

Rumen Ciliates (Ciliophora, Trichostomatia) of Domestic Cattle (*Bos taurus taurus* Linnaeus, 1758) in Kyrgyzstan

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Abstract: The present study provides an assessment of the rumen ciliate composition in domestic cattle sampled from Bishkek, Kyrgyzstan. Examination of rumen contents from 15 individuals revealed a total of 4 morphotypes and 20 ciliate species assigned to 10 genera and 2 families. The genus *Entodinium* dominated ciliate composition, detected in all hosts, with *Entodinium simulans* exhibiting 100% prevalence. In contrast, *Entodinium bimastus*, *Diplodinium dentatum*, and *Ostracodinium trivesiculatum* were each recorded in a single individual, corresponding to a prevalence of 6.7%. Species richness per host ranged from 2 to 15, with a mean of 7.1 ± 3.6 . The average density of rumen ciliates was estimated at $10.8 \pm 6.2 \times 10^4$ cells mL⁻¹. These findings constitute the first detailed characterization of rumen ciliate composition in cattle from Kyrgyzstan.

Keywords: Community, endosymbiont, eukaryotic microorganism, host, protozoa, ruminant.

Kırgızistan'daki Evcil Sığırların (*Bos taurus taurus* Linnaeus, 1758) İşkembe Siliyatları (Ciliophora, Trichostomatia)

Öz: Bu çalışma, Kırgızistan'ın Bişkek kentinden örneklenen evcil sığırlarda işkembe siliyat kompozisyonunun bir değerlendirmesini sunmaktadır. On beş bireyden elde edilen işkembe içeriklerinin incelenmesi sonucunda, 2 aile ve 10 cinse ait toplam 20 siliyat türü ile birlikte 4 morfoloji belirlenmiştir. *Entodinium* cinsi bütün konaklarda *Entodinium simulans* türü ile tespit edilmiş olup, %100 yaygınlıkla siliyat kompozisyon yapısındaki baskın cinstir. Buna karşılık, *Entodinium bimastus*, *Diplodinium dentatum* ve *Ostracodinium trivesiculatum* türlerinin her biri %6.7 yaygınlıkla tek bir bireyden kayıt edilmiştir. Konak başına tespit edilen tür çeşitliliği 2 ile 15 arasında değişmekte olup ortalama 7.1 ± 3.6 'dır. İşkembe siliyatlarının ortalama yoğunluğu $10.8 \pm 6.2 \times 10^4$ hücre mL⁻¹'dir. Bu bulgular, Kırgızistan'daki sığırların işkembe siliyat kompozisyonuna ilişkin ilk ayrıntılı tanımlamayı sunmaktadır.

Anahtar kelimeler: Komünite, endosimbiont, ökaryotik mikroorganizma, konak, protozoonlar, geviş getiren hayvan.

1. Introduction

The rumen represents the first compartment of the gastrointestinal tract in both wild and domesticated ruminants, where the microbial fermentation of plant structural carbohydrates primarily occurs. This anaerobic chamber provides a highly specialized and complex habitat for a diverse community of microorganisms (Hungate, 1966; Williams & Coleman, 1992; Mizrahi, 2013; Patel & Ambalam, 2018; Öztürk & Gür, 2021). The rumen microbial ecosystem comprises viruses, bacteria, archaea, and eukaryotic microorganisms, including fungi and ciliate protozoa, with ciliates representing the dominant eukaryotic group (Ogimoto & Imai, 1981; Dehority, 1986; Imai, 1998; Choundry et al., 2015; Park et al., 2024; Somasundaram & Yu, 2025).

Ciliates contribute to several critical ruminal processes, including feed digestion, pH stabilization, methane production, nitrogen metabolism, and the formation of volatile fatty acids (VFAs). As predators, they regulate the population dynamics and metabolic processes

of prokaryotes (Williams & Coleman, 1992; Newbold et al., 2015; Yu et al., 2025). Ciliate protozoa are ubiquitous inhabitants of the rumen environment and are estimated to constitute approximately 25–50% of the total microbial biomass (Newbold et al., 2015; Firkins et al., 2020; Solomon et al., 2021; Park et al., 2024). Similar to bacteria and archaea, the ciliate community comprises a highly diverse assemblage of species. These ciliates exhibit considerable variation in morphology and size, ranging from relatively large species to much smaller forms (Ogimoto & Imai, 1981; Williams & Coleman, 1992; Dehority, 1993).

Rumen ciliates are classified within the class Litostomatea, the subclass Trichostomatia, and the orders Vestibuliferida and Entodiniomorpha. The entodiniomorphid ciliates are divided into three suborders: Archistomatina, Blepharocorythina, and Entodiniomorpha. Among them, members of the family Ophryoscolecidae within the suborder Entodiniomorpha are predominant, accounting for over 80% of all rumen ciliates, and are further divided into three subfamilies: Entodiniinae, Diplodiniinae, and

Ophryoscolecinae (Imai, 1998; Lynn, 2008). These anaerobic ciliates persist throughout the lifetime of their hosts and transfaunation occurs exclusively through direct contact. For instance, saliva deposited on feed by a faunated animal, followed by ingestion of the contaminated material by another ruminant, can result in the transfer of ciliates. Similarly, maternal grooming of offspring represents another route for ciliate transmission (Dehority, 1986; Imai, 1998; Moon-van der Staay et al., 2014)

Since these endosymbionts were first described in the mid-19th century by Gruby & Delafond (1843), numerous studies have focused on the species composition of rumen ciliates in cattle across Asia (Tung et al., 1989; Ito & Imai, 1990; Ito et al., 1994; Göçmen et al., 2003; Güreli, 2016; Güreli & Akman, 2017; Güreli & Yürücüoğlu, 2019). Nevertheless, no data are available on the rumen ciliates of cattle in Kyrgyzstan. The aim of this study was to characterize the rumen ciliate composition of domestic cattle (*Bos taurus taurus*) in Kyrgyzstan and to compare the findings with previously published reports.

