

Comparative Studies of Rumen pH, Total Protozoa Count, Generic and Species Composition of Ciliates in Camel, Buffalo, Cattle, Sheep and Goat in Egypt

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Abstract: Rumen liquor samples were collected from 180 domestic ruminants (30 camels, 35 buffaloes, 48 cattle, 32 sheep and 35 goats) belonging to private farms in Egypt and examined for determination of rumen pH, total protozoa count (TPC), generic and species composition, identification, description and measurement of rumen ciliates dimensions. Rumen pH of camels, buffaloes, cattle, sheep and goats were 6.84 ± 0.08 , 6.65 ± 0.34 , 6.82 ± 0.12 , 6.06 ± 0.05 and 6.25 ± 0.07 , respectively; while total protozoa count ($\times 10^4/\text{ml}$) were 14.18 ± 17.9 , 16.02 ± 3.41 , 11.35 ± 2.53 , 28.13 ± 4.13 and 13.38 ± 2.26 , respectively. The exclusive diverse species of protozoa were 4 in camels, 7 in buffaloes, 10 in cattle, 1 in sheep and 1 in goats. The common species presented in all ruminants were *Dasytricha ruminatum*, *Entodinium caudatum f. caudatum*, *Ent. exiguum*, *Epidinium caudatum* and *Epid. Bicaudatum*. In camels, buffaloes, cattle, sheep and goats the number of recognized genera was 9, 9, 12, 6 and 7; while the number of species was 25, 22, 38, 14 and 19 respectively. Fifty four recognized ciliates were morphologically described; their dimensions were measured and illustrated in figures. Each breed of ruminants has its own unique ciliates and others which are common; and in each breed the individual animal has its ciliates population type which varies according to the generic and species composition. Obtained results should be considered in diagnostic panel for evaluation of rumen function, detection of rumen ciliates population types; and rumen juice transplantation therapeutic process for digestive disorders in ruminants in Egypt.

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1. Introduction

Rumen protozoa contribute significantly to the digestion of ruminants as anaerobic fermentative microorganisms (Ushida, 2011). Regardless that rumen protozoa are important to the nutrition of the host they play an important role in rumen metabolism by removal of carbohydrates from bacterial attack and digestion of bacteria (Coleman, 1979). Rumen protozoa constitute about 50% of rumen biological population, represent about 20% of gained protein by the host with digestibility at the abomasum of 91%, 7.5 –15% of the total lipids present in rumen digesta come from protozoa (Keeney, 1970), which are also a significant source of unsaturated fatty acids (Váradyová *et al.*, 2008), detoxify the toxins of poisonous plants and eliminate some toxins out of the digestive tract, stabilize the number of Streptococci to reduce the produced harmful lactic acid, *Entodinium* species of ciliate protozoa; which is the most abundant, reaching up to 90% of total population in high concentrate diets (Williams and Withers, 1993; Franzolin and Dehority, 1998); digest starch and protein to produce the amino acids which are essential for bacteria and protozoa; and they have the ability to utilize the lactic acid produced in the camel rumen (Baraka, 2006a).

On the basis of cell morphology ciliates have been classified into at least five families containing 24 different genera, although new species are still reported yearly (Dehority, 2005). In Egypt, Nassar (1971), Sakr (1988), Baraka (1995), Selim *et al.* (1996), Kubesy and Dehority (2002), Baraka and Dedorty (2003), Baraka (2006a,b), Baraka (2010) and Baraka (2011), investigated the ciliates of cattle, buffaloes, sheep and camels.

Microscopical examination of rumen ciliate protozoa provides rapid useful information disclosing the condition in rumen as well as monitoring nutritional health of animals (Ogimoto and Imai, 1981). The determination of the protozoa populations does not imply in the use of complex and hard-to-execute techniques, although it is time consuming and needs practice; this examination particularly helps in clinical expected diagnosis (Soares *et al.*, 2008).

Objectives of this work were determination of rumen pH, total protozoa count (TPC), generic and species composition, identification, description and measurement of rumen ciliates dimensions in different ruminants and detection of common and diverse species of ciliates between them; in order to be considered in diagnostic panel for evaluation of

rumen function, rumen ciliates typing and rumen juice transplantation therapeutic process in ruminants.

2. Material and Methods:

This work was performed in Laboratory of Rumenology, Department of Medicine and Infectious Diseases, Faculty of Veterinary Medicine, Cairo University. Rumen liquor samples of 180 ruminant farm animals during 2007 - 2010 were collected from Egyptian private farms (30 camels, 35 buffaloes, 48 cattle, 32 sheep and 35 goats). Rumen liquor samples (200 ml) were collected before morning meal, using a stomach tube (varied according to species of animals), connected to a suction pump and passed through a mouth gag. Rumen juice pH was measured immediately (using SMP1 pH-meter).

Determination of total protozoa counts (TPC) using Sedgwick-Rafter chamber; generic and species composition of rumen protozoa population were applied according to the method described by **Dehority (1993)**. Identification and description of rumen ciliate protozoa in different ruminants were applied according to data recorded by local and national authors **Nassar (1971)**, **Dehority (1974)**, **Dehority (1979)**, **Ogimoto and Imai (1981)**, **Dehority (1984)**, **Norman (1985)**, **Williams (1986)**, **Sakr (1988)**, **Dehority (1993)**, **Akira, et al. (1994)**, **Selim, et al. (1996)**, **Selim et al. (1999)**, **Bayram (2000)**, **Bayram et al. (2001a&b)**, **Kubesy and Dehority (2002)**, **Baraka and Dehority (2003)**, **Mermer et al. (2003)**, **Baraka et al. (2005)**, **Bayram and Karaoglu (2005)**, **Baraka (2006a, b)**, **Bayram and Sezgen (2006)**, **Baraka (2010)** and **Baraka (2011)**.

Ciliates were identified and their dimensions were measured using research microscope (Boeco-Germany), micrometer eye piece (MOB-1-16×) and digital camera (Canon A650 IS). Obtained data were statistically analyzed using the SPSS Statistical Computer Software. Copyright (c) SPSS Inc., 2007 version 16.0.

3. Results:

Examination of strained rumen samples in Table 1 showed that high pH values were recorded in camel and cattle while lower values were in buffaloes, goat and sheep; Total protozoa count was the highest in sheep and reduced in buffaloes, camel, goat and cattle. The species *Diplodinium* was the dominant in camel; while species *Entodinium* was the dominant in all other ruminants. It was clear that percentages of species *Epidinium*, *Holotricha* and *Ophryoscolex* were in the same range in true ruminants, but higher considerable percentages were recorded in camels.

The distribution of rumen ciliates in camels, buffaloes, cattle, sheep and goats in Table 2 presented

a total number of 54 rumen ciliates identified, described, measured and arranged in orders, families, species, genera and forma as following:

Order: PROSTOMATIDA

Family: BUETSCHLIIDAE

Genus: BUETSCHLIA

Body is uniformly ciliated, except for long cilia surrounding the cytostome, ovoid with truncated anterior end and round posterior end, circular cytostome is at anterior end. Ectoplasm at anterior end is thick and macronucleus is spherical. There is an anterior concretion vacuole.

