

Conference Paper

To the Macro-morphology of the Stomach in Red Deer

Sergey Chebakov, Vladimir Zhukov, and Lia Tkachenko

Altai State Agrarian University, Barnaul, Russia

Abstract

Reindeer antler breeding in Altai is a promising industry. Dietary meat and antlers, which are used in Oriental medicine, are received from red deer. In this regard, the study of the morphology of red deer and in particular its digestive system is relevant. The digestive system provides the body with nutrients and energy. Red deer have a four-chamber stomach. 1 -- Rumen is the largest part of the stomach, it is used for hydrolysis of feed. It consists of mucous, muscular and serous membranes. The mucous membrane has papillae. 2 -- The reticulum is a small part, there are cells on the inner surface, it performs the function of sorting the feed. 3 The omasum separates the liquid fraction of the feed from the dense fraction, has inside flat outgrowths. 4 In the abomasum, the same processes occur as in the single-chambered stomach. The stomach doesn't develop evenly. Stomach chambers grow most intensively up to 6 months and then up to 2 years. Then their growth energy decreases, the growth is doubtful.

Corresponding Author:

Sergey Chebakov
chebakov-s@mail.ru

Received: 25 October 2019

Accepted: 15 November 2019

Published: 25 November 2019

Publishing services provided by
Knowledge E

© Sergey Chebakov et al. This article is distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use and redistribution provided that the original author and source are credited.

Selection and Peer-review under the responsibility of the AgroSMART 2019 Conference Committee.

1. Introduction

Reindeer antler breeding in Altai is one of the most promising areas of animal husbandry. Dietary meat, antlers and blood, enzyme-endocrine raw materials are used to prepare biologically active additives and preparations, the use of which gives the human body a high healing effect. All this has become especially important in the conditions of expansion of the Altai recreational zone.

Knowledge of the morphology of the digestive organs in red deer is important for understanding the issues of morpho-physiology and adaptation of the digestive organs to changing diets and types of nutrition, prevention of diseases of the digestive system. A special role is played by the stomach organopathology of red deer stomach when analyzing the population pathology of animals in the Altai Mountains [11].

Stomach morphology in ruminants is devoted to a number of works of domestic and foreign researchers [1, 4, 5, 7--9]. At the same time, the analysis of the available data

OPEN ACCESS

shows that the macro-morphology of the anterior part of the digestive tract in red deer is not sufficiently studied in the age aspect and requires clarification.

2. Objects and Methods of Research

The object of this study were stomachs from 12 red deer (age -- from birth to 13 years). The material was obtained from clinically healthy animals during planned slaughter in the Altai Territory and the Republic of Altai. Classical methods of preparation, manufacture of histological preparations, as well as special methods for the study of the vascular system, linear, weight and volume parameters were used in the work [12]. The results were statistically processed. The relative increase in the body's performance was calculated using the Brody method.

3. Results of the Research

The stomach of red deer, like other ruminants, is multi-chamber (Fig. 1).

The first, most voluminous chamber is the scar [1]. For adult red deer, its perimeter is 208 cm, its internal volume is 58--62 liters. In newborns, the scarlet rumen occupies the left subcostal region. After 6 months of age, the scar is in the left side of the abdomen.

The front, rear and side furrows separate the top and bottom halves of the bag. Inside the rumen, the mucous folds run parallel to the furrows. In the back of the organ, there's a coronal groove. Blind bags are clearly visible.

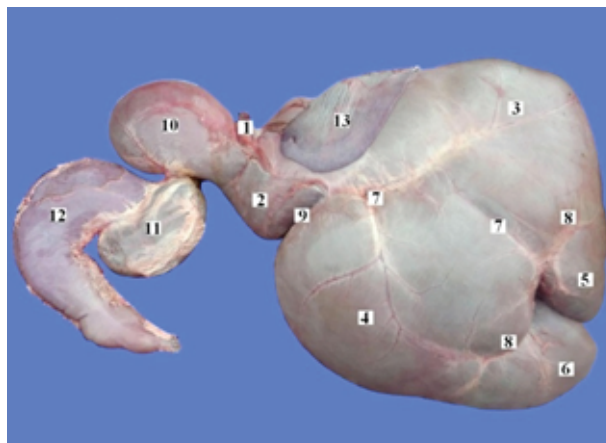


Figure 1: Stomach of the red deer, 7 years. Left-side view: 1 -- end of esophagus; 2 -- anterior part of rumen; 3 -- upper half-bag; 4 -- lower half-bag; 5--6 -- blind bags; 7--9 -- troughs; 10 -- reticulum; 11 -- omasum; 12 -- abomasum; 13 -- lien.