2. Material and Method

Rumen contents were collected from 15 domestic cattle (*Bos taurus taurus*) immediately after slaughter in Bishkek, Kyrgyzstan between March and May 2014. The cattle were fed barley, wheat, straw, and clover, with additional pasture grazing. The samples were thoroughly homogenized and immediately fixed with an equal volume of 18.5% formalin, as described by Dehority (1984). In the laboratory, the fixed material was filtered through a 2.56 mm mesh gauze and stained with Methyl Green Formalin Saline (MFS) solution to determine differential and total cell counts. The MFS solution was used to visualize nuclei, and a 2% Lugol's iodine solution was applied to reveal skeletal plates (Ogimoto & Imai, 1981; Güreli, 2014; Güreli & Yürücüoğlu, 2024).

The prevalence of ciliate species was calculated according to the method described by Bush et al. (1997). Total cell numbers were determined using a Neubauer hemocytometer (Güreli et al., 2016). Differential counts for each species were estimated from prepared smear slides (Güreli & Mohamed, 2021). Statistical analyses were performed using SPSS version 23. The identification and classification of ciliate species and genera were based primarily on the descriptions of Dogiel (1927), Ogimoto & Imai (1981), Williams & Coleman (1992), and Dehority (1993).

Ciliates were examined at 400× magnification under a light microscope equipped with an imaging system (Zeiss Primo Star, Oberkochen, Germany). The orientation of ciliates was based on Dogiel (1927).

All data for Figures 2–5 were prepared in Excel worksheets. The online software Morpheus (<https://software.broadinstitute.org/morpheus/>) was used to generate Figure 2 and SankeyMATIC (<https://sankeymatic.com/build/>) was used for Figure 4. Figure 3 was created using Excel graphics.

Cluster analysis of presence/absence data (Pielou, 1984) was performed using the Jaccard distance and the group-average method (UPGMA) in PAST version 4.0

(Hammer et al., 2001). This analysis was used to assess similarities and differences among the ciliate fauna of domestic cattle from different regions in Asia.

3. Results and Discussion

In this study, a total of 4 morphotypes and 20 ciliate species, belonging to 10 genera and 2 families, were identified from rumen samples collected from 15 domestic cattle in Bishkek, Kyrgyzstan (Fig. 1). The genus *Entodinium* was present in all animals and *Entodinium simulans* showed a 100% prevalence. In contrast, *Entodinium bimastus*, *Diplodinium dentatum*, and *Ostracodinium trivesiculatum* were each detected in only one animal (6.7% prevalence). The relative abundance of *E. simulans* was high (45.5%), whereas that of *D. dentatum* was low (0.2%). The rumen ciliate community was dominated by *Entodinium* species (mean 82.4%; min–max 61.7–92.6%) (Table 1, Fig. 2). The number of species per animal ranged from 2 to 15, with an average of 7.1 ± 3.6 (SD). The average density of rumen ciliates was $10.8 \pm 6.2 \times 10^4$ cells mL⁻¹, ranging from 2.0 to 23.0×10^4 cells mL⁻¹ (Table 2, Fig. 3).

This is the first report of rumen ciliates in domestic cattle in Kyrgyzstan. All ciliate species detected in the examined animals were previously known and no novel species were recorded. In addition, the total number of detected species was higher than that in domestic goats in Kyrgyzstan but lower than that in domestic sheep in Kyrgyzstan. When comparing the ciliate densities reported in surveys conducted on cattle from various countries in Asia, as well as on domestic sheep and goats in Kyrgyzstan, the average ciliate density in the rumen of domestic cattle in Kyrgyzstan ($10.8 \pm 6.2 \times 10^4$ cells mL⁻¹) was considerably lower than that reported in domestic cattle from Taiwan (Tung et al., 1989), Japan (Ito & Imai, 1990; Ito et al., 1994), and Türkiye (Göçmen et al., 2003; Güreli, 2016; Güreli & Akman, 2017; Güreli & Yürücüoğlu, 2019), as well as in domestic sheep and goats in Kyrgyzstan (Güreli et al., 2016) (Table 2). These differences in ciliate composition and density may be related to variations in host animals, their close contact with other ruminants, and differences in geographical location and diet, including the selection and quantity of specific food types. Additionally, the number of hosts examined or a combination of these factors may be important drivers of these variations (Imai et al., 1989; Ito & Imai, 1990; Güreli, 2016; Güreli & Akman, 2017).

However, *Charonina ventriculi*, *Entodinium caudatum*, *E. chatterjeei*, *E. dubardi*, *E. ovinum*, *E. parvum*, *E. rostratum*, *E. simplex*, *Diplodinium anisacanthum*, *D. polygonale*, *Eodinium postero-vesiculatum*, *Eudiplodinium bovis*, *Eu. maggii*, *Metadinium medium*, *Ostracodinium clipeolum*, *O. mammosum*, *O. obtusum*, and *Epidinium ecaudatum* have been reported from domestic cattle in other regions of Asia (Tung et al., 1989; Ito & Imai, 1990; Ito et al., 1994; Göçmen et al., 2003; Güreli, 2016; Güreli & Akman, 2017; Güreli & Yürücüoğlu, 2019) but were not observed in the present study. The ciliate composition in cattle from Kyrgyzstan appears to be lower than that reported in other studies (Tables 2, 3, Fig. 4). The Jaccard similarity index revealed variation in rumen ciliate composition among the studied countries. The highest similarity was observed between Taiwan and Japan (0.70), followed by Japan and