Buetschlia parva

Body is ovoid with attenuated anterior end and round posterior one. Whole body is uniformly ciliated except anterior long cilia around cytostome. Macronucleus is near posterior end, globular in shape. Oval contractile vacuole is anterior to the nucleus and to one side. No cytophyge. It is found in the rumen of camel, buffaloes and sheep. Body measures are 30-70 × 20-50 μm.

Buetschlia neglectum

Ovoid body with pointed posterior end and has 4 indentations, looks like a cross in cross section. Cytoplasm is granular. Macronucleus is cylindrical. Oval contractile vacuole is anterior to macronucleus and to one side of protozon. It is found in the rumen of camel. Body measures are 40-60 × 20-30 μm.

Buetschlia nana

Very small infusaria present in the rumen of camels. Body is ellipsoid to ovoid in shape. Macronucleus is sausage in shape near anterior extremity of pharynx and extends posterior. Spherical micronucleus is in left side of macronucleus. Ectoplasm forms two anterior and two posterior spines, posterior spines are longer and more twisted. Body measures are 17-21 × 12-17 μm.

Buetschlia omnivora

Body is globular in shape with granular cytoplasm. Anterior pole includes large mouth and its side is engorged forming circular lips. Mouth leads to pharynx and infundibulum. Macronucleus is oblique situated, ovoid in shape and curved. Contractile vacuoles are one anterior to macronucleus and small one in anterior half near to one side. It is found in the rumen of camels. Body measures are 30-100 × 27-100 μm.

Buetschlia polymorphella bovis

Body is generally ovoid with anterior one third tapered like a flask. Uniform cilia are present in two ciliary zones; large one on tapered anterior 1/3 area and smaller one is a small tuft consists of a few cilia near a cytoproct on the posterior end of the body. Macronucleus is sub-spherical and situated at central part of the body. Spherical micronucleus is

near the margin of macronucleus. Contractile vacuole is at posterior end of body and concretion vacuole is at middle of the body and close to the surface. It is found in the rumen of cattle. Body measures are $25-40 \times 20-25 \mu\text{m}$.

Order: TRICHOSTOMATORIDA

Family: ISOTRICHIDAE

Genus: ISOTRICHIA

Body is oval and flattened with dense longitudinal rows of cilia. Cytostome is at or near the anterior end. Macronucleus is kidney shaped and connected with micronucleus by fibrils forming the karyophore. Several contractile vacuoles are present. Locomotion is toward the rear side.

Isotricha prostoma

Body is oval and uniformly covered with cilia. Body is tapered at the level of cytostome which is sub-terminal. Macronucleus is kidney shape. Mouth is located at the end opposite the leading or anterior end. This location has elicited speculation as to what is actually the anterior end. It is found in the rumen of cattle, buffaloes, camel and goats. Body measures are $80-100 \times 50-120 \mu\text{m}$.

Isotricha intestinalis

Body is oval and macronucleus is kidney shape. Cytostome is more sub-terminal at the level of macronucleus. Mouth is on one side of the cell equidistant between the posterior end and the middle. It is found in the rumen of cattle, buffaloes, camel and goats. Body measures are $90-200 \times 45-150 \mu\text{m}$.

Genus: DASYTRICHA

Body is oval and flattened with macronucleus in the middle. Cilia are in spiral longitudinal rows.

Dasytricha ruminatum

Body is oval, covered with cilia in spiral longitudinal rows and is smaller than *isotricha* and commonly occurs in greater numbers in the rumen. Mouth is at the posterior end. Elliptical macronucleus is in middle or posterior third of the body. There are no contractile vacuoles. It is present in the rumen of cattle, buffaloes, camel, sheep and goats. Body measures are $45-100 \times 25-50 \mu\text{m}$.

Dasytricha kabanii

Body is ellipsoidal and cilia covers about four fifth of body surface. Ovoid macronucleus is at posterior part of body; and micronucleus is spherical and at the margin of macronucleus. There is one contractile vacuole at posterior end. It is found in the rumen of camels only. Body measures are $60-120 \times 35-55 \mu\text{m}$.

Family: BLEPHAROCORYTHIDAE

Genus: CHARONINA

Charonina ventricularis

Body is cylindrical and wide at anterior end with two ciliary tufts near the posterior end. Esophagus is very long and directed to the

macronucleus, which is spherical to globular and located in middle to posterior part of the body. It is found in the rumen of cattle, sheep and camel. Body measures are $24-36 \times 12-15 \mu\text{m}$.

Order: ENTODINOMORPHIDA

Family: OPHRYOSCOLECIDAE

Subfamily: ENOTODININAE

Entodiniomorphs lack the abundant cilia covering the surface of the holotrichs, but have evolved the highly specialized bands of syncilia which function both in locomotion and food ingestion. Shape and position of the macro- and micronucleus are important in identifying species.

Genus: ENTODINIUM

Body is truncated anteriorly with one ciliary zone and single adoral contractile vacuole. No skeletal plates. Macronucleus is cylindrical or sausage shaped between micronucleus and nearest side (right side). Contractile vacuole is anterior.

Entodinium caudatum f. caudatum

Body is truncated anteriorly with single adoral zone. Macronucleus is cylindrical to wedge shaped and is nearly $\frac{1}{2}$ of body length broader anterior than in posterior with a contractile vacuole at anterior pole. Pointed to slight rounded lobes are present on both upper and lower posterior left side. It is found in the rumen of camels, buffaloes, cattle, sheep and goats. Body measures are $25-70 \times 25-50 \mu\text{m}$.

Entodinium rectagulum f. caudatum

Body is rectangular and macronucleus is about $\frac{1}{2}$ of body length. Pointed to slightly rounded lobes are on both upper and lower posterior left side. Contractile vacuole is at the base of adoral membranelle zone. It is found in the rumen of camel, buffaloes and sheep. Body measures are $25-50 \times 25-40 \mu\text{m}$.

Entodinium caudatum f. lobospinosum

Body is truncated and macronucleus is nearly $\frac{1}{2}$ of body length broader anterior than in posterior with a contractile vacuole at anterior pole. Pointed to slight rounded lobe is on posterior left side. It is found in the rumen of cattle. Body measures are $30-70 \times 30-60 \mu\text{m}$.

Entodinium williamsi f. turcicum

Body is ovoid or quadric-angular to ellipsoid and generally wider at mid-point. There are two spines and a spinated lobe at the posterior end of the body. The lobe and the left spine are approximately the same. Macronucleus is spherical to ellipsoid in side view. Micronucleus is usually ellipsoid or ovoid in shape and situated in left ventral posterior edge of the macronucleus. Contractile vacuole lies to the ventral side and to the left of the macronucleus. It is found in the rumen of cattle. Body measures are $35-65 \times 28-50 \mu\text{m}$.

Entodinium caudatum f. dubardi

Oval body truncated anteriorly with contractile vacuole at edge of triangular macronucleus. Anus is on right side of small posterior left lobe. It is found in the rumen of cattle and goat. Body measures are $25-45 \times 25-35 \mu\text{m}$.

