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Anatomical Studies on the Reticulum and Reticular Groove of Non-Descript Goats of Jammu Region

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ABSTRACT

The present study was carried on six stomach samples from adult apparently healthy non-descript goats. Reticulum was spherical in outline and separated from rumen by a distinct rumino-reticular groove. Mucosa of the reticulum formed typical honeycomb shaped cells which were smaller near reticular groove as compared to the cells towards the floor of the organ. The cells towards the floor of reticulum were sub-divided by secondary and tertiary crests which were absent from the cells towards the reticular groove. Histologically, reticulum consisted of tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa. Lamina epithelia consisted of keratinized stratified squamous epithelium. Lamina muscularis mucosae was present only at the tip of primary reticular crests. Tunica muscularis consisted of inner circular and outer longitudinal layers of smooth muscle layers. At reticular groove, tunica muscularis presented middle oblique muscular layer. The thickness of epithelium was significantly higher at floor of reticulum than towards oesophageal groove. Outer muscular layer was thicker than inner muscular layer towards oesophageal groove whereas at floor, inner muscular layer was thicker. Towards the level of reticulo-omasal opening, the floor of the reticular groove presented papillae resembling the claws of a small bird. The entire reticular groove and its lips were lined by stratified squamous keratinized epithelium. Lamina muscularis mucosae was incomplete and seen mainly in the lips of reticular groove. The floor of groove presented transverse smooth muscle fibers whereas lips contained thick longitudinal smooth muscle fibers.

HIGHLIGHTS

- The honeycomb shaped cells were smaller near reticular groove.
- Histologically, lamina muscularis mucosae was present only at the tip of primary reticular crests
- Tunica muscularis consisted of two layers of smooth muscle but at reticular groove, tunica muscularis had three muscle layers.

Keywords: Anatomy, goat, histology, reticulum, reticular groove

Union territory of Jammu & Kashmir is blessed with land, environment and socio-cultural setup which are appropriate for the rearing of small ruminants. Goat rearing has advantages when compared to other farm animals as goats do not require expensive buildings and equipments. Goats have high dry matter and fiber digestibility and thus can subsit on poor woody vegetation which no other animal will consume. Hence, the people below poverty line are also able to rear the goat. Hence, goat is popularly known as 'Poor Man's Cow'.

Animal health directly reflects the better production which depends on better nutrient supply, proper digestion and absorption. The digestive system of ruminants is unique in a way that it allows them to use energy from fibrous plant material better than other herbivores. Ruminant forestomach includes rumen, reticulum and omasum. Forestomach have a unique sorting function which ensures that large ingesta particles are regurgitated and remasticated (Fritz *et al.,* 2009). This mechanism facilitates a high digestive efficiency (Clauss *et al.,* 2009).

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Literature is available on the histology of fore-stomach of cattle, buffalo and sheep (Scala *et al.,* 2011), gross morphology and biometry of fore-stomach of Black buck (Kumari *et al.,* 2013), morphology of stomach of Swamp buffalo (Nurliani *et al.,* 2015), macroscopic anatomy of reticulum in wild ruminant species (Clauss *et al.,* 2009). However, meager information is available on the gross anatomy and histomorphometry of reticulum and reticular groove of non-descript goats of Jammu region. Hence, the present study was planned and executed.

MATERIALS AND METHODS

For the study, six stomach samples from adult apparently healthy non-descript goats were collected from slaughter houses in and around Jammu region. Immediately after collection, the stomach was cleaned with running water and brought to the laboratory for recording the gross morphological and biometrical studies. Following parameters were recorded:

1. Total empty weight (gm) of stomach and weight (gm) of reticulum was recorded with help of Monopan balance.
2. Capacity (ml) of entire stomach and reticulum was carried out by filling with water and measuring with help of measuring cylinder.
3. Circumference (cm) of reticulum as longitudinal and transverse circumference from the middle of the reticulum,
4. Cranio-caudal width (cm) of reticulum.
5. Length (cm) and width (cm) of honey-comb cells.