In the lower part under the rumen there is a grid, and on the right surface near it there is a small and large intestine and abomasum.

The rumen of red deer has the most voluminous pre-stomach compared to other sections. It has a volume of approximately 58.0 ± 0.33 l (92.0 % of the total), abomasum of 3.5 ± 0.25 l (4.8 %), omasum of 1.5 ± 0.1 l (1.8 %), grid of 1.6 ± 0.08 l (2.3 %),

Newborn red deer have approximately 38 % of the size of the abomasum of all stomach chambers. In the first days of postnatal ontogenesis, the rumen lags behind other chambers. By the age of six months, the rumen is of the size of a mature red deer. Later on, in the age-related aspect, the growth energy of the scar decreases [2–4].

Research data indicate (Table 1) that a higher relative increase in weight and volume of the organ was obtained at the age of a newborn calf up to the age of six months -- 190.7 and 194.1 % (data correspond to age), ($P \geq 0.99$). Abdominal perimeters have a significant increase: in the frontal and vertical planes -- 155 and 125 % ($P \geq 0.99$). By the age of 18–24 months of postnatal ontogenesis the organ growth rate decreases: weight, approximately -- up to 95, % volume -- up to 109 %, rumen perimeter -- up to 30.2 and 35.2 %, respectively. The probability level to the listed indicators is -- ($P \geq 0.99$).

TABLE 1: Biometric data from the rumen of red deer (M±m).

Organ performance	Age of the animals				
	newborns	6–8 months	18–24 months	4–5 years	10 years and older
Perimeter in the frontal plane (cm)	28.01 ± 1.57	130.45 ± 8.40	188.36 ± 10.72	195.45 ± 9.30	208.44 ± 15.50
Cross perimeter (cm)	18.05 ± 0.99	77.23 ± 4.42	126.36 ± 5.8	145.40 ± 9.92	160.38 ± 12.08
Mass of rumen without content (d)	57.12 ± 6.40	2595.15 ± 180.55	7260.190 ± 330.45	8640.54 ± 410.08	8927.32 ± 350.22
Internal volume (l)	0.22 ± 0.09	12.8 ± 0.15	47.3 ± 0.27	55.8 ± 0.45	57.2 ± 0.25

By the age of four to five years, the rate of scar growth decreases. At the same time, the relative length of the organ slightly increases and is about --15 % ($P \geq 0.95$), the volume and mass account for --15.8 % and 16.9 % ($P \geq 0.99$). In subsequent age periods, the parameters of the rumen growth are not reliable ($P \leq 0.95$).

The rumen is characterized by wave development [2, 4, 5, 9]. In summer, the development intensity exceeds that of autumn-winter due to differences in diet and natural-climatic conditions.

At the histological level, the rumen has a mucous, muscular and serous membrane. The mucous membrane has grown up -- papillae of cylindrical and flattened shape [2, 7, 13]. The longest of them often have tops with outgrowths.

Mature animals (over 3 years old) per unit area (1 cm^2) contain about 54--65 papillae, in the rear parts of the rumen -- 32--38 pieces. Their length is about 7--20 mm. The shortest papillae are located in the area of internal folds -- 3--4 mm (Fig. 2).