Entodinium longinucleatum

Body is ellipsoid, flattened and macronucleus is as long as body length. Contractile vacuole is close to upper side of macronucleus. It is found in the rumen of cattle, buffaloes, camel and sheep. Body measures are $45-110 \times 25-80 \mu\text{m}$.

Entodinium longinucleatum f. spinolobum

Body is ellipsoid in shape and there are two spines and one lobe at posterior end of body. One spine on right side and the second at upper left side, while the lobe is at lower left side. Right spine is longer than left one. Esophagus is relatively short. Macronucleus is very long and extends along right body side. Micronucleus is ellipsoid and present at upper third of macronucleus. Contractile vacuole is at upper left side of macronucleus. It is present in the rumen of cattle and buffaloes. Body measures are $45-60 \times 30-40 \mu\text{m}$.

Entodinium ciculum

Body is ellipsoidal, longer than wide measuring. Right side is strongly convex, with large cuticle flange along right mid-line, terminating at posterior end in sharp spine; left side nearly parallel to main body axis and terminates in thin posterior left spine, long curved slightly to the right. Adoral membranelle zone is slanting slightly to the left from main body axis. Esophagus extends to mid-region of macronucleus. Macronucleus is rod shaped; situated at some distance from right body margin. Micronucleus is resting in a small depression near mid-region of left side of macronucleus. Contractile vacuole is directly anterior to the left side of macronucleus. It is found in the rumen of buffaloes. Body measures are $36-40 \times 23-31 \mu\text{m}$.

Entodinium yunnense f. yunnense

Body is ellipsoidal and macronucleus extends along the right side of the body; from near rectum to anterior end at anterior one sixth of its length. Micronucleus is ellipsoid and lies on the left side of the anterior third of macronucleus. One contractile vacuole is at left upper side of macronucleus. It is found in the rumen of cattle. Body measures are $40-60 \times 28-40 \mu\text{m}$.

Entodinium yunnense f. spinonucleatum

Ellipsoidal body in side view, both sides are convex, widest part is at middle of cell. Left body side extends at the end with single sharp spine; and may curve slightly to the right. Posterior right side ranges from smooth rounded lobe to sharp spine. Adoral membranelle zone is at right angle of the main body axis. Esophagus is short funnel shaped, at a

distance from mid of macronucleus. Macronucleus extends along entire right side near the anterior end at the rectum. Micronucleus is ellipsoid and located at left of macronucleus and at anterior 1/3 of it. Contractile vacuole lies to the left of upper surface of macronucleus, just anterior to micronucleus. It is found in the rumen of cattle. Body measures are $26-41 \times 24-33 \mu\text{m}$.

Entodinium nanellum

Body is ovoid, with thin macronucleus of wedge-shape and longer than $\frac{1}{2}$ of body length. Esophagus curves to the macronucleus. It is found in the rumen of cattle, camel, buffaloes and goat. Body measures are $22-32 \times 12-18 \mu\text{m}$.

Entodinium constrictum

Body is ellipsoid or ovoid in side view. Right side is convex. Left side has indentation at the level of base of adoral membranelle zone. It is found in the rumen of cattle, camel, sheep and goat. Body measures are $30-40 \times 20-30 \mu\text{m}$.

Entodinium bovis

Body is ellipsoid in side view, both sides are convex, a small left lobe is present. Adoral membranelle zone slants away from the macronucleus and the esophagus is bending sharply to the right, terminating posterior to the micronucleus. Macronucleus is triangular to club shaped, lies on right side, its anterior part bends to left. Micronucleus is small ellipsoidal lies to the left of macronucleus below the level of adoral zone. Contractile vacuole lies at left upper part of macronucleus just anterior to the micronucleus. It is found in the rumen of cattle and camel. Body measures are $24-44 \times 18-33 \mu\text{m}$.

Entodinium bursa

Flattened body with macronucleus about $\frac{4}{5}$ of body length; dense granular cytoplasm, contractile vacuole is anterior, body surface has longitudinal striation. It is found in the rumen of cattle, sheep and goat. Body measures are $80-120 \times 75-100 \mu\text{m}$.

Entodinium exiguum

Body is elongated oval, straight esophagus, parallel with long body axis, macronucleus irregular shaped (short and thick) shorter than $\frac{1}{2}$ of body length, generally lies in middle third of body. It is found in the rumen of cattle, buffaloes, sheep, camel and goat. Body measures are $20-35 \times 15-25 \mu\text{m}$.

Entodinium dalli

Body is roughly spherical to ellipsoid; dorsal side of body is generally convex; ventral side has weak and wide depression on the body wall at the level of base of adoral ciliary zone. Posterior convex end terminates in a long rudimentary spine on the dorsal side, a left blunt lobe and right short spine on the ventral side. Macronucleus is spherical to ellipsoidal at the level of base of adoral ciliary zone.

Micronucleus is spherical or ellipsoidal and situated at some distance posteriorly from the base of the ventral edge of the macronucleus. It is found in the rumen of sheep. Body measures are 26-40 × 25-37 μm.

Entodinium imaii

Body is ovoid and widest at 1/4 of the body level. Dorsal side is convex and humpbacked anteriorly. The ventral side is almost straight but slightly depressed on the mid-surface. In the posterior part of the body, there is one dorsal spine, extending outwardly but sometimes bending dorsally and towards the anterior part. Another triangular spine and a back-shaped lobe on the right side are also present. The right lobe is shorter than the secondary spine on the left. Adoral lips do not protrude beyond the convex curve of the anterior end of the body. Adoral zone is slightly slanted and extends approximately half the length of the body. Macronucleus, which is spherical, mostly concave on the ventral side and convex on the dorsal side, is located at almost the anterior tip of the body. It is bean-shaped but, rarely, is ellipsoidal. Micronucleus is ellipsoidal and is situated close to the left posterior of the macronucleus. Contractile vacuole lies left posterior or left of the macronucleus. It is found in the rumen of cattle. Body measures are 20-35 × 20-25 μm.

Entodinium salmani

Body is ellipsoidal and dorsal side slightly depressed in mid-body; widest in anterior half of the body. There is an invagination on the dorsal side at the mid-point of the body. Esophagus is funnel-shaped and bent towards the macronucleus. An elongate macronucleus is situated in the middle of the body, very close to the dorsal surface. Micronucleus is a relatively big and triangular to ellipsoidal, situated near the anterior or the posterior edge of the macronucleus; a contractile vacuole is situated anterior to the macronucleus on a line ventral to its axis. At the posterior end of the body 0-3 caudal processes which gives the forma *Entodinium salmani f. salmani*, *Entodinium salmani f. monospinosum*, *Entodinium salmani f. bispinosum* and *Entodinium salmani f. trispinosum*. It is found in the rumen of goat. Body measures are 35-60 × 25-40 μm.

Entodinium oktemae

Body is ovoid to ellipsoidal and is widest at the midpoint. A spine and two matching spinated lobes are present at the posterior end. The spine is on the dorsal side, whereas the lobes are located ventrally on both sides. The dorsal spine is bending sometimes dorsally or towards the left side of the body. Macro- and micronuclei are spherical and the micronucleus is situated posterior or anterior on the left of the macronucleus, generally in its vicinity. Contractile

vacuole is located before or at the level of macronucleus on its ventral side. It is found in the rumen of cattle. Body measures are 50-75 × 35-46 μm.