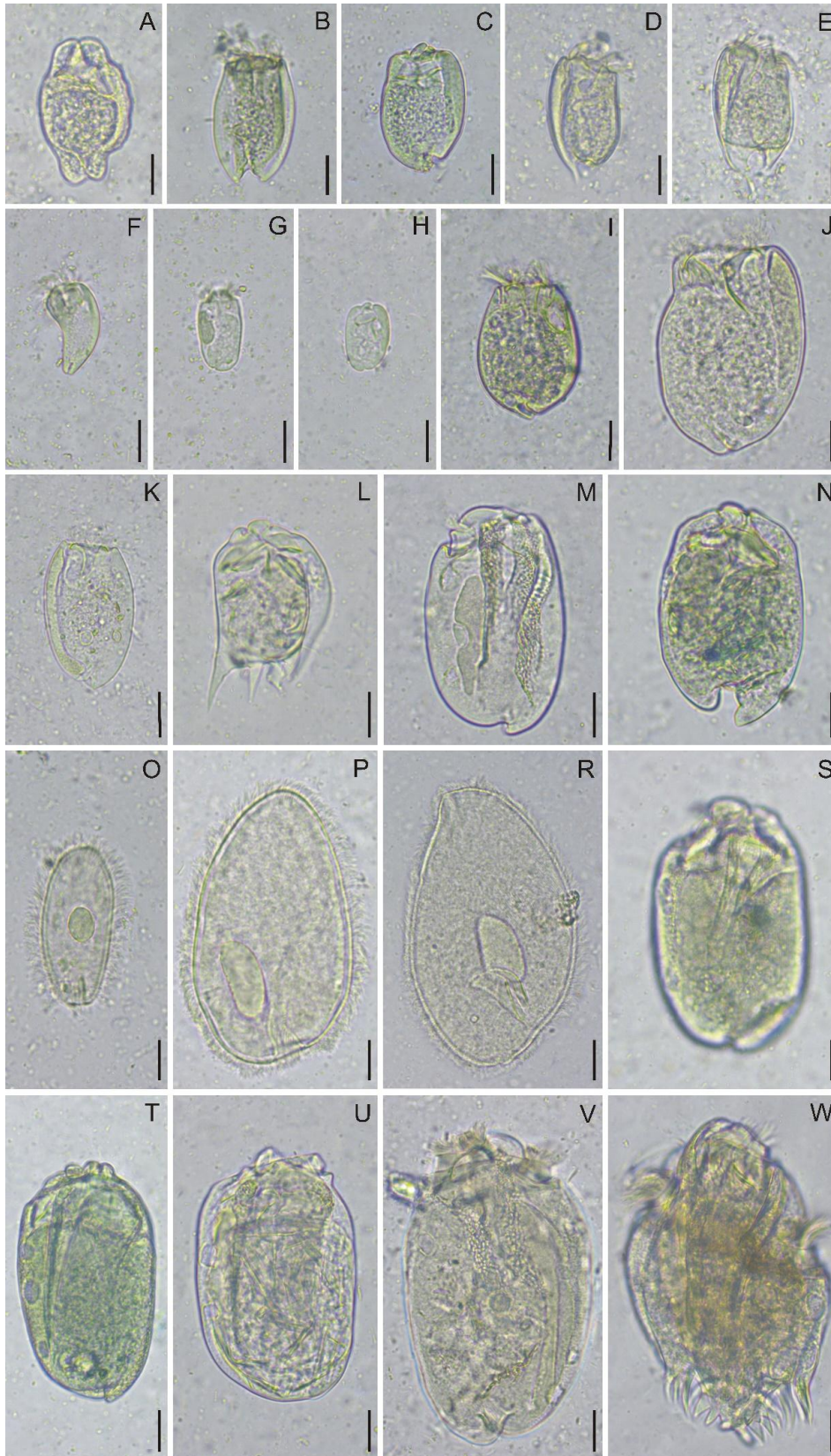


Figure 1. Photomicrographs of rumen ciliates in MFS. (A) *Entodinium bimastus* from the left side; (B) *E. dilobum* from the left side; (C) *E. simulans* m. *dubardi* from the left side; (D) *E. simulans* m. *lobosospinosum* from the right side; (E) *E. simulans* m. *caudatum* from the right side; (F) *E. minimum* from the left side; (G) *E. exiguum* from the right side; (H) *E. nanellum* from the left side; (I) *E. ellipsoideum* from the left side; (J) *E. bursa* from the left side; (K) *E. longinucleatum* from the right side; (L) *Diplodinium dentatum* from the left side; (M) *Enoploplastron triloricaum* from the right side; (N) *Eudiplodinium dilobum* from the right side, (O) *Dasytricha ruminantium* from the left side; (P) *Isotricha prostoma* from the right side; (R) *I. intestinalis* from the right side; (S) *Metadinium affine* from the right side; (T) *Ostracodinium trivesiculatum* from the right side; (U) *O. gracile* from the right side; (V) *Polyplastron multivesiculatum* from the left side; (W) *Ophryoscolex purkynjei* m. *purkynjei* from the right side. Scale bars: 10 μ m (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, S, T, U), 20 μ m (P, R, V, W).