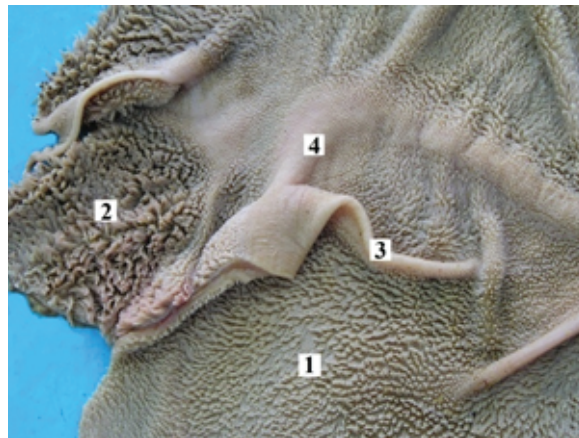


Figure 2: The papillae of the mucous membrane of the rumen. Red deer, 8 years: 1 -- papillae of the lower half-bag; 2 -- blind bags and their papillae; 3-4 -- inner fold with short papillae.

Inside the scar is lined with orogenic epithelium formed by several layers. This is a layer of producing cells with dark-basophilic cytoplasm, a middle layer with light cytoplasm and a layer with oxyphilic cytoplasm on the mucous membrane surface, consisting of 3--4 rows of flat cells [7, 8] (Fig. 3).

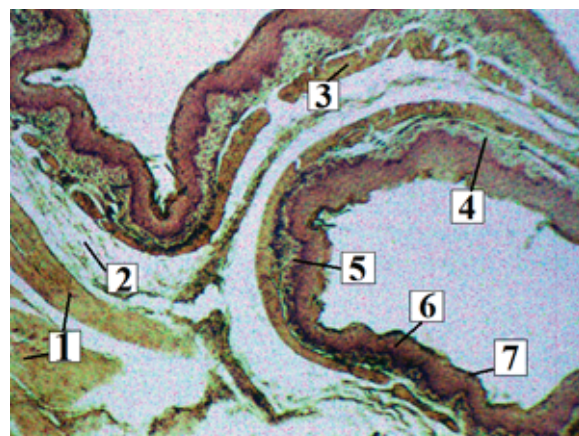


Figure 3: Microstructure of the rumen papilla. Red deer, 5 years. Hematoxylin and eosin dyeing. Magnification by 40 times: 1 -- layers of the muscular shell; 2 -- submucosal layer; 3 -- smooth muscular plate; 4 -- own layer of mucous membrane; 5 -- producing epithelial layer with basophilic cytoplasm; 6 -- middle epithelial layer with low-basophilic cytoplasm; 7 -- surface four-row layer of flat cells with oxyphilic cytoplasm.

The base of the entire rumen mucous membrane is formed by loose connective tissue, as well as smooth muscular elements entering the papillae.

The muscular membrane consists of circular and longitudinal layers. The latter is located outside and its myocytes are somewhat oblique. The folds of the organ have a strongly thickened muscular membrane -- up to 3.5 times. The thickness of the serous membrane reaches 240--310 μm , is represented by loose connective tissue and mesothelium.

As the analysis of the obtained morphological data has shown (Table 2), higher growth energy is observed from 35 days of postnatal development in the layers of the muscular membrane and in the scar tissue of the mucous membrane.

TABLE 2: Thickness of the wall of the rumen of red deer of different ages ($M \pm m$, μm).

Age	The mucous membrane	Height of papillae	The muscular membrane	Serous membrane
Newborns	270 \pm 12.3	2.8 \pm 0,18	557 \pm 23.9	150 \pm 12.6
1 month	340 \pm 0.7	4.7 \pm 0,22	993 \pm 45.8	165 \pm 10.8
3 months	380 \pm 40.2	7.5 \pm 0,15	1620 \pm 113.2	172 \pm 25.5
6--8 months	445 \pm 82.5	9.9 \pm 0,33	2136 \pm 95.5	190 \pm 33.3
18--24 months	512 \pm 64.6	14.2 \pm 0.47	2680 \pm 68.4	233 \pm 45.5
Adult species	560 \pm 73.2	19.0 \pm 1.45	3215 \pm 127.8	250 \pm 25.5

By the age of seven months, the parameters increase by about four times, and by the age of 4--4.5 years, the increase is on average 6 times higher than the newborn age. The mucous membrane has a lower growth rates. For the specified age periods it increases in 1.6 and 2.1 times. Relatively low tension of development has a serous membrane -- in 1.25 and 1.7 times (in accordance with the specified periods).