Entodinium bimastus

Body is ovoid to ellipsoidal and is widest at the midpoint. Macronucleus is band-like or wedge shaped. Contractile vacuole is at left of anterior part of macronucleus. Esophagus is directed toward middle part of macronucleus. It is found in the rumen of buffaloes. Body measures are 30-60 × 30-45 μm.

Subfamily: DIPLODINIINAE

Has a second band of cilia (left zone), parallel to adoral zone on the anterior end of the cell; left ciliary zone is smaller than adoral zone. Skeletal plates divide the subfamily into: *Diplodinium* (without skeletal plates), *Eudiplodinium* (1 narrow skeletal plate), *Ostracodinium* (1 broad skeletal plate), *Metadinium* (2 skeletal plates may be fused in posterior region), *Enoploplastron* (3 skeletal plates), *Elytroplastron* (4 skeletal plates) and *Polyplastron* (5 skeletal plates).

Genus: DIPLODINIUM

Diplodinium anisacanthum

The body is oval to triangular with posterior oblique and truncated end. Macronucleus is sausage in shape with anterior curved end toward the ventral aspect. It is found in the rumen of cattle and camel. Body measures are 150-210 × 90-120 μm.

Diplodinium monocanthum

The body is oval to triangular with posterior oblique and truncated end. There is only single posterior spine. Macronucleus is sausage in shape with anterior curved end toward the ventral aspect. It is found in the rumen of cattle, buffaloes and camel. Body measures are 60-90 × 40-60 μm.

Diplodinium tetracanthum

The body is oval to triangular and ends posteriorly with four spines. It is found in the rumen of cattle, buffaloes and camel. Body measures are 60-80 × 40-60 μm.

Diplodinium dentatum

The body has six heavy incurved posterior spines. Spine on right side is the longest one. Macronucleus is long; it is heavy and rod like. The anterior end is curved. Two contractile vacuoles are on left side. It is found in the rumen of cattle, buffaloes, goat and camel. Body measures are 60-80 × 50-65 μm.

Diplodinium lobatum

The body has three prominent lobes on left side of the macronucleus. Two contractile vacuoles are at both poles of the macronucleus. It is found in the rumen of cattle and sheep. Body measures are 40-60 × 24-40 μm.

Genus: EUDIPLODINIUM

Eudiplodinium magii

There is one narrow skeletal plate extends downward near the posterior end of macronucleus. Macronucleus is hook or pistol like. Two contractile vacuoles. The rectum is large. It is found in the rumen of cattle, buffaloes and camel. Body measures are $110-220 \times 75-150 \mu\text{m}$.

Genus: OSTRACODINIUM*Ostracodinium gracile*

The body is flattened and ellipsoid. It has one large skeletal plate board shaped. Two contractile vacuoles are between macronucleus and left body wall. It is found in the rumen of buffaloes. Body measures are $90-130 \times 40-70 \mu\text{m}$.

Ostracodinium nucleolobum

The body is roughly triangular to flattened ellipsoidal and left side is slightly convex, while right side is nearly flat. Posterior end is rounded to flatten. Long board like skeletal plate runs along the body and turns inward at the left edge. Macronucleus has two lobes. Two contractile vacuoles are at the left body margin. It is found in the rumen of buffaloes. Body measures are $45-40 \times 35-55 \mu\text{m}$.

Ostracodinium clipeolum

The body has one large skeletal plate of board shaped and three contractile vacuoles between macronucleus and left body wall are present. Body ends with large lobe. It is found in the rumen of cattle. Body measures are $60-130 \times 40-70 \mu\text{m}$.

Ostracodinium tieti

The body is ellipsoid and both sides are convex, with small lobe on posterior right side. Single skeletal plate extends posterior to left side at angle 30 to main body axis until it reaches mid-point of body to bend sharply and aligns with body axis. Macronucleus is rod shaped lying beneath left margin of skeletal plate; micronucleus is ellipsoidal lying under anterior mid-region of macronucleus. All three contractile vacuoles are beneath macronucleus. It is found in the rumen of buffaloes. Body measures are $50-80 \times 35-60 \mu\text{m}$.

Ostracodinium mammosum

The body has one board like skeletal plate, two caudal lobes, round lobe on left side, right lobe concave on left side. Three contractile vacuoles are between macronucleus and left body wall. It is found in the rumen of buffaloes. Body measures are $40-110 \times 25-70 \mu\text{m}$.

Genus: METADINIUM*Metadinium banksi*

Body is ellipsoid and both body sides are slightly convex; posterior end is smoothly rounded. Two skeletal plates on upper side generally fused posterior, the plates are not parallel. Rectum is wide and lined with longitudinal fibrils; anus is on upper side, slightly to right of main body axis.

Macronucleus consists of 3 lobes; while micronucleus is ellipsoid and lies in a depression anterior to middle lobe of macronucleus. Two contractile vacuoles between macronucleus and lower left body margin, one anterior to micronucleus and one in the depression between middle and posterior lobes. It is found in the rumen of goat, buffaloes and cattle. Body measures are $118-162 \times 75-118 \mu\text{m}$.

Metadinium affine

The body has narrow skeletal plates fused at posterior end or lying adjacent to each other (V-shaped). Macronucleus is rod-shaped. Posterior end of cell rounded with small lobe on right side. It is found in the rumen of buffaloes. Body measures are $90-120 \times 50-90 \mu\text{m}$.

Metadinium esalqum

Flattened ellipsoidal body with two skeletal plates fused posteriorly and posterior three fourth of the macronucleus; which consists of main two lobes and two contractile vacuoles. The rectum is large. It is found in the rumen of goat, buffaloes and cattle. Body measures are $70-100 \times 50-70 \mu\text{m}$.

Metadinium medium

The body has two skeletal plates, fused at posterior end of macronucleus which consists of three lobes. The body ends with large rectum. It is found in the rumen of cattle. Body measures are $150-250 \times 90-175 \mu\text{m}$.

Genus: ELYTROPLASTRON*Elytroplastron bubali*

The body has two medium width skeletal plates are on upper side, long skeletal plate on lower side and small plate on right side; while four contractile vacuoles between left edge of macronucleus and left side of body. It is found in the rumen of cattle. Body measures are $110-165 \times 65-100 \mu\text{m}$.

SUBFAMILY: OPHRYOSCOLECINAE**Genus: EPIDINIUM***Epidinium caudatum*

Elongated twisted body around the main axis and macronucleus is club shaped. The body ends with one caudal spine. It is found in the rumen of cattle, sheep, goat, buffaloes and camel. Body measures are $80-140 \times 35-55 \mu\text{m}$.

Epidinium bicaudatum

Body is elongated and twisted around the main axis and macronucleus is club shaped. The body ends with two caudal spines. It is found in the rumen of cattle, sheep, goat, buffaloes and camel. Body measures are $80-140 \times 35-55 \mu\text{m}$.