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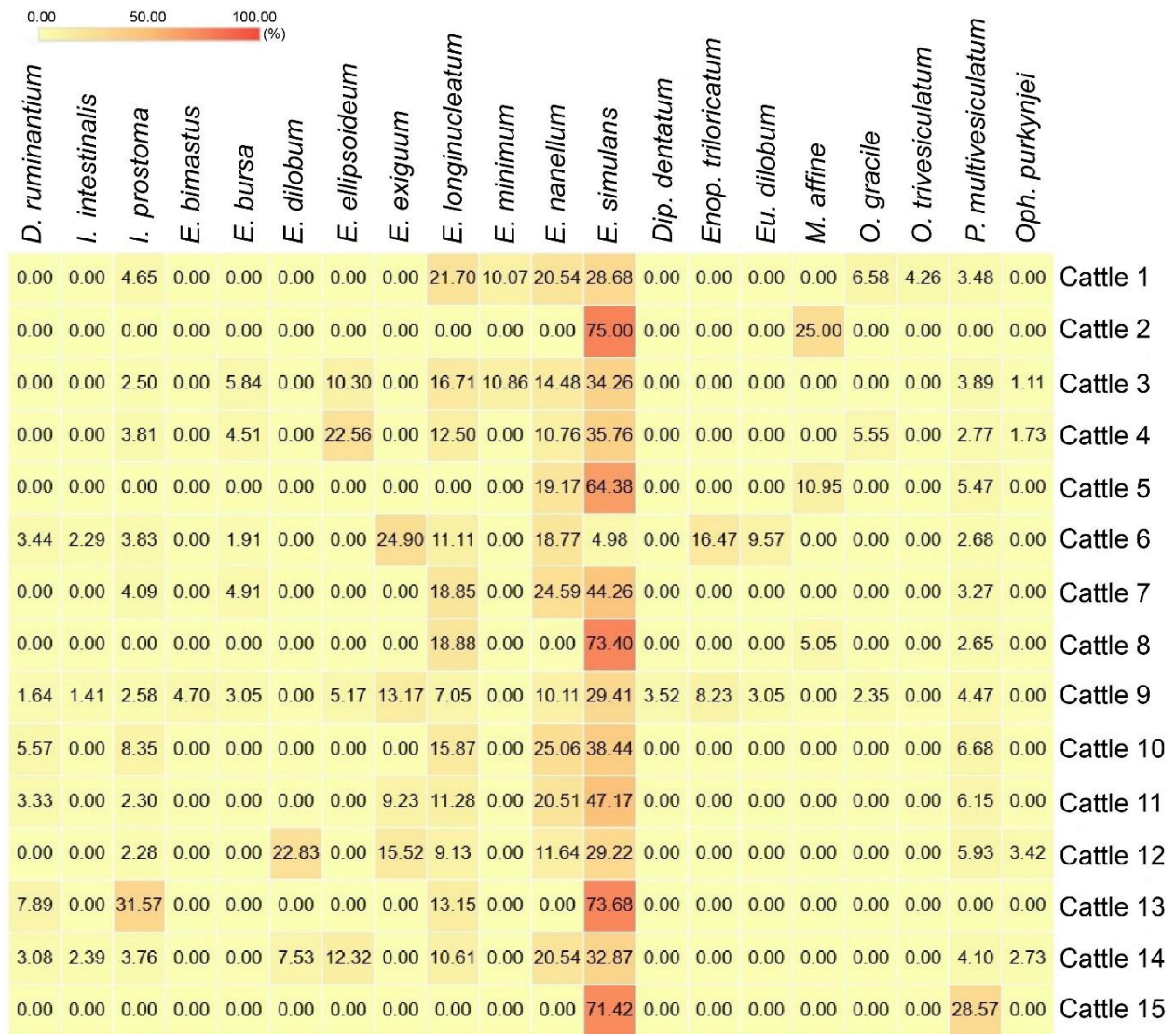


Figure 2. A heatmap showing the relative abundance of ciliate species in the rumen of individual cattle from Kyrgyzstan (*D*: *Dasytricha*, *Dip*: *Diplodinium*, *E*: *Entodinium*, *Enop*: *Enoploastron*, *Eu*: *Eudiplodinium*, *I*: *Isotricha*, *M*: *Metadinium*, *O*: *Ostracodinium*, *Oph*: *Ophryoscolex*).

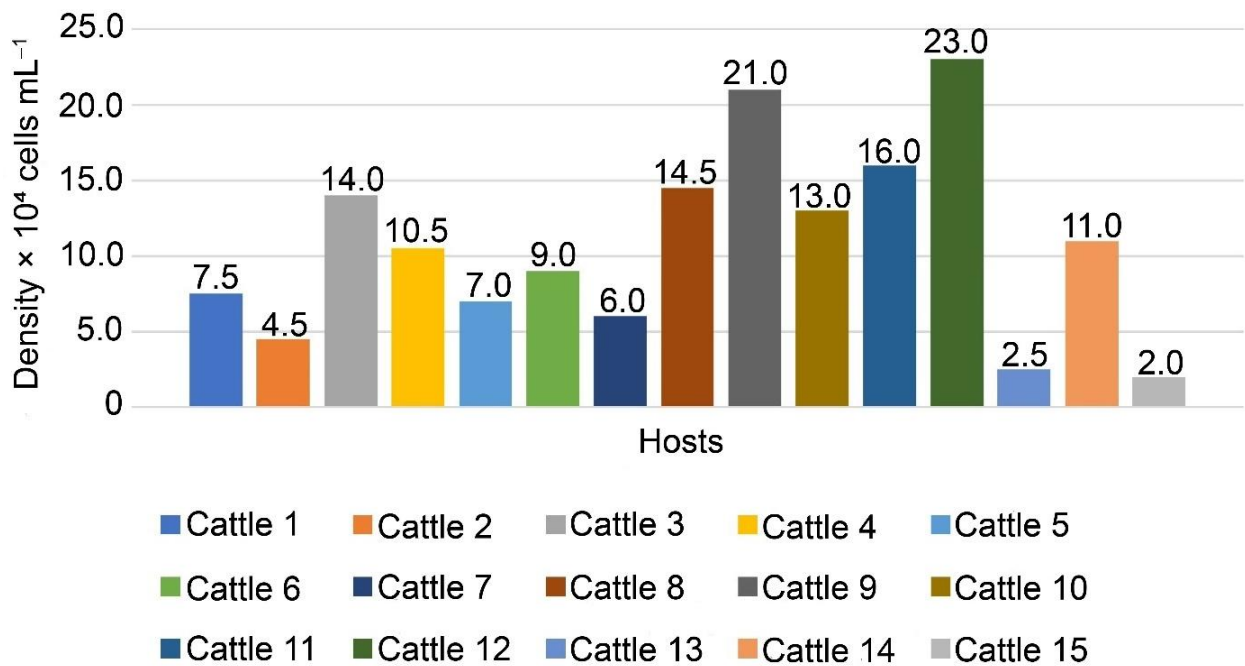


Figure 3. Rumen ciliate densities (× 10⁴ cells mL⁻¹) of 15 domestic cattle in Kyrgyzstan.