The grid is a continuation of the rumen from which it is separated by a furrow and communicates with the rumen -- ostium rumenoreticularis, and with the slit-like hole omasum -- ostium reticuloomasium [1, 2]. The grid of red deer is located in front of and below the scar on the sword-shaped cartilage of the sternum, projected at the level of 6--8th intercostal.

The oesophageal gutter, which consists of two lips and a bottom, runs along its back wall. The base of the lips of the gutter is a longitudinal smooth musculature, and the base of the bottom is a transverse abdominal muscle. The length of the gutter reaches up to 12--15 cm, the height of the lips -- up to 2.0 cm (Fig. 4).

The mucous membrane of the grid is made up of noncorrected folds, of which 4--7 cells are formed. They're covered with small orogival papillae on top. The height of the cell walls reaches 8--12 mm.



Figure 4: The mucous membrane of the mesh (the drug is reversed). Red deer, 7 years: 1 -- polygonal cells; 2 -- esophageal gutter; 3 -- grid-omasum opening.

On the side surfaces of the walls there are often pointed papillae -- I and II orders of magnitude. The mucous membrane of the cells has a well developed mucous layer, a submucosal base and a muscular plate. The mucous membrane is lined with multilayer orogenic epithelium, which thickness reaches -- 93 μm (Fig. 5).

The muscular membrane at the bottom of the grid forms an inner circular layer and an outer longitudinal layer, in other parts of the body the direction of smooth myocytes changes to the opposite. Muscle layers are represented by diffusely located myocytes, and in the walls of cells -- by elongated muscle tie (400x500 microns).

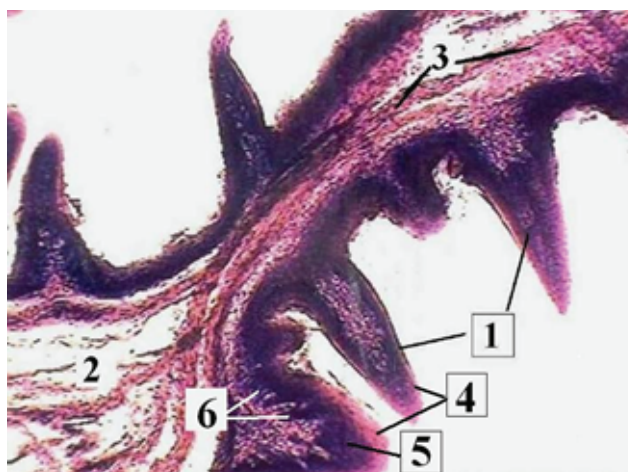


Figure 5: Mesh cell wall fragment. Red deer, 5 years. Hematoxylin with eosiny. Magnification by 40 times: 1 -- studded papillae -- outgrowths; 2 -- actually-slimy layer of mucous membrane; 3 -- muscular plate; 4 -- polygonal cells; 5 -- intermediate cells; 6 -- sprout epithelial cells.

The serous membrane reaches a considerable thickness of up to 220 microns and contains large vessels and nerve bundles.

Among the macroindicators of the grid, the greatest relative increase is in weight and volume, by 6--7 months of postnatal development they reach, respectively, 118 and 120 % (of the newborn), ($P \geq 0.999$), the perimeter is -- 90 % ($P \geq 0.99$). By the age of two years, the organ growth dynamics is decreasing. Growth energy is observed up to 4-5 months in organ volume -- 28 % ($P \geq 0.95$). Later on, the changes in the above indicators are almost invisible and unreliable (Table 2). 3). The obtained data on the dynamics of grid development are consistent with those of other ruminants [2, 4, 5].

TABLE 3: Morphometric parameters of the grid in red deer ($M \pm m$).