Epidinium graini

Body is elongated and there are two to four transverse periplastic pellicle foldings resembling coronets. Skeletal plate complex is composed of three plates lying close together from left ventral edge of adoral zone to the end of cytoproct tube. According

to the number of pellicles there are three forma: *Epidinium graini f. graini* (2 pellicles), *Epidinium graini f. caudatricoronatum* (3 pellicles) and *Epidinium graini f. cauda quadricoronatum* (4 pellicles). It is found in the rumen of goat, cattle and camel. Body measures are 70-125 × 350-50 μm.

Epidinium ecaudatum

Elongated twisted body around the main axis and macronucleus is club shaped. The body ends without caudal spine. It is found in the rumen of camel, cattle, sheep and goat. Body measures are 100-150 × 35-60 μm.

Epidinium cattanei

Body is elongated and macronucleus is club shaped. The body ends with five caudal spines one on the right side, two on the left and one each on upper and lower side, body is relatively short. It is found in the rumen of cattle and goat. Body measures are 80-120 × 40-70 μm.

Genus: OPHRYOSCOLEX

Left ciliary zone forms a girdle which extends three fourths the distance around the body and located about half way between the middle of the cell and the anterior end. Skeletal complex is composed of three plates on upper right side.

Ophryoscolex caudatus

The body is large and characterized by complicated spination and the long caudal spine which is nearly half length of the body. It is found in the rumen of cattle and goat. Body measures are 140-160 × 80-100 μm.

Ophryoscolex purkynje

The body is characterized by the long caudal spination which may be in two groups or three (*Ophryoscolex purkynje f. bicarionatus* and *Ophryoscolex purkynje f. tricarionatus*). It is found in the rumen of cattle and goat. Body measures are 140-220 × 70-150 μm.

Genus: CALOSCOLEX

Caloscolex camelinus

Found only in the rumen of camels and its body is cylindrical, anterior extremity is broad; posterior extremity decreases in width gradually. Macronucleus is long. three contactile vacuoles are on left side of body. According to caudal spination three forma are present : *Caloscolex camelinus f. leavis* (without spines), *Caloscolex camelinus f. monocuspis* (one spine) and *Caloscolex camelinus f. tricuspis* (3spines). Body measures are 290-350 × 170-220 μm.

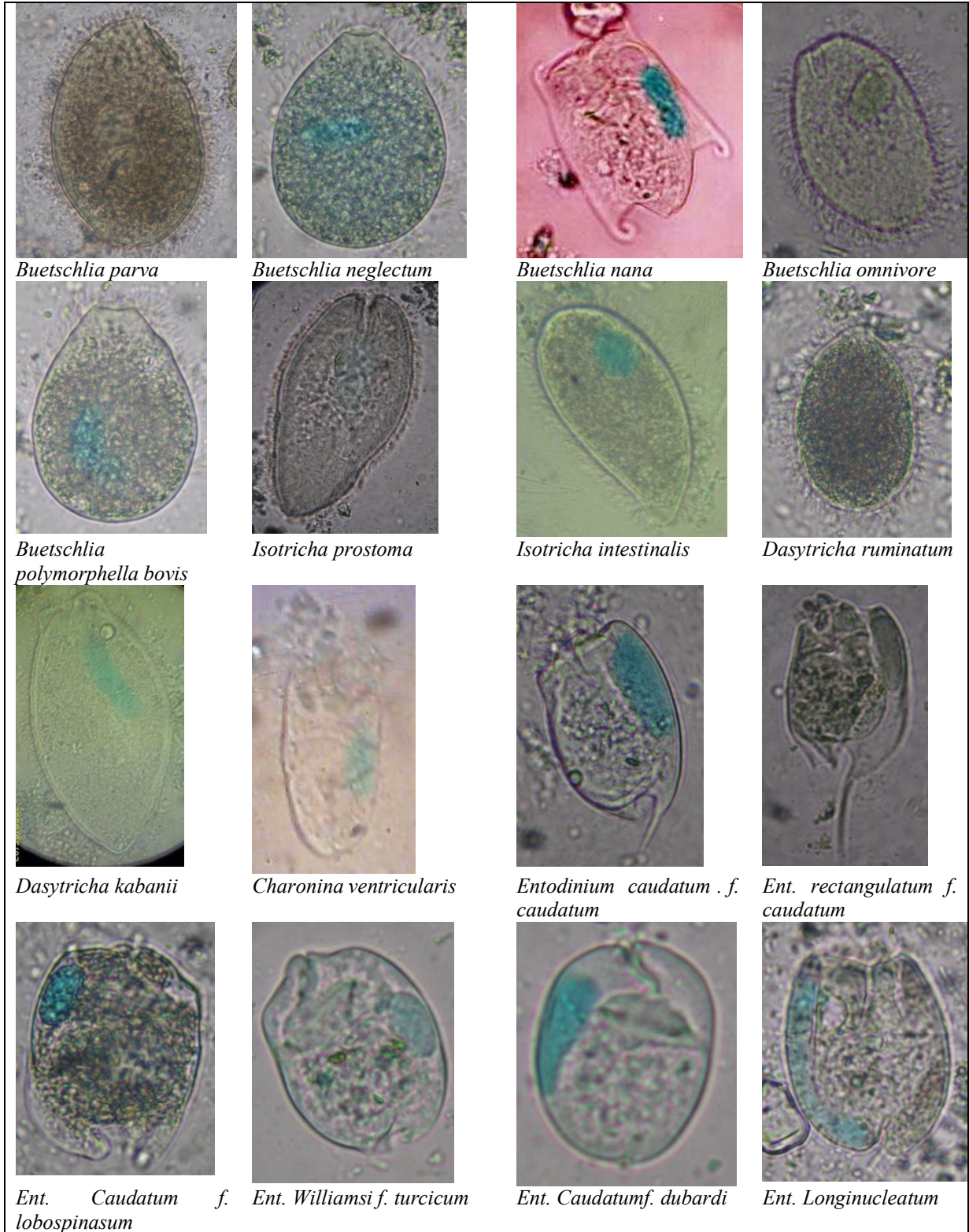
Table 1: Rumen pH, total protozoa count and generic composition of rumen ciliates in camels, buffaloes, cattle, sheep and goats:

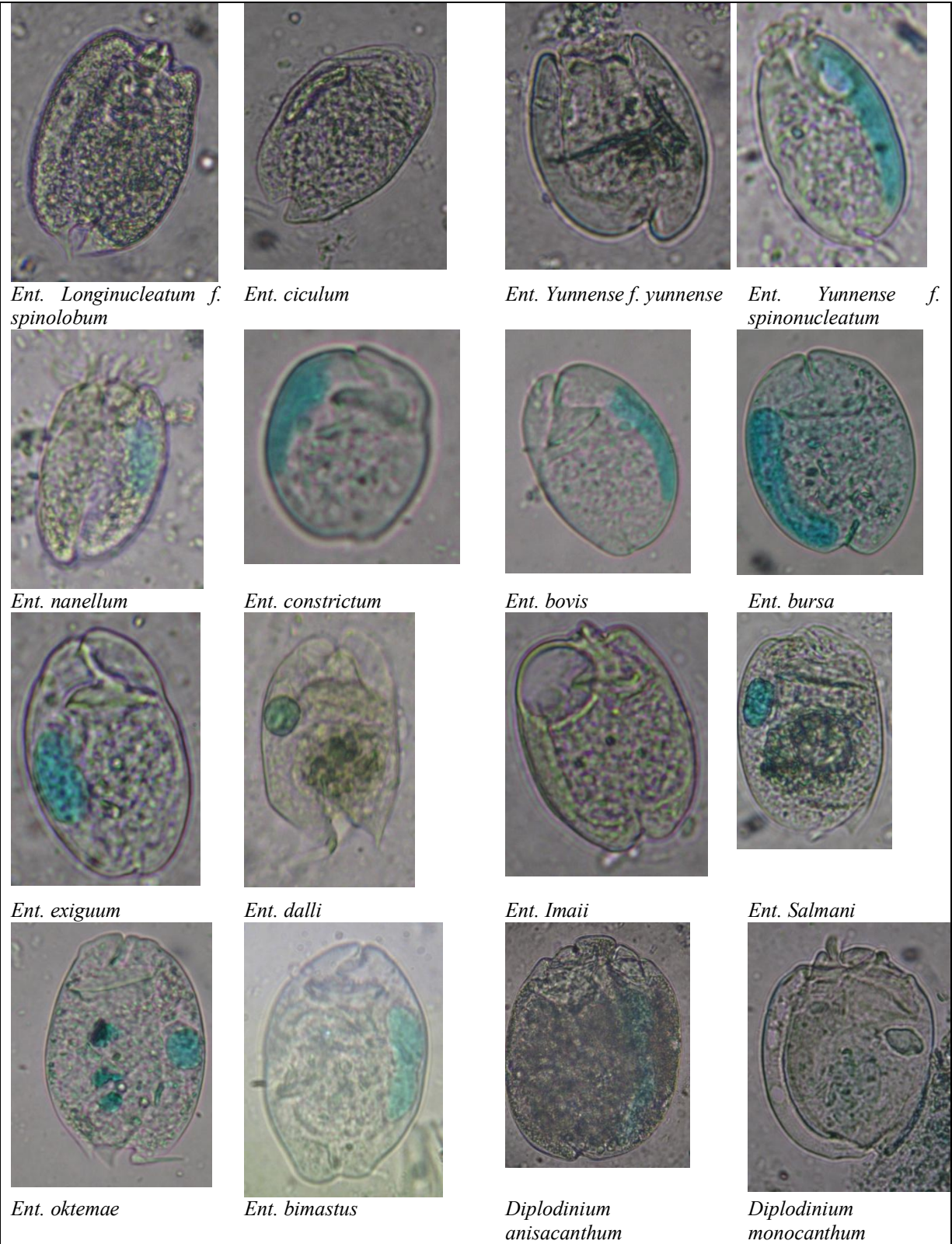
Constituents (No.)	Camels (30)	Buffaloes (35)	Cattle (48)	Sheep (32)	Goats (35)
pH	6.84±0.08	6.65±0.34	6.82±0.12	6.06±0.05	6.25±0.07
protozoa count (×10 ⁴ /ml)	14.18±1.90	16.02±3.41	11.35±2.53	28.13±4.13	13.38±2.26
Entodinium (%)	35.00±5.88	89.50±2.62	90.40±1.87	90.40±	93.00±2.35
Diplodinium (%)	42.00±7.57	3.70±0.14	2.30±1.32	2.80±1.40	2.00±0.07
Epidinium (%)	6.00±1.03	2.00±0.34	0.70±0.51	3.60±1.62	0.50±0.03
Holotricha (%)	7.05±2.07	2.80±0.41	5.90±1.34	4.20±1.94	3.50±1.72
Ophryoscolex (%)	10.0±2.78	2.00±1.80	0.80±0.14	0.00±0.00	1.00±0.91

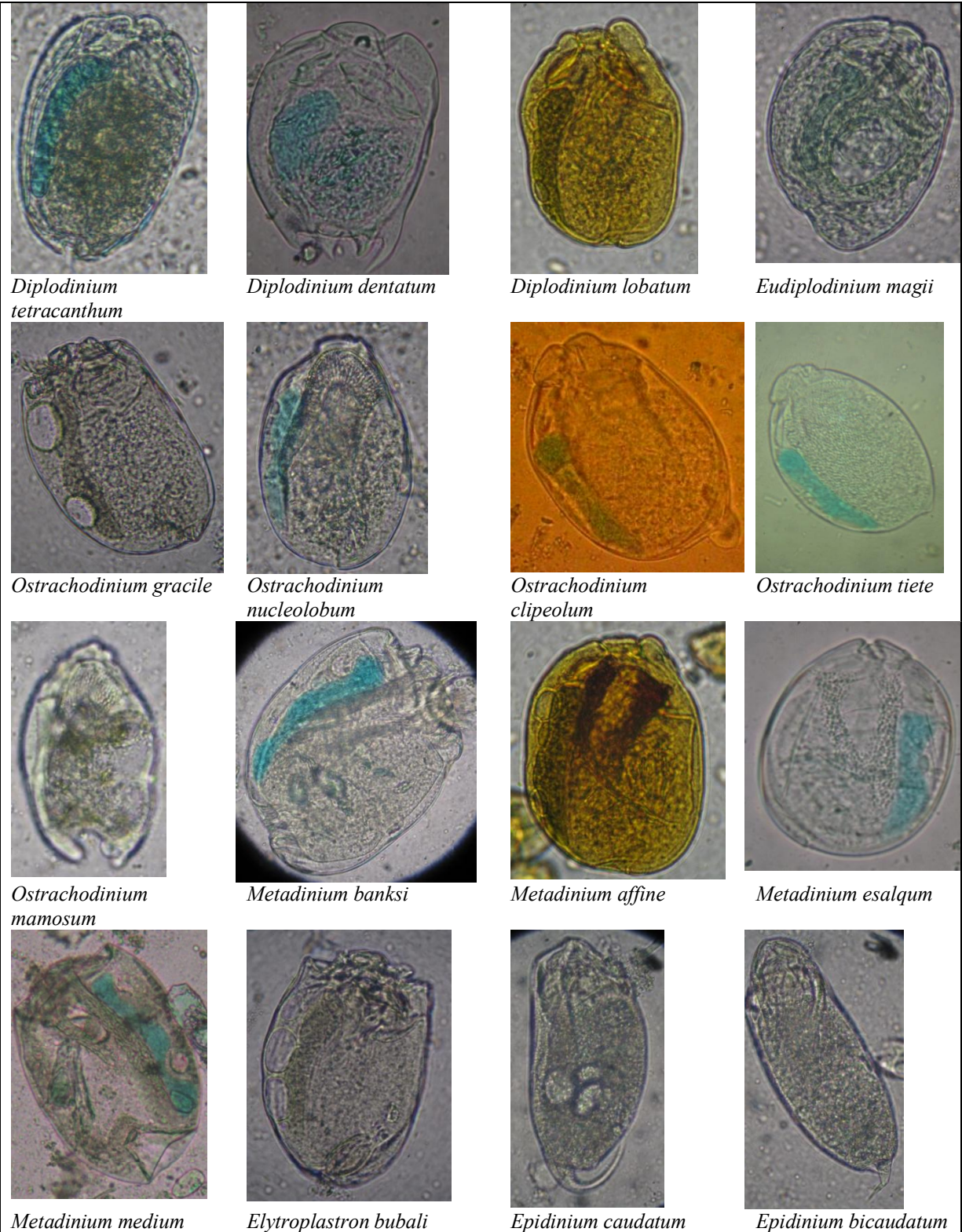
Table 2: The distribution of rumen ciliates in camels, buffaloes, cattle, sheep and goats:

RUMEN CILIATES	Camel	Buffaloes	Cattle	Sheep	Goat
OERDER: PROSTOMA Schewaihoff 1896					
FAMILY: BUETSCHLIDAE Poche, 1913					
Genus: BUETSCHLIA Schuberg, 1988					
<i>Buetschlia parva</i>	+	+	-	+	-
<i>Buetschlia neglectum</i>	+	-	-	-	-
<i>Buetschlia nana</i>	+	-	-	-	-
<i>Buetschlia omnivore</i>	+	-	-	-	-
<i>Buetschlia polymorphella bovis</i>	-	-	+	-	-
OERDER: TRICHOSTOMATORIDA Butschli, 1889					
FAMILY: ISOTRICHIDAE Poche, 1913					
Genus: ISOTRICHIA Stein 1859					
<i>Isotricha prostoma</i>	+	+	+	-	+
<i>Isotricha intestinalis</i>	+	+	+	-	+
Genus: DASYTRICHA Schuberg 1888					
<i>Dasytricha ruminatum</i>	+	+	+	+	+
<i>Dasytricha kabanii</i>	+	-	-	-	-
FAMILY: BLEPHAROCORYTHIDAE Hsiung, 1929					
Genus: CHARONINA Strand, 1928					
<i>Charonina ventricularis</i>	+	-	+	+	-
OERDER: ENTODINOMORPHIDA Reichenow 1929					

FAMILY: OPHRYOSCOLECIDAE Stein 1858					
SUBFAMILY: ENTODININAE Lubinsky 1957					
Genus: ENTODINIUM Stein 1858					
<i>Ent. Caudatum</i> f. <i>caudatum</i>	+	+	+	+	+
<i>Ent. rectangulatum</i> f. <i>caudatum</i>	+	+	-	+	-
<i>Ent. Caudatum</i> f. <i>lobospinasum</i>	-	-	+	-	-
<i>Ent. Williamsi</i> f. <i>turcicum</i>	-	-	+	-	-
<i>Ent. Caudatum</i> f. <i>dubardi</i>	-	-	+	-	+
<i>Ent. longinucleatum</i>	+	+	+	+	-
<i>Ent. Longinucleatum</i> f. <i>spinolobum</i>	-	+	+	-	-
<i>Ent. ciculum</i>	-	+	-	-	-
<i>Ent. Yunnense</i> f. <i>yunnense</i>	-	-	+	-	-
<i>Ent. Yunnense</i> f. <i>spinonucleatum</i>	-	-	+	-	-
<i>Ent. nanellum</i>	+	+	+	-	+
<i>Ent. constrictum</i>	+	-	+	+	+
<i>Ent. bovis</i>	+	-	+	-	-
<i>Ent. bursa</i>	-	-	+	+	+
<i>Ent. exiguum</i>	+	+	+	+	+
<i>Ent. dalli</i>	-	-	-	+	-
<i>Ent. Imaii</i>	-	-	+	-	-
<i>Ent. Salmani</i>	-	-	-	-	+
<i>Ent. oktemae</i>	-	-	+	-	-
<i>Ent. bimastus</i>	-	+	-	-	-
SUBFAMILY: DIPLODININAE Lubinsky 1957					
Genus: DIPLODINIUM Schuberg 1888					
<i>Diplodinium anisacanthum</i>	+	-	+	-	-
<i>Diplodinium monocanthum</i>	+	+	+	-	-
<i>Diplodinium tetracanthum</i>	+	-	+	-	-
<i>Diplodinium dentatum</i>	+	+	+	-	+
<i>Diplodinium lobatum</i>	-	-	+	+	-
Genus: EUDIPLODINIUM Dogiel 1927					
<i>Eudiplodinium magii</i>	+	+	+	-	-
Genus: OSTRACHODINIUM Dogiel 1927					
<i>Ostrachodinium gracile</i>	-	+	-	-	-
<i>Ostrachodinium nucleolobum</i>	-	+	-	-	-
<i>Ostrachodinium clipeolum</i>	-	-	+	-	-
<i>Ostrachodinium tiete</i>	-	+	-	-	-
<i>Ostrachodinium mamosum</i>	-	+	-	-	-
Genus: METADINIUM Awerinzew and Mutafova 1914					
<i>Metadinium banksi</i>	-	+	+	-	+
<i>Metadinium affine</i>	-	+	-	-	-
<i>Metadinium esalqum</i>	-	+	+	-	+
<i>Metadinium medium</i>	-	-	+	-	-
Genus: ELYTROPLASTRON Kofoid and Mc Lennan, 1932					
<i>Elytroplastron bubali</i>	-	-	+	-	-
SUBFAMILY: OPHRYOSCOLECINAE Lubinsky 1957					
Genus: EPIDINIUM Crawley 1923					
<i>Epidinium caudatum</i>	+	+	+	+	+
<i>Epidinium bicaudatum</i>	+	+	+	+	+
<i>Epidinium graini</i>	+	-	+	-	+
<i>Epidinium ecaudatum</i>	+	-	+	+	+
<i>Epidinium cattanei</i>	-	-	+	-	+
Genus: OPHRYOSCOLEX Stein, 1858					
<i>Ophryoscolex caudatus</i>	-	-	+	-	+
<i>Ophryoscolex purkynjie</i>	-	-	+	-	+
Genus: CALOSCOLEX Dogiel, 1926					
<i>Caloscolex camelinus</i>	+	-	-	-	-