After recording the gross and biometrical parameters, tissue samples were collected from two sites, i.e. dorsal (close to oesophageal groove) and ventral (floor of reticulum) and preserved in 10% Neutral Buffered Formalin (NBF) solution (Luna, 1968). The tissue samples were processed and tissue sections of 5 µ thickness were obtained. The sections were stained with Haematoxylin & Eosin for routine histomorphology, Von Gieson & Verhoeff's and Gomori stains for connective tissue fibers (Luna, 1968). The micrometrical observations were taken i.e. thickness (µ) of lamina epithelia, lamina-propria submucosa, tunica muscularis and tunica serosa of reticulum, length (µ) and width (µ) of primary reticular crest. All the data was subjected to standard statistical analysis (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

Gross morphology and biometry of reticulum

Reticulum was the 2nd but most cranially located compartment of goat stomach as also observed in Surti goat (Mahendrakumar, 2017). In large ruminants, reticulum was the smallest compartment whereas in sheep and goats, omasum is the smallest compartment (Nickel *et al*., 1979). It was somewhat spherical in outline (Fig. 1) and was located in between diaphragm and rumen. Machado and Oliveira (2008) stated that the reticulum of marsh deer was of pyriform shape and more developed than the omasum. It consisted of parietal/left and visceral/right surface both of which were convex. Dorsally, it continued with the cranial sac of rumen whereas ventrally, reticulum was separated from rumen by a distinct rumino-reticular groove as also observed by Colville and Bassert (2008) and Mahendrakumar (2017) in Surti goat. Interiorly, reticulum communicated with oesophagus and rumen through reticular groove and with omasum via reticulo-omasal orifice.

The mucosa of the reticulum of non-descript goats was pale brown in colour and formed permanent crests known as *cristae reticuli* which generally intersect to form honeycomb shaped cells known as *cellulae reticuli* (Fig. 2, 3). Majority of them were hexagonal in outline. Colville and Bassert (2008) stated that 4-6 sided structures of the honeycomb served to increase the surface area of the reticulum and thus increased the absorptive surface. Hofmann and Schnorr (1982) suggested that the honeycomb pattern of reticulum helps in contracting the organ. Pasiquini and Spurgeon (1989) also described the interior of the reticulum as honeycomb appearance due to intersecting mucosal crests. Reece (2005) observed that the crests were papillated in sheep but smooth in cattle. These cells were smaller near reticular groove/lesser curvature (Fig. 2) as compared to the cells which were present towards the floor of the organ/greater curvature (Fig. 3). Similar observation was made by Nurliani *et al*. (2015) in swamp buffalo, Perez *et al*. (2015) in deer and Mahendrakumar (2017) in Surti goat. The cells towards the floor of reticulum were sub-divided by secondary and

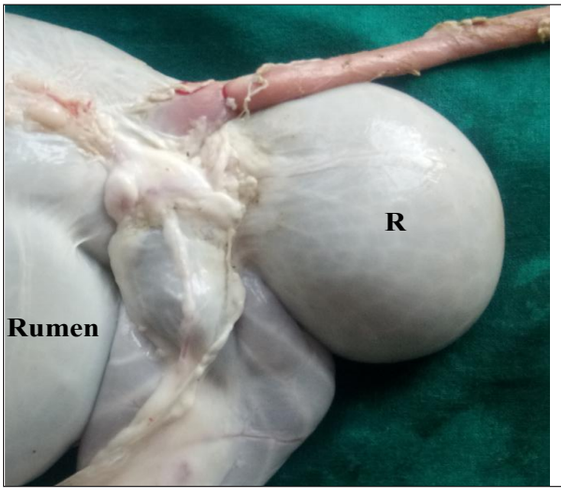

Fig. 1: Photograph of reticulum (R) of non-descript goat showing visceral surface

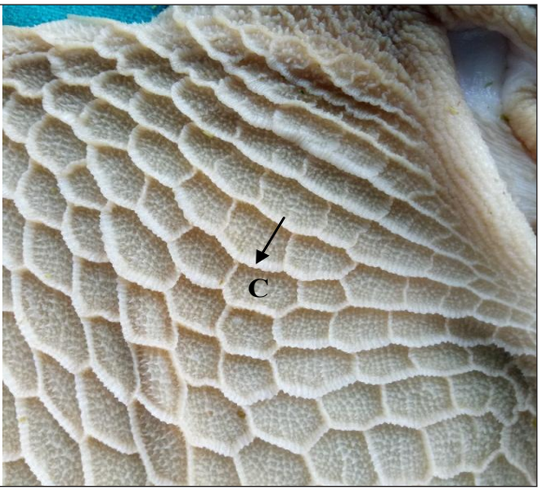

Fig. 2: Photograph showing interior of reticulum (towards reticular groove) having typical honeycomb shaped cells (C) bordered by primary crests (arrow). Secondary and tertiary crests are absent