Organ performance	Age of the animals				
	Newborns	6--8 months	18--24 months	4--5 years	Older than 10 years
Perimeter in cross section (cm)	13.0 \pm 0.93	34,3 \pm 1,22	48.0 \pm 2.25	48.4 \pm 3.12	50.1 \pm 3.85
Mass without content (g)	22 \pm 1.15	87 \pm 3.27	248 \pm 8,82	257 \pm 4.50	265 \pm 9.45
Internal volume (l)	0.11 \pm 0.09	0.42 \pm 0.27	1,2 \pm 0,45	1.6 \pm 0.27	1.7 \pm 0.15

The analysis of grid microstructure parameters shows that at different age stages the muscular membrane is superior to other membranes in terms of the degree of development (tab. 4). By the age of four, it's increasing 3.5 times. The thickness of serous and mucous membranes increases by 1.3 and 1.8 times, respectively. In subsequent age periods, the change in their thickness is not reliable ($P \leq 0.95$).

TABLE 4: Age parameters of grid wall thickness in red deer ($M \pm m$, μ m).

Age	The mucous membrane	The muscular membrane	Serous membrane
Newborns	250 \pm 22.3	850 \pm 46.9	165 \pm 36.6
1 month	265 \pm 34.7	1190 \pm 98.8	160 \pm 25.0
3 months	325 \pm 66.2	1640 \pm 120.4	175 \pm 28.8
6--8 months	395 \pm 70.0	2136 \pm 95.5	188 \pm 48.2
18--24 months	410 \pm 55.0	3090 \pm 187.4	215 \pm 62.5
Adult species	415 \pm 76.2	3157 \pm 142.8	220 \pm 55.5

The third stomach chamber is a omasum. By its function, it acts as an organ that squeezes out the liquid component of the contents and pushes it into the abomasum. The omasum is located to the right of the rumen and to the left of the liver, behind and above the abomasum and grid. It is projected to 7th and 10th rib levels.

The omasum is connected to neighboring cameras by means of grid-omasum and omasum openings. Its surface is curved (large and small).

The mucous membrane has outgrowths. We have identified three varieties of them. Small outgrowths -- 18--19 pieces, with a height of 6--10 mm. Average outgrowths, their height reaches 35 mm, the number -- up to 13 pieces, large outgrowths in number -- 10--12 pieces, with a height of 65 mm (Fig. 6).

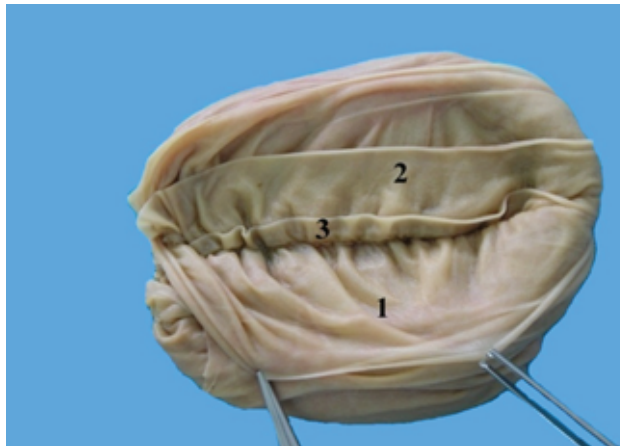


Figure 6: The texture of the mucous membrane of a deer omasum. Age 5 years: 1 -- large outgrowth; 2 -- average outgrowth; 3 -- small outgrowth.

The wall thickness of the omasum (excluding outgrowths) is less than the wall thickness of the grid. The mucous membrane is lined, as in other pre-stomachs, with multilayered orogenic epithelium. The muscular lamina of the leaflets is well developed, the submucosal layer of the mucous membrane is also well expressed.

The muscular membrane contains internal circular and external longitudinal layers, less pronounced than in other pre-stomachs. The serous membrane is sufficiently developed, its thickness sometimes reaches up to 1700 microns (Fig. 7)

The weight, volume and linear values of the omasum do not change evenly. The most intensive dynamics of growth is manifested by 7 months of postnatal development. Their indicators reach 65--80 % with a probability level of $P \geq 0.999$. At the same time, there is a steady manifestation of the growth energy of the omasum's weight indicators up to two and a half years -- 76 % ($P \geq 0.99$). This increase in weight may be due to the continued development of outgrowths (Table 5). After 4.5 years of age, the reliability of the indicators decreases. Biometric methods revealed a negative relationship between the weight and volume of the omasum ($r = -0.2$).