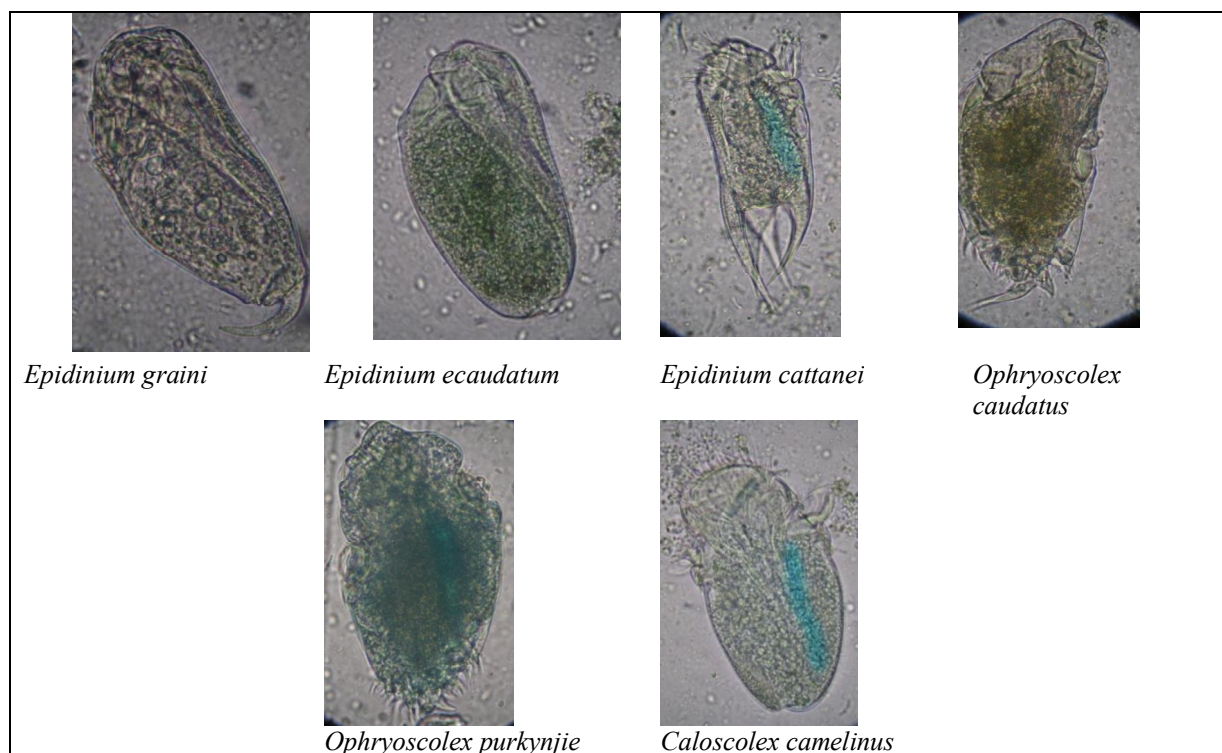


Fig. 1: Identified rumen ciliates in camel, buffaloes, cattle, sheep and goat stained with methylene green formal saline under (100×/1.25 oil) research microscope (Boeco-Germany), micrometer eye piece (MOB-1-16[×]) and digital camera (Canon A650 IS 20.0 MP):

4. Discussion:

Mean value of rumen pH in camels were in agreement with that recorded by Bhatia *et al.* (1986), Baraka *et al.* (2000), Baraka (2001), Kubesy and Dehority (2002), Baraka (2006) and Kamal (2008); while higher values were recorded by Rouissi and Guesmi (1996) and Selim *et al.* (1999). Total protozoa count was in agreement with that mentioned by Bhatia *et al.* (1986), Baraka (1995), Kubesy and Dehority (2002); while higher count recorded by Rouissi and Guesmi (1996) and Baraka (2006a, b).

In buffaloes mean value of rumen pH was in agreement with values recorded in by Paul and Srivastava (2002), Franzolin *et al.* (2010) and Baraka (2011), while Philip and Al-Badrani (2008) mentioned higher values. Estimated total protozoa count was in agreement with that mentioned by Lopez *et al.* (2004), Tsankova *et al.* (2010) and Baraka (2011). Higher values were recorded by Philip and Al-Badrani (2008), Rispoli *et al.* (2009), Franzolin and Alves (2010), Franzolin *et al.* (2010), while low values were mentioned by Imai *et al.* (1981), Shimizu *et al.* (1983) and Barbosa *et al.* (2010).

In cattle mean values of pH and total protozoa count were in agreement with values recorded by Imai *et al.* (1989) Imai and Kinoshita (1997), and

Baraka (2010); lower values were recorded by Imai (1986), while higher values were recorded by Rong and Imai (2002), Bayram *et al.* (2003) and Talari *et al.* (2004).

In sheep, mean values of pH were in agreement with values recorded by Maglad *et al.* (1984), Kubesy *et al.* (1998) and Machmuller *et al.* (2003); while higher values were recorded by Carro *et al.*, 2005, Sarandan *et al.* (2009) and Afaf *et al.* (2009). Total protozoa count was in agreement with that recorded by Hungate *et al.* (1971), Crha *et al.* (1991), while Oktem *et al.* (1997), Muchmuller *et al.* (2003), Sarandan *et al.* (2009). Lower TPC was recorded by Selim *et al.* (1999) and Trabalaza *et al.* (2008).

In goats, mean value of pH was in agreement with values recorded by Abd El-Samee and Abdou (1997); while lower values were mentioned by Choughary and Organ (1979) and, Ndlovu and Hove (1995). Total protozoa count was lower than that recorded by Imai *et al.* (1978), Rai *et al.* (1972) and Bayram and Mehmet (2002).

Rumen ciliates populations in ruminants have been divided into four main types, A, B, O and K, according to the generic composition; all of which contain *Entodinium* and *Holotricha* spp. (Imai *et al.*, 1978; Williams and Coleman 1992; Bayram *et al.*

2001,b); while in camels Valle *et al.* (2008) reported that the protozoa population is only type B.

According to the distribution of genera, species and forms of rumen ciliates, our results were in agreement with that, in all true ruminants *Entodinium* spp. was the major component and more than 80% of ciliates (Dehority, 2003; Tsankova *et al.*, 2010; Baraka, 2011). But, in camels *Diplodinium* spp. was the dominant component of ciliates and levels of *Epidinium*, *Holotricha* and *Ophryoscolex* spp. were higher than that in other ruminants (Baraka and Dehority, 2003).

In camels, buffaloes, cattle, sheep and goats the number of genera were 9, 9, 12, 6 and 7; number of species was 25, 22, 38, 14 and 19 while number of forms was 2, 3, 6, 2 and 2 respectively.

The exclusive diverse species were four species in camels (*Buetschlia neglectum*, *Buetschlia omnivore*, *Dasytricha kabanni* and *Caloscolex camelinus*); Seven species in buffaloes (*Ent. ciclum*, *Ent. bimastus*, *Ostrachodinium gracile*, *Ostr. Nucleolobum*, *Ostr. Tiete*, *Ostr. Mamosum* and *Metadinium affine*), ten species in cattle (*Buetschlia polymorphilla bovis*, *Ent. caudatum f. lobospinosum*, *Ent. williamsi f. turcicum*, *Ent. yunnense f. yunnense*, *Ent. y. f. spinonucleatum*, *Ent. imaii*, *Ent. oktemae*, *Ostr. Clipeolum*, *Metadinium medium* and *Elytroplastron bubali*), one species in sheep (*Ent. dalli*) and one species in goats (*Ent. salamani*).

The common species of ciliates presented in all ruminants were *Dasytricha ruminatum*, *Entodinium caudatum f. caudatum*, *Ent. exiguum*, *Epidinium caudatum* and *Epid. Bicaudatum*.

Conclusions

Each breed of ruminants has its own unique ciliates and others which are common; and in each breed the individual animal has its ciliates population type which varies according to the generic and species composition. Obtained results should be considered in diagnostic panel for evaluation of rumen function, detection of rumen ciliates population types and rumen juice transplantation therapeutic process of digestive disorders in ruminants in Egypt.

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