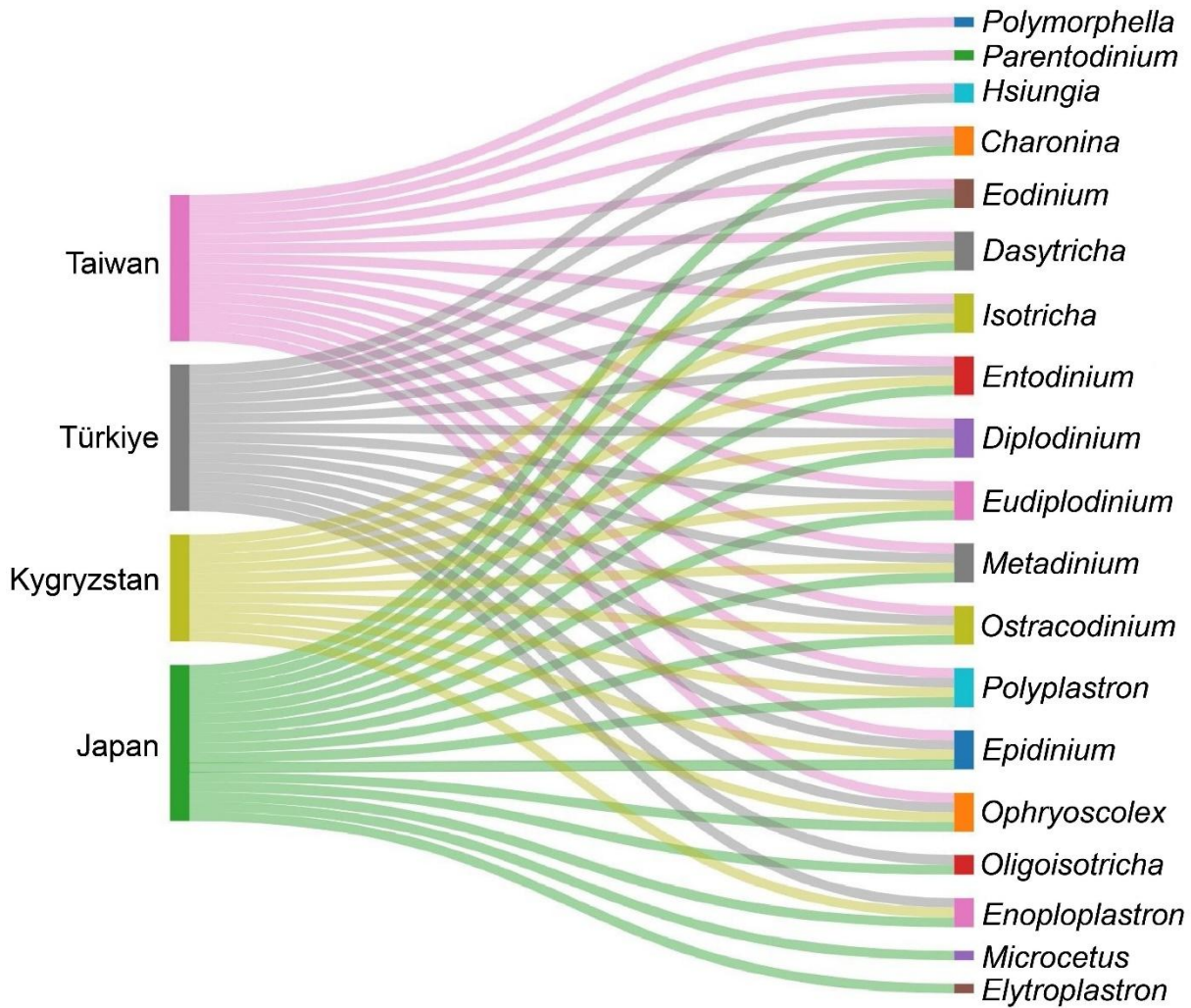


Figure 4. A Sankey diagram showing the distribution of rumen ciliate genera across different regions of Asia. Flows represent connections between countries and genera. Colors on the left indicate the countries. References: (Taiwan) Tung et al., 1989; (Japan) Ito & Imai, 1990; Ito et al., 1994; (Türkiye) Göçmen et al., 2003; Gürelli, 2016; Gürelli & Akman, 2017; Gürelli & Yürüçüoğlu, 2019; (Kyrgyzstan) Present study.

Table 1. Prevalence and relative abundance of rumen ciliates in 15 domestic cattle in Kyrgyzstan. Max, maximum; Mean, arithmetic mean; Min, minimum; SD, standard deviation.