Comparing the thicknesses of the membranes of newborns' red deer and red deer of other ages, it was found that the muscular membrane grows more actively. At the age of six months its increase is about 3.4 times (1210 ± 33.0 microns), at the age of 4.5 years in 4 times (1620 ± 120.6 microns). hickness of mucous membrane during these

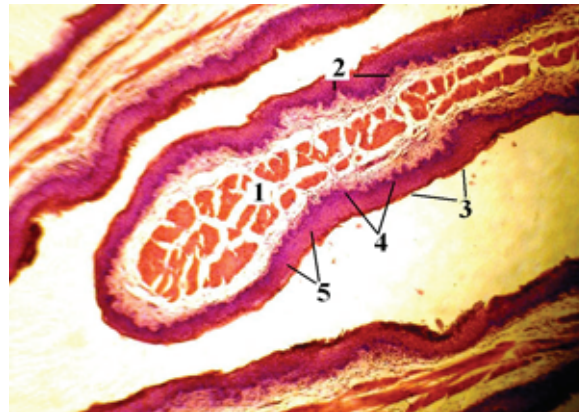


Figure 7: The upper part of the omasum's outgrowth. Red deer, 5 years. Dyeing hematoxylin and eosin. Magnification by 40 times: 1 -- club-shaped thickening of the muscular plate; 2 -- muscular plate microscopes; 3 -- polygonal cells; 4 -- sprout epithelial layer; 5 -- intermediate cells.

TABLE 5: Length, weight and internal volume of the omasum in red deer (M±m).

Organ performance	Age of the animals				
	Newborns	6--8 months	18--24 months	4--5 years	10 years
Perimeter in cross section (cm)	12±0.09	25±1.15	30±4.25	38±2.45	38±0.72
Mass without content (g)	22.0±3.09	140±12.7	320±25.5	389±13.8	410±46.02
Internal volume (l)	0.09 ±0.005	0.30±0.04	0.8±0.027	0.9±0.04	1.1 ± 0.05

time intervals increases by 1.6 (285 ± 42.2 microns) and 1.7 (335 ± 20.5 microns) times, respectively (Tab. 6). Similar changes occur in other ruminants in most cases [3, 4, 7].

TABLE 6: Microscopic parameters of the wall of the red deer omasum (M±m, µm).

Age	Epithelial thickness of the mucous membrane	The thickness of the mucous membrane	The thickness of the muscular membrane	The thickness of the serous membrane
Newborns	46±0.8	250±3.6	800±6.6	850±8,8
6 months	60±0.6	297±5.2	1200 ± 25.5	1200±12.2
4--5 years	66±0.8	350±28.0	1650±20.4	1300±12.2
7--10 years	63±0.9	380±9.2	1880±10.9	1680±8.4

A study of the vascular system shows that the omasum is a functionally quite active organ. Its leaves are dominated by leptoareal blood vessels, indicating a high level of hemodynamics [10] (Fig. 8).

The abomasum is a true stomach, which is analogous to the single-chamber stomach in many morphofunctional features. In the case of red deer, it has a curved and elongated shape. Most of the abomasum lies under the book, the body is located above the area of the sword-shaped cartilage and partially on the umbilical cord area (behind the grid).

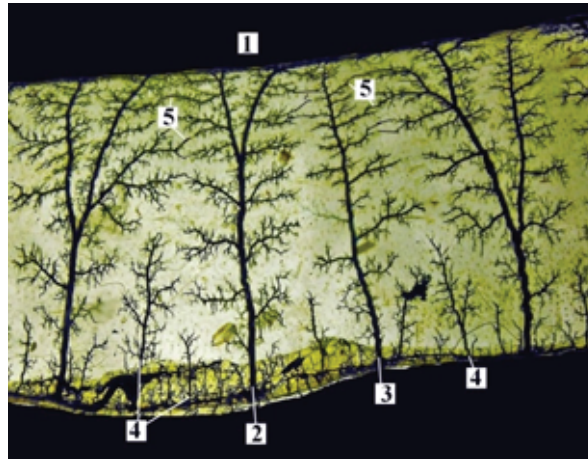


Figure 8: Intra-organic vessels, an outgrowth of a deer book. Age 2 years. Injected drug with polychrome mass: 1 -- edge of the outgrowth inverted into the cavity of the omasum; 2-bifurcation narrow field (leptoareal) artery; 3 -- unitary artery; 4-shortened arteries; 5 -- anastomoses between the branches of vessels.