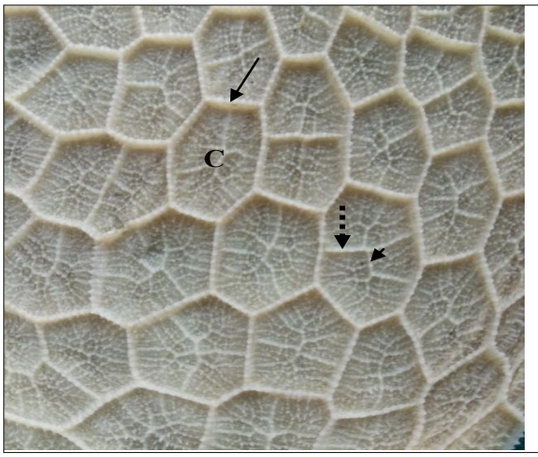

Fig. 3: Photograph showing interior of reticulum (towards floor of reticulum) having typical honeycomb shaped cells (C) bordered by primary crests (arrow). Secondary (dotted arrow) and tertiary crests (arrow head) are prominent

Fig. 4: Photomicrograph showing lamina epithelia (E), propria submucosa (S), inner muscular (I), outer muscular (O) layer, tunica serosa (Se), lamina muscularis mucosae (MM) in primary crest. H & E stain, 40x

tertiary crests (Fig. 3) which were absent from the cells towards the reticular groove (Fig. 2). Both the crests and floor of cells were studded with small conical papillae as also observed by Konig and Liebich (2009) in ruminants. Honeycomb cells of reticulum of deer were not divided and were devoid of secondary crests (Perez *et al.,* 2015).

Various biometrical parameters of reticulum are presented in Table 1. The mean empty weight of reticulum (88.52 ± 2.04 gm) was 12.67% of the total empty weight of the stomach (698.62 ± 37.17 gm). It was lesser when compared with values recorded in other species (in deer, the empty weight of reticulum was 98.5 ± 15.3 gm (Perez *et al.*, 2015) and in Surti goat (Mahendrakumar, 2017) it was 121.5 ± 5.29 gm). The capacity of reticulum (638.89 ± 59.27 ml) was 6.53% of the total volume of the stomach (9788.83 ± 655.29 ml). The longitudinal (29.88 ± 0.28 cm) circumference was greater than transverse circumference

(23.70 ± 0.89 cm) which were in approximation with the findings of Mahendrakumar (2017) in Surti goat (29.08 ± 1.27 cm and 25.95 ± 1.86 cm, respectively). In black buck, the longitudinal diameter was 17.7 ± 0.72 cm and transverse diameter was 14.4 ± 0.72 cm (Kumari *et al*., 2013).

Table 1: Showing various biometrical parameters of reticulum of non-descript goats of Jammu region

Sl. No.	Parameter	Mean ± SE
1	Empty weight (gm) of reticulum	88.52 ± 2.04
2	Capacity (ml) of reticulum	638.89 ± 59.27
3	Longitudinal circumference (cm)	29.88 ± 0.28
4	Transverse circumference (cm)	23.70 ± 0.89
5	Height (cm) of reticulum	13.77 ± 0.61
6	Cranio-caudal width (cm)	10.78 ± 0.34
7	Length (cm) of honeycomb cells towards reticular groove	1.14 ± 0.03
8	Width (cm) of honeycomb cells towards reticular groove	0.88 ± 0.03
9	Length (cm) of honeycomb cells towards reticulum floor	2.00 ± 0.05
10	Width (cm) of honeycomb cells towards reticulum floor	1.42 ± 0.03
11	Length (cm) of reticular groove	8.70 ± 0.07

The height of reticulum (13.77 ± 0.61 cm) was greater than its cranio-caudal width (10.78 ± 0.34 cm). Perez and Vazques (2012) recorded slightly lower values in Brown Brocket deer (reticulum height as 12.0 ± 1.41 cm and cranio-caudal length as 8.38 ± 1.49 cm). Perez *et al*. (2015) calculated the height and cranio-caudal length of reticulum of deer as 19.2 ± 0.8 cm and 11.6 ± 1.2 cm, respectively. The same was 12.2 ± 2.4 cm and 12.0 ± 0.5 cm, respectively in Dorcas Gazelle (Jerbi *et al.* 2016). Length (2.00 ± 0.05 cm) and width (1.42 ± 0.03 cm) of honeycomb cells towards the floor/greater curvature of reticulum was greater than the length (1.14 ± 0.03 cm) and width (0.88 ± 0.03) of cells present towards reticular groove/lesser curvature of reticulum. In Surti goat, length and width of reticular cells was 19.17 ± 0.67 mm and 13.97 ± 0.48 mm, respectively (Mahendrakumar, 2017).