Subclass/Order/Suborder/Family/Genus/ Species/Morphotype	Prevalence (%)	Relative Abundance (%)	
		Mean ± SD	Min-Max Value
Subclass Trichostomatia Bütschli, 1889			
Order Vestibuliferida de Puytorac et al., 1974			
Family Isotrichidae Bütschli, 1889			
<i>Dasytricha</i> Schuberg, 1888	40.0	1.7 ± 2.5	0–7.9
<i>ruminantium</i> Schuberg, 1888	40.0	1.7 ± 2.5	0–7.9
<i>Isotricha</i> Stein, 1859	73.3	5.1 ± 7.8	0–31.6
<i>intestinalis</i> Stein, 1859	20.0	0.4 ± 0.9	0–2.4
<i>prostoma</i> Stein, 1859	73.3	4.6 ± 7.8	0–31.6
Order Entodiniomorpha Reichenow in Doflein & Reichenow, 1929			
Suborder Entodiniomorpha Reichenow in Doflein & Reichenow, 1929			
Family Ophryoscolecidae Stein, 1859			
Subfamily Entodiniinae Lubinsky, 1957			
<i>Entodinium</i> Stein, 1858	100.0	82.4 ± 8.9	61.7–92.6
<i>bimastus</i> Dogiel, 1927	6.7	0.3 ± 1.2	0–4.7
<i>bursa</i> Stein, 1858	33.3	1.3 ± 2.1	0–5.8

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Subclass/Order/Suborder/Family/Genus/ Species/Morphotype	Prevalence (%)	Relative Abundance (%)	
		Mean ± SD	Min–Max Value
<i>dilobum</i> (Dogiel, 1927)	13.3	2.0 ± 6.1	0–22.8
<i>ellipsoideum</i> (Kofoid & MacLennan, 1930)	26.7	3.4 ± 6.7	0–22.6
<i>exiguum</i> Dogiel, 1925	26.7	4.2 ± 7.8	0–24.9
<i>longinucleatum</i> Dogiel, 1925	80.0	11.1 ± 7.0	0–21.7
<i>minimum</i> Schuberg, 1888	13.3	1.4 ± 3.7	0–10.9
<i>nanellum</i> Dogiel, 1922	73.3	13.1 ± 9.3	0–25.1
<i>simulans</i> Lubinsky, 1957	100.0	45.5 ± 21.3	5.0–75.0
m. <i>dubardi</i> Lubinsky, 1957	93.3	27.1 ± 21.4	0–75.0
m. <i>lobosospinosum</i> Lubinsky, 1957	80.0	6.5 ± 5.1	0–16.2
m. <i>caudatum</i> Lubinsky, 1957	86.7	12.0 ± 8.2	0–26.3
Subfamily Diplodiniinae Lubinsky, 1957			
<i>Diplodinium</i> Schuberg, 1888	6.7	0.2 ± 0.9	0–3.5
<i>dentatum</i> (Stein, 1858)	6.7	0.2 ± 0.9	0–3.5
<i>Enoploplastron</i> Kofoid & MacLennan, 1932	13.3	1.6 ± 4.6	0–16.5
<i>triloricatum</i> (Dogiel, 1925)	13.3	1.6 ± 4.6	0–16.5
<i>Eudiplodinium</i> Dogiel, 1927	13.3	0.8 ± 2.5	0–9.6
<i>dilobum</i> (Dogiel, 1927)	13.3	0.8 ± 2.5	0–9.6
<i>Metadinium</i> Awerinzew & Mutafova, 1914	20.0	2.7 ± 6.9	0–25.0
<i>affine</i> (Dogiel & Fedorowa, 1925)	20.0	2.7 ± 6.9	0–25.0
<i>Ostracodinium</i> Dogiel, 1927	20.0	1.3 ± 3.1	0–10.9
<i>gracile</i> (Dogiel, 1925)	20.0	1.0 ± 2.2	0–6.6
<i>trivesiculatum</i> Kofoid & MacLennan, 1932	6.7	0.3 ± 1.1	0–4.3
<i>Polyplastron</i> Dogiel, 1927	86.7	5.3 ± 6.7	0–28.6
<i>multivesiculatum</i> (Dogiel & Fedorowa, 1925)	86.7	5.3 ± 6.7	0–28.6
Subfamily Ophryoscolecinae Lubinsky, 1957			
<i>Ophryoscolex</i> Stein, 1858	26.7	0.6 ± 1.1	0–3.4
<i>purkynjei</i> Stein, 1858	26.7	0.6 ± 1.1	0–3.4
m. <i>purkynjei</i> Stein, 1858	26.7	0.6 ± 1.1	0–3.4
Total	10 genera, 20 species, 4 morphotypes		

Table 2. Average ciliate densities and the distribution of total ciliate genera and species found in the rumen of domestic cattle, sheep, and goat from various regions in Asia (^aData not reported, ^bMean ± SD).

Localities, Host	Average ciliate densities (× 10 ⁴ cells mL ⁻¹)	Min–Max Value of densities (× 10 ⁴ cells mL ⁻¹)	Total no of genera	Total no of species	Number of animals	References
Taiwan, Holstein cattle	33.8 ± 40.7 ^b	1.3–202.0	15	46	28	Tung et al., 1989
Japan (Hokkaido), Holstein-Friesian cattle	53.7 ^a	14.5–168.2	15	48	71	Ito & Imai, 1990
Japan (Kagoshima), Japanese beef black	18.7 ^a	a	13	42	30	Ito et al., 1994
Japan (Hokkaido), Holstein-Friesian cattle	40.3 ^a	a	15	46	125	Ito et al., 1994
Türkiye (İzmir), domestic cattle	52.4 ± 20.7 ^b	16.0–87.5	13	51	28	Göçmen et al., 2003
Türkiye (Kastamonu), domestic cattle	96.8 ± 43.3 ^b	23.5–169.0	15	47	25	Gürelli, 2016
Türkiye (İstanbul), domestic cattle	31.8 ± 21.3 ^b	4.5–79.0	13	35	15	Gürelli & Akman, 2017
Türkiye (Antalya), domestic cattle	100.0 ± 74.4 ^b	28.5–260.0	10	29	15	Gürelli & Yürütcüoğlu, 2019
Kyrgyzstan (Bishkek), domestic sheep	28.1 ± 20.0 ^b	9.5–88.5	12	28	14	Gürelli et al., 2016
Kyrgyzstan (Bishkek), domestic goat	37.0 ^a	a	8	12	1	Gürelli et al., 2016
Kyrgyzstan (Bishkek), domestic cattle	10.8 ± 6.2 ^b	2.0–23.0	10	20	15	Present study

Table 3. Distribution of rumen ciliate species in domestic cattle across different regions of Asia.

