	0–1.40	10.71
<i>Diplodinium dentatum</i> f. <i>anisacanthum</i>	0.50 \pm 0.83	0–2.90	42.86
<i>Diplodinium minor</i>	0.02 \pm 0.08	0–0.42	10.71
<i>Eodinium posterovesiculatum</i>	0.07 \pm 0.23	0–1.05	14.29
<i>Eodinium monolobosum</i>	0.20 \pm 0.80	0–4.19	14.29
<i>Eudiplodinium rostratum</i>	0.43 \pm 0.52	0–1.80	67.86
<i>Eudiplodinium maggi</i>	0.30 \pm 0.66	0–2.66	50.00
<i>Eudiplodinium bovis</i> f. <i>bovis</i>	2.48 \pm 3.82	0–11.84	57.14
<i>Eudiplodinium bovis</i> f. <i>monolobum</i>	0.03 \pm 0.09	0–0.36	7.14
<i>Eudiplodinium bovis</i> f. <i>dilobum</i>	0.08 \pm 0.28	0–1.06	7.14
<i>Eudiplodinium dehorityi</i>	1.04 \pm 3.77	0–13.31	14.29
<i>Metadinium affine</i>	0.47 \pm 0.70	0–2.76	50.00
<i>Metadinium medium</i>	0.03 \pm 0.10	0–0.41	10.71
<i>Ostracodinium gracile</i> f. <i>gracile</i>	0.40 \pm 0.83	0–3.14	28.57
<i>Ostracodinium gracile</i> f. <i>monolobum</i>	0.05 \pm 0.20	0–1.05	7.14
<i>Ostracodinium trivesiculatum</i>	0.28 \pm 0.49	0–1.85	42.86
<i>Ostracodinium obtusum</i>	0.02 \pm 0.08	0–0.40	14.29
<i>Ostracodinium quadrivesiculatum</i>	0.04 \pm 0.15	0–0.69	7.14
<i>Ostracodinium clipeolum</i>	0.04 \pm 0.13	0–0.60	7.14
<i>Polyplastron multivesiculatum</i>	0.92 \pm 3.05	0–16.18	60.71
<i>Enoploplastron trilocaratum</i>	0.04 \pm 0.20	0–1.08	7.14
<i>Epidinium ecaudatum</i> f. <i>ecaudatum</i>	1.50 \pm 3.43	0–14.08	46.43
<i>Epidinium ecaudatum</i> f. <i>bulbiferum</i>	0.04 \pm 0.12	0–0.57	42.86
<i>Epidinium ecaudatum</i> f. <i>diodonta</i>	0.09 \pm 0.41	0–2.18	42.86
<i>Epidinium ecaudatum</i> f. <i>triodonta</i>	0.02 \pm 0.06	0–0.23	42.86

Table 2. Continued

Genus/Species/Formae	Occurrence rate (%)		Frequency of occurrence (%)
	Mean ± SD	Range	
<i>Epidinium ecaudatum</i> f. <i>tetradonta</i>	0.03 ± 0.12	0–0.57	42.86
<i>Epidinium ecaudatum</i> f. <i>pentodonta</i>	0.03 ± 0.10	0–0.46	42.86
<i>Epidinium ecaudatum</i> f. <i>caudatum</i>	1.82 ± 4.75	0–24.57	42.86
<i>Epidinium ecaudatum</i> f. <i>bicaudatum</i>	0.07 ± 0.16	0–0.66	17.85
<i>Epidinium ecaudatum</i> f. <i>tricaudatum</i>	0.01 ± 0.04	0–0.21	7.14
<i>Epidinium ecaudatum</i> f. <i>quadricaudatum</i>	0.01 ± 0.02	0–0.11	3.57
<i>Epidinium ecaudatum</i> f. <i>cattanei</i>	0.10 ± 0.29	0–1.10	14.29
<i>Epidinium graini</i> f. <i>graini</i>	0.29 ± 0.67	0–2.76	21.43
<i>Epidinium graini</i> f. <i>caudotricoronatum</i>	0.34 ± 0.91	0–3.62	17.86
<i>Epidinium graini</i> f. <i>caudoquadricoronatum</i>	0.06 ± 0.23	0–1.05	7.14
<i>Ophryoscolex purkynjei</i> f. <i>bifidobincinctus</i>	0.05 ± 0.16	0–0.70	25.00
<i>Ophryoscolex purkynjei</i> f. <i>purkynjei</i>	0.37 ± 0.79	0–3.00	25.00
<i>Ophryoscolex purkynjei</i> f. <i>bifidoquadricinctus</i>	0.03 ± 0.08	0–0.40	10.71