The piloric part is directed to the right subcostal area and then rises dorso-kaudal, where it passes to the duodenum. The length of the large curvature is 60--78 cm, the small one -- 38--45 cm, the volume -- up to 9 liters (10 % of the total stomach volume).

The mucous membrane is gathered mainly in longitudinal spiral folds up to 30 pieces, up to 2.5 cm. The folds increase the suction area of the mucous membrane (Fig. 9).

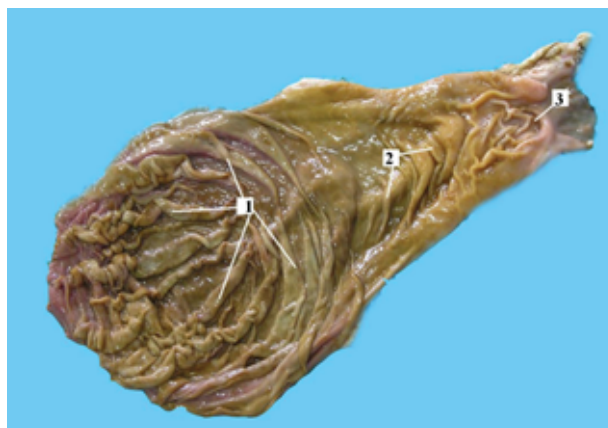


Figure 9: The mucous membrane of the abomasum. Red deer, 6.5 years. 1 -- longitudinal folds of the abomasum; 2 -- transverse folds of the pyrus; 3 -- sphincter.

The mucous membrane of the organ contains a lot of iron. The thickness of the mucous membrane is 1820 microns, the ferrous layer reaches -- 1200 microns.

End parts of the glands in all areas of the abomasum reach the muscular layer of mucous membrane. With age, the size of the glands increases, they become longer and wider [7] (Tabl. 7).

In adult animals, the muscle thickness in the pyloric part of the abomasum can reach 2000 μm. The thickness of the abomasum wall in adult animals is 3 times higher than in newborns.

TABLE 7: Morphological indicators of the fundamental part of the abomasum in red deer (M±m, μm).

Age	Thickness ferrous layer	Thickness mucous layer	Thickness of the muscular layer
newborns	340±4.4	630±14.4	680±12.2
6 months	660±8.2	1200±11.2	1050±4.6
12 months	1040±8.6	1470±15.6	1510±12.8
7–10 years	1240±5.6	1700±19.0	1740±14.4

The mucous membrane contains cardiac, bottom and pyloric glands. Cardial glands are tubular, stacked tightly, have long and wide outlet ducts. End sections of glands with wide cavities are 30–38 microns. Fundamental glands are well developed, the diameter of the end sections is 28–36 microns. The main cells of cubic and rounded shape, their nucleus cytoplasm have a pronounced basophilicity. There are quite a lot of cladding cells, and their oxyphilic cytoplasm has granularity. The layer of pyloric glands is somewhat smaller. Cells have light cytoplasm and the nuclei are pushed to the base (Fig. 10).

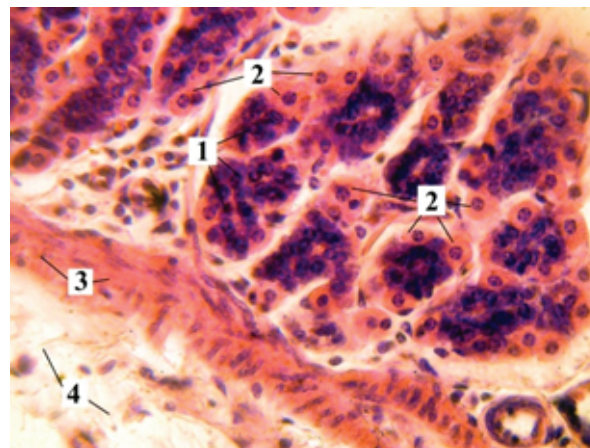


Figure 10: End sections of the foundation glands of red deer pyrus, 5 years old. Hematoxylin and eosin. Magnified. 90 times. 1 -- main cells; 2 -- cladding cells; 3 -- muscular plate; 4 -- submucosal base.