Subclass/Order/Suborder/Family/Subfamily/Genus/Species	Geographical Regions ^a			
	Taiwan (1)	Japan (2)	Türkiye (3)	Kyrgyzstan (4)
Subclass Trichostomatia				
Order Vestibuliferida				
Family Isotrichidae				
<i>Dasytricha ruminantium</i>	+	+	+	+
<i>Isotricha intestinalis</i>	+	+	+	+
<i>Isotricha prostoma</i>	+	+	+	+
<i>Oligoisotricha bubali</i>	-	+	+	-
<i>Microcetus lappus</i>	-	+	-	-
Order Entodiniomorpha				
Suborder Archistomatina				
Family Buetschliidae				
<i>Hsiungia triciliata</i>	+	-	+	-
<i>Polymorphella bovis</i>	+	-	-	-
Suborder Blepharocorythina				
Family Blepharocorythidae				
<i>Charonina ventriculi</i>	+	+	+	-
Suborder Entodiniomorpha				
Family Parentodiniidae				
<i>Parentodinium africanum</i>	+	-	-	-
Family Ophryoscolecidae				
Subfamily Entodiniinae				
<i>Entodinium anteroneucleatum</i>	-	-	+	-
<i>Entodinium basoglui</i>	-	-	+	-
<i>Entodinium biconcavum</i>	+	+	-	-
<i>Entodinium bifidum</i>	-	-	+	-
<i>Entodinium bimastus</i>	+	+	+	+
<i>Entodinium bovis</i>	-	+	+	-
<i>Entodinium bursa</i>	+	+	+	+
<i>Entodinium caudatum</i>	+	+	+	-
<i>Entodinium chatterjeei</i>	+	+	+	-
<i>Entodinium constrictum</i>	-	-	+	-
<i>Entodinium convexum</i>	-	+	-	-
<i>Entodinium dalli</i>	-	-	+	-
<i>Entodinium dilobum</i>	+	+	+	+
<i>Entodinium dubardi</i>	+	+	+	-
<i>Entodinium ellipsoideum</i>	-	-	+	+
<i>Entodinium ekendrae</i>	-	+	-	-
<i>Entodinium exiguum</i>	+	+	+	+
<i>Entodinium furca</i>	+	-	+	-
<i>Entodinium imaii</i>	-	-	+	-
<i>Entodinium kastamonicum</i>	-	-	+	-
<i>Entodinium longinucleatum</i>	+	+	+	+
<i>Entodinium minimum</i>	+	+	+	+
<i>Entodinium nanellum</i>	+	+	+	+
<i>Entodinium oektemae</i>	-	-	+	-
<i>Entodinium okoppensis</i>	-	+	+	-
<i>Entodinium ovinum</i>	+	+	+	-
<i>Entodinium palmare</i>	-	-	+	-

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Subclass/Order/Suborder/Family/Subfamily/Genus/Species	Geographical Regions ^a			
	Taiwan (1)	Japan (2)	Türkiye (3)	Kyrgyzstan (4)
<i>Entodinium parvum</i>	+	+	+	-
<i>Entodinium quadricuspis</i>	-	+	+	-
<i>Entodinium rectangulatum</i>	+	+	+	+
<i>Entodinium rostratum</i>	+	+	+	-
<i>Entodinium simplex</i>	+	+	+	-
<i>Entodinium simulans</i>	-	+	+	+
<i>Entodinium triacum</i>	-	-	+	-
<i>Entodinium williamsi</i>	-	-	+	-
<i>Entodinium yumense</i>	-	+	-	-
Subfamily Diplodiniinae				
<i>Diplodinium anisacanthum</i>	+	+	+	-
<i>Diplodinium dentatum</i>	+	+	+	+
<i>Diplodinium dogieli</i>	-	-	+	-
<i>Diplodinium minor</i>	-	+	+	-
<i>Diplodinium polygonale</i>	+	+	+	-
<i>Diplodinium rangiferi</i>	-	-	+	-
<i>Elytroplastron bubali</i>	-	+	-	-
<i>Enoploplastron triloricatum</i>	-	+	+	+
<i>Eodinium posterovesiculatum</i>	+	+	+	-
<i>Eodinium rectangulatum</i>	+	+	-	-
<i>Eudiplodinium bovis</i>	+	+	+	-
<i>Eudiplodinium bubalus</i>	+	+	-	-
<i>Eudiplodinium dilobum</i>	+	+	+	+
<i>Eudiplodinium dehorityi</i>	-	-	+	-
<i>Eudiplodinium maggii</i>	+	+	+	-
<i>Eudiplodinium monolobum</i>	+	+	-	-
<i>Eudiplodinium rostratum</i>	+	+	+	-
<i>Metadinium affine</i>	+	+	+	+
<i>Metadinium medium</i>	+	+	+	-
<i>Metadinium ypsilon</i>	+	+	-	-
<i>Ostracodinium anaticum</i>	-	-	+	-
<i>Ostracodinium clipeolum</i>	+	+	+	-
<i>Ostracodinium dogieli</i>	-	-	+	-
<i>Ostracodinium gracile</i>	+	+	+	+
<i>Ostracodinium mammosum</i>	+	+	+	-
<i>Ostracodinium munham</i>	-	+	+	-
<i>Ostracodinium obtusum</i>	+	+	+	-
<i>Ostracodinium quadriovesiculatum</i>	-	+	+	-
<i>Ostracodinium triovesiculatum</i>	+	+	+	+
<i>Polyplastron multivesiculatum</i>	+	+	+	+
Subfamily Ophryoscolecinae				
<i>Epidinium ecaudatum</i>	+	+	+	-
<i>Epidinium graini</i>	-	-	+	-
<i>Ophryoscolex purkynjei</i>	+	+	+	+

^aReferences: (1) Tung et al., 1989; (2) Ito & Imai, 1990; Ito et al., 1994; (3) Göçmen et al., 2003; Güreli, 2016; Güreli & Akman, 2017; Güreli & Yürücüoğlu, 2019; (4) Present study.