- Göçmen, B. & Öktem, N. 1996. New rumen ciliates from Turkish domestic cattle (*Bos taurus* L.): I—The presence of *Entodinium dalli* Dehority, 1974 with a new forma, *E. dalli* f. *rudidorsospinatum* n.f. and comparisons with *Entodinium williamsi* n. sp. *Europ. J. Protistol.*, **32**:513–522.
- Göçmen, B., Falakali-Mutaf, B. & Tosunoglu, M. 2001. New rumen ciliates from Turkish domestic cattle (*Bos taurus* L.): 3. *Eudiplodinium dehorityi* n. sp. *T. Parazitol. Derg. (Acta Parasitol. Tr.)*, **25**:1–3.
- Göçmen, B., Torun, S. & Öktem, N. 1999. Türkiye Evcil Koyun (*Ovis ammon aries*)'larinin Iskembe Siliyat (Protozoa: Ciliophora) Faunasi Hakkında Bir Ön Çalışma: II-Familiya Ophryoscolecidae (Entodiniomorphida). *Doga-Tr. J. Zool.*, **23**(Turk. Suppl. 2):473–490.
- Göçmen, B., Tosunoglu, M. & Falakali, B. 2001. New rumen ciliates from Turkish domestic cattle (*Bos taurus* L.): 3. *Entodinium oektemae* n. sp. and *Entodinium imaii* n. sp. (Entodiniidae, Entodiniomorphida). *Turk. J. Zool.*, **25**:269–274.
- Göçmen, B., Dehority, B. A., Talu, G. H. & Rastgeldi, S. 2001. The rumen ciliate Ophryoscolecid (Entodiniomorphida) and Isotrichid (Trichostomatida) fauna of domestic sheep (*Ovis ammon aries*) from the Turkish Republic of Northern Cyprus. *J. Eukaryot. Microbiol.*, **48**:455–459.
- Grain, J. 1994. Infusoirs Ciliés (Ordre des Entodiniomorphida). *Traité de Zoologie, Grasse, P. (ed.)*, Paris, **2**:327–364.
- Hsiung, T.-S. 1932. A general survey of the protozoan fauna of the Chinese cattle. *Bull. Fan Mem. Inst. Biol.*, **3**:87–107.
- Hungate, R. E. 1955. Mutualistic Intestinal Protozoa. In: Hunter, S. H. & Lwoff, A. (ed.), *Biochemistry and Physiology of Protozoa*. Vol. **2**. Academic Press, London. p.159–200.
- Imai, S. 1981. Four new rumen ciliates, *Entodinium ogimotoi* sp. n., *E. bubalum* sp. n., *E. fujitai* sp. n. and *E. tsunodai* sp. n. and *Oligoisotricha bubali* (Dogiel, 1928) n. comb. *Jpn. J. Vet. Sci.*, **43**:201–209.
- Imai, S. 1984. New rumen ciliates, *Polymorphella bovis* sp. n. and *Entodinium longinucleatum* forma *spinolobum* f. n., from the Zebu cattle in Thailand. *Jpn. J. Vet. Sci.*, **46**:391–395.
- Imai, S. 1985. Rumen ciliate protozoal fauna of Bali cattle (*Bos javanicus domesticus*) and water buffalo (*Bubalus bubalis*) in Indonesia, with the description of a new species, *Entodinium javanicum* sp. n. *Zool. Sci.*, **2**:591–600.
- Imai, S., 1986. Rumen ciliate protozoal fauna of Zebu cattle (*Bos taurus indicus*) in Sri Lanka, with the description of a new species, *Diplodinium sinhalicum* sp. nov. *Zool. Sci.*, **3**:699–706.
- Imai, S. 1988. Ciliate protozoa in the rumen of Kenyan Zebu cattle, *Bos taurus indicus*, with the description of four new species. *J. Protozool.*, **35**:130–136.
- Imai, S. & Kinoshita, M. 1997. Comparison of rumen ciliate compositions among Hereford, Holstein and Zebu cattle in Mexico. *Rev. Soc. Mex. Hist. Nat.*, **47**:85–91.
- Imai, S. & Ogimoto, K. 1984. Rumen ciliate protozoal fauna and bacterial flora of Zebu cattle (*Bos indicus*) and the water buffalo (*Bubalus bubalis*) in Thailand. *Jpn. J. Zootech. Sci.*, **55**:576–583.
- Imai, S., Katsuno, M. & Ogimoto, K. 1978. Distribution of rumen ciliate protozoa in cattle, sheep and goat and experimental transfaunation of them. *Jpn. J. Zootech. Sci.*, **49**:494–505.
- Imai, S., Katsuno, M. & Ogimoto, K. 1979. Type of the pattern of the rumen ciliate composition of the domestic ruminants and the predator-prey interaction of ciliates. *Jpn. J. Zootech. Sci.*, **50**:79–87.