Histomorphology and micrometry of reticulum

Histologically, reticulum consisted of four layers namely tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa (Fig. 4). The lamina epithelia consisted of keratinized stratified squamous epithelium having stratum basale, stratum spinosum, stratum granulosum and stratum corneum. The cells of stratum basale were columnar. The cells of stratum spinosum were polyhedral and larger than the basal cells. The stratum granulosum was one to three cells thick. Few of the cells were swollen with nucleus surrounded by clear cytoplasm. The upper keratinized layer protect against abrasion by the rough, fibrous diet as also quoted by Dyce *et al.* (2002). In yak, the mucosal epithelium of reticulum was not keratinized (Wang *et al.,* 2014). In present study, the epithelial mucosa of reticulum was folded to form primary reticular crests whose lateral border presented prominent conical ridges. The epithelium formed epidermal pegs which were more prominent in reticular crests. Lamina propria consisted of dense irregular connective tissue as also observed by Ramkrishna and Gadre (2004) in domestic animals and contained abundant collagen fibers with few reticular and elastic fibers (Fig. 5, 6). Smaller vessels, lymphatics and capillaries were also seen. Lamina muscularis mucosae was present only at the tip of primary reticular crests (Fig. 4) as reported earlier by Ikemizu *et al.* (1994) in domestic ruminants and Sultana *et al.* (2021) in sheep. Secondary reticular crests were devoid of any muscularis mucosae layer. Due to absence of muscularis mucosae layer, the lamina propria merged with tunica submucosa forming lamina propria submucosa rich in collagen and elastic fibers (Fig. 5). Agungpriyono *et al*. (1995) reported continuous and well developed muscularis mucosae in reticulum of mouse deer.

Tunica muscularis consisted of inner circular and outer longitudinal layers of smooth muscle layers. Loose connective tissue and blood vessels were also recorded in between. At reticular groove, tunica muscularis consisted of three muscle layers with presence middle oblique muscular layer (Fig. 7). Outermost layer was tunica serosa which consisted of loose connective tissue, various blood vessels and nerve fibers. Mesothelium was not observed.

Various micrometrical parameters of reticulum are presented in Table 2. The thickness of epithelium was significantly higher at floor of reticulum (84.92 ± 4.13 µ) than towards oesophageal groove (72.37 ± 3.72 µ). Similar pattern was seen for the thickness of lamina propria-submucosa, 254.59 ± 31.66 µ at floor of reticulum

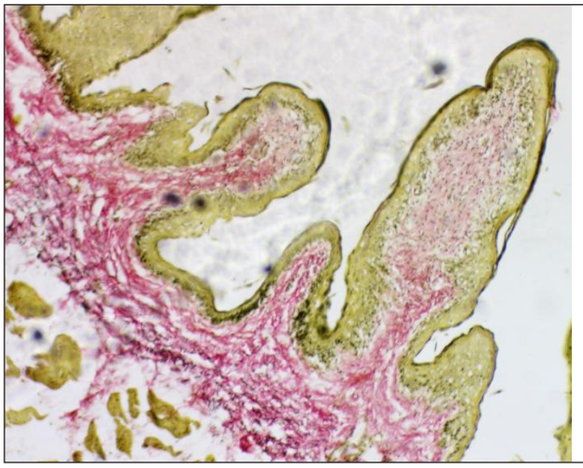

Fig. 5: Photomicrograph showing presence of abundant collagen fibers with few elastic fibers in core of reticular crests and lamina propria submucosa. Van Gieson & Verhoeff's stain, 100x