Türkiye (0.61), and Taiwan and Türkiye (0.53). In contrast, Kyrgyzstan showed the lowest similarity values with the other countries, ranging from 0.33 to 0.39 (Table 4). The

UPGMA dendrogram supported these findings, clustering Taiwan and Japan together at the highest similarity level. Türkiye was grouped with this cluster at a lower similarity

level, whereas Kyrgyzstan formed a distinct, more distant branch, indicating a markedly different ciliate composition (Fig. 5). The clustering pattern indicates that geographical distribution, together with host diet and environmental conditions, may play a significant role in the composition of rumen ciliates. The close association between Taiwan and Japan may reflect similarities in feeding practices and ecological conditions associated with their geographical proximity. In contrast, the distinct positioning of Kyrgyzstan suggests a unique rumen ciliate community structure, likely influenced by its geographical isolation and regional environmental characteristics. This divergence may be attributed to spatial variations in climate, pasture composition, and livestock management systems across different geographical regions.

Table 4. Jaccard similarity indices among rumen ciliate composition of domestic cattle from Taiwan, Japan, Türkiye, and Kyrgyzstan based on the data in the references given in Table 3.

	Taiwan	Japan	Türkiye	Kyrgyzstan
Taiwan	-			
Japan	0.70	-		
Türkiye	0.53	0.61	-	
Kyrgyzstan	0.39	0.37	0.33	-

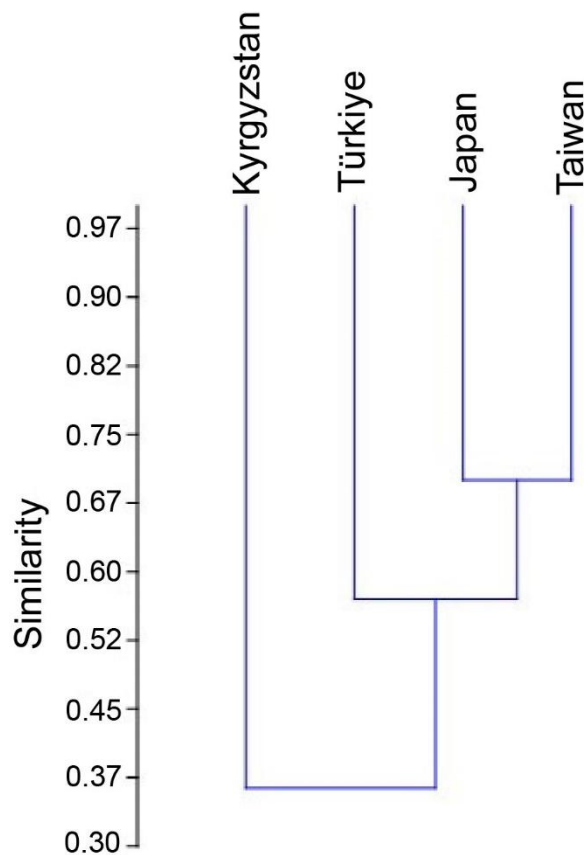


Figure 5. UPGMA dendrogram based on Jaccard similarity indices illustrating the clustering pattern of rumen ciliate communities of domestic cattle from Taiwan, Japan, Türkiye, and Kyrgyzstan.

Entodinium spp. are among the most common ciliates in the rumen, possibly due to their widespread distribution and the host animal's diet (Ogimoto & Imai, 1981; Imai, 1998). *Entodinium* spp. grow rapidly and their relative abundance increases when the host is fed a concentrate-rich diet (Hungate, 1966). These ciliates

primarily utilize starch grains as their main energy source (Abou Akkada & Howard, 1960). The host animal can also exert some degree of control over the composition of its rumen fauna. The selection of specific feed types and differences in feed intake among animal species are important factors influencing rumen ciliate communities (Dehority, 1974; Ito et al., 1993). In addition, rumen pH, turnover rate, and feeding frequency are key factors affecting both ciliate composition and abundance (Dehority, 1978; Franzolin & Dehority, 1996).

Rumen ciliate populations in ruminants have been classified into four main types (Eadie, 1957, 1962; Imai et al., 1978, 1979; Ogimoto & Imai, 1981; Williams & Coleman, 1992). All four groups include the genera *Entodinium*, *Dasytricha*, and *Isotricha*, but they are differentiated based on the presence or absence of specific species. The A-type ciliate population is characterized by the presence of *Polyplastron multivesiculatum* and, usually, though not always, *Metadinium affine*. The B-type ciliate population contains *Epidinium* spp., *Eudiplodinium maggii*, or both. The K-type ciliate population is associated with the presence of *Elytroplastron bubali*. In contrast, the O-type ciliate population includes only *Entodinium*, *Dasytricha*, and *Isotricha*. The A-type and B-type ciliate populations do not occur in the same host, as the predatory activity of *P. multivesiculatum* can eliminate *E. maggii* and *Epidinium* spp. In the present study, 13 of 15 cattle from Kyrgyzstan harbored A-type ciliates, whereas the remaining 2 animals harbored O-type ciliates (Fig. 2).

In conclusion, the rumen ciliate community in cattle from Kyrgyzstan exhibits relatively low species diversity, highlighting the need for further studies across different regions to better understand the factors shaping ciliate composition.

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