- Imai, S., Han, S. S., Cheng, K.-J. & Kudo, H. 1989. Composition of the rumen ciliate population in experimental herds of cattle and sheep in Lethbridge, Alberta, Western Canada. *Can. J. Microbiol.*, **35**:686–690.
- Ito, A. & Imai, S. 1990. Ciliated protozoa in the rumen of Holstein-Friesian cattle (*Bos taurus taurus*) in Hokkaido, Japan, with the description of two new species. *Zool. Sci.*, **7**:449–458.
- Ito, A., Imai, S. & Ogimoto, K. 1994. Rumen ciliate composition and diversity of Japanese beef black cattle in comparison with those of Holstein-Friesian cattle. *J. Vet. Med. Sci.*, **56**:707–714.
- Kofoid, C. A. & MacLennan, R. F. 1930. Ciliates from *Bos indicus* Linn. I. The genus *Entodinium* Stein. Univ. Calif. (Berkeley) *Publ. Zool.*, **33**:471–544.
- Kofoid, C. A. & MacLennan, R. F. 1932. Ciliates from *Bos indicus* Linn. II. A revision of *Diplodinium* Schuberg. Univ. Calif. (Berkeley) *Publ. Zool.*, **37**:53–153.
- Kofoid, C. A. & MacLennan, R. F. 1933. Ciliates from *Bos indicus* Linn. III. *Epidinium* Crawley, *Epiplastron* gen. nov. and *Ophryoscolex* Stein. Univ. Calif. (Berkeley) *Publ. Zool.*, **39**:1–33.
- Latteur, B. 1966. *Epidinium dactylodonta* n. sp. Ciliate Ophryoscolecidae du rumen de l'Antilope *Tragelaphus scriptus* Pallas. *Bull. Inst. R. Sci. Nat. Belg.*, **42**:1–27.
- Levine, N. D., Corliss, J. O., Cox, F. E. G., Deroux, G., Grain, J., Honigberg, B. M., Leedale, G. F., Loeblich, A. B., Lom, J., Lynn, D., Merinfeld, E. G., Page, F. C., Poljansky, G., Sprague, V., Vavra, J. & Wallace, F. G. 1980. A newly revised classification of the protozoa. *J. Protozool.*, **27**:37–58.
- Lubinsky, G. 1957. Studies on the evolution of the Ophryoscolecidae (Ciliate: Oligoisotricha). I. A new species of *Entodinium* with “caudatum”, “loboso-spinosum” and “dubardi” forms, and some evolutionary trends in the genus *Entodinium*. *Can. J. Zool.*, **35**:111–133.
- Lubinsky, G. 1958. Ophryoscolecidae (Ciliata: Entodiniomorphida) of reindeer (*Rangifer tarandus* L.) from the Canadian Arctic. I. Entodiniinae. *Can. J. Zool.*, **36**:819–835.
- Nagasawa, T., Uchida, T. & Onodera, R. 1992. Exopeptidase activity of mixed rumen ciliate protozoa. *Anim. Sci. Technol. (Jpn.)*, **63**:481–487.
- Ogimoto, K. & Imai, S. 1981. Atlas of Rumen Microbiology. Japan Sci. Soc. Press, Tokyo, 231 p.
- Öktem, N. & Göçmen, B. 1996: Türkiye Evcil Sığır (*Bos taurus taurus* L.) Iskembesinden Yeni Bir Siliyat Grubu (Entodiniomorphida: Ophryoscolecidae) ve Yeni Bir Tür, *Entodinium basoglui* sp. nov. Hakkında, *Doğa-Tr. J. Zool.*, **20**(Suppl.):271–278.
- Öktem, N., Göçmen, B. & Torun, S. 1997. Türkiye Evcil Koyun (*Ovis ammon aries*)'larinin Iskembe Siliyat (Protozoa: Ciliophora) Faunasi Hakkında Bir Ön Çalışma: I-Familiya Isotrichidae (Trichostomatida) ve Entodiniidae (Entodiniomorphida). *Doğa-Tr. J. Zool.*, **21**:475–502.

- Shinchi, S. & Abe, M. 1987a. Species of rumen ciliate protozoa which produce extracellular protease and influence of bacteria on its activity. *Jpn. J. Zootech. Sci.*, **58**:72-79.
- Shinchi, S. & Abe, M. 1987b. Decomposition of soluble casein by rumen ciliate protozoa. *Jpn. J. Zootech. Sci.*, **58**:833-838.
- Shinchi, S., Itoh, T., Abe, M. & Kandatsu, M. 1986. Effect of rumen ciliate protozoa on the proteolytic activity of cell-free rumen liquid. *Jpn. J. Zootech. Sci.*, **57**:89-96.
- Williams, A. G. 1979. Extracellular carbohydrase formation by rumen holotrich ciliates. *J. Protozool.*, **26**:665-672.
- Williams, A. G. & Coleman, G. S. 1992: The Rumen Protozoa. Brock/Springer Series in Contemporary Bioscience, Springer-Verlag, New York, 442 p.

Received 08/12/02, 12/16/02; accepted 12/16/02