4. Conclusion

As a result, the macro-micro-morphology and peculiarities of multi-chamber stomach development in red deer are subordinated to common regularities typical of other ruminants. At the same time, it is possible to consider the following distinctive features:

more pronounced blind bags, sufficiently high mucous membrane papillae, significant multi-row epithelial cells, pronounced growth energy and relatively early stabilization of organ formation caused by the transition to plant nutrition and adaptation of animals to extreme living conditions.

Grid development, as well as other stomach chambers in red deer has an uneven wave-like character. The greatest growth of macro- and microindicators is observed in the first months of life, as well as in the spring and summer period. By the age of 6–8 months the grid topographically occupies the position typical for adult animals.

Reliable preservation of the tension of the book's mass growth up to 2 years (in comparison with other indicators), apparently, is connected with further development of leaflets of the first and second order.

References

- [1] Akayevsky, A.I. (1939). *Anatomy of a red deer*. Moscow, p. 186.
- [2] Vasiliev, K.A. (1991). *Morphofunctional characteristics of yak ontogenesis by periods of development*. Ulan-ud.: Buryat, Fr. in, 224 p.
- [3] Vishnevskaya, M.D. (1963). *Stomach and intestine growth in ontogenesis of cattle and moose as ruminant animals taking into account their ecological differences*. Ivanovo, p. 21.
- [4] Szczecinov, J.I.A. (1971). *Peculiarities of growth, development and topodynamics of the stomach and esophageal gutter in the ontogenesis of cattle*: PhD dissertation thesis. Omsk, 30 p.
- [5] Davletova, L.V. *Biology of development of digestive organs of ruminants and omnivorous animals*, 136 p.
- [6] Arias, J.L., Gabrera, R., Valencia, A. (1978). Observations on the histological development of the bovine rumen papillae. Morphological changes due to age. *Zbl. Veterinarmed*, no. 2, pp. 140–151.
- [7] Korosteleva, N.I. (1970). Morphology and innervation of the gastrointestinal tract of the red deer. PhD dissertation thesis. Barnaul, 20 p.
- [8] Turevsky. A.A. (1961). To the cytochemistry of the pre-stomach epithelium of cattle. *Matlya All-Union conf. on biochemistry of agricultural animals*, iss. 2. Moscow, pp. 119–120.
- [9] Perez-Barberia, F.J., Gordon, I.J., Illius, A. (2002). Phylogenetic analysis of stomach adaptation in digestive strategies in American ruminans. *Oecologia*, vol. 127, pp. 30–39.

- [10] Alaev, A.N. (1961). Intravenous arteries of the gastrointestinal tract of the carnivorous and herbivorous animals. Structure, blood supply and inner organs inner innervation. *Coll. of scientific articles*. Volgograd, pp. 251--254.
- [11] Zhukov, V.M. (2016). Fundamentals of the analysis of the animal population pathology. *Veterinary*, no.10, pp. 43--45.
- [12] Tkachenko, L.V., Malofeev, Yu.M., Konovalov, V.K., Tyutyunnikov, S.V. (2011). *Method of preparation of colored mass for vascular system nalewashing in anatomical studies*. Pat. No. 2423702 Russian Federation, IPC 51 G01N33/49, A01N1/00, C09D4/02. 2010109950/15; 16.03.2010; published on 10.07.2011, Bulletin no. 19, p. 7.
- [13] Chebakov, S.N. (2012). Features of topography and macro-morphology of the scar in red deer in postnatal ontogenesis. *Vestnik AGAU*, no. 1, pp. 63--68.