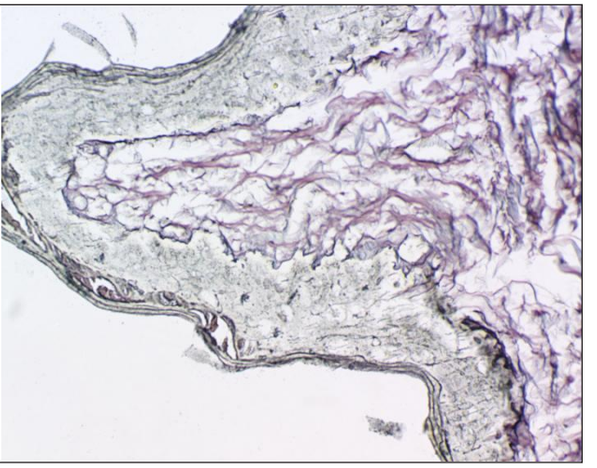

Fig. 6: Photomicrograph showing presence of reticular fibers. Gomori's stain, 400x

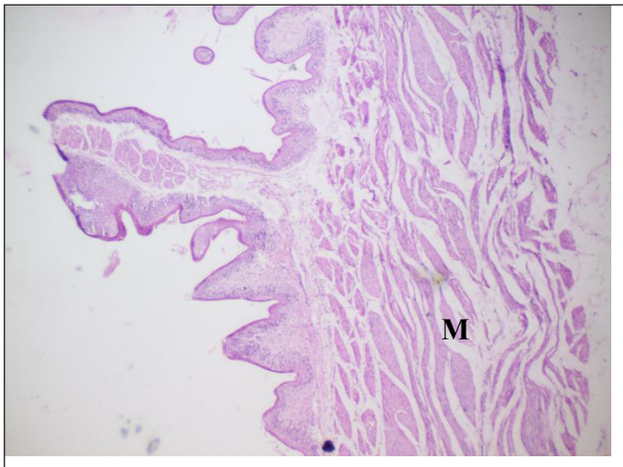

Fig. 7: Photomicrograph showing presence of middle oblique muscle (M) layer towards reticular groove. H & E stain, 40x

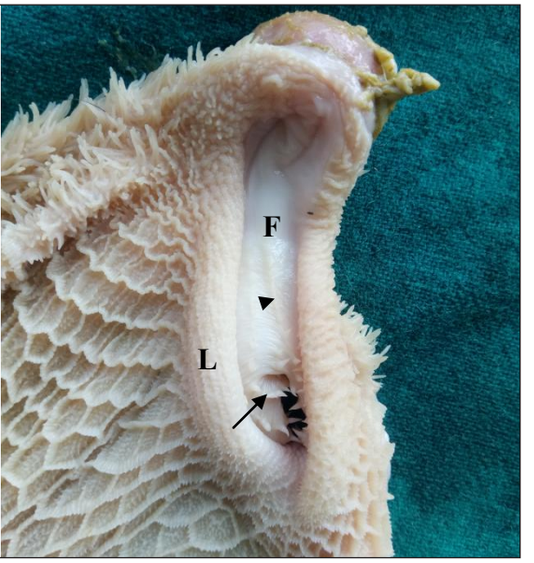

Fig. 8: Photograph showing lips (L) and floor (F) of reticular groove with presence of papillae unguiculiformes (arrow) towards reticulo-omasal opening. Floor presented longitudinal folds (arrow head).

and 172.60 ± 10.50 µ towards oesophageal groove. Tunica muscularis was thick towards oesophageal groove (1104.4 ± 84.06 µ) as compared to thickness at floor of reticulum (864.30 ± 77.75 µ). Outer muscular layer was thicker than inner muscular layer towards oesophageal groove whereas at floor, inner muscular layer was thicker (Table 2). The thickness of tunica muscularis in present study was less as compared to previous studies in yak where thickness of inner row muscle and the outer longitudinal muscle varied from 1,537.4 to 2,369.9 µm and 1,501.6 to 1,895.4 µm, respectively (Wang *et al.,* 2014). In sheep, the thickness was 1114 ± 8.1 µm thick (Sultana *et al.,* 2021). Tunica serosa showed no significant difference in thickness at floor (128.79 ± 9.72 µ) and towards oesophageal groove

Table 2: Showing various micrometrical parameters of reticulum of non-descript goats of Jammu region

Sl. No.	Parameter (µ)	Towards oesophageal groove		Towards floor of reticulum	
		Mean	SE	Mean	SE
1	Thickness epithelium	72.37[a]	3.72	84.92[b]	4.13
2	Thickness LP submucosa	172.60 [a]	10.50	254.59[b]	31.66
3	Inner muscle layer	349.73[a]	30.88	452.37[a]	41.45
4	Outer muscle layer	733.08[a]	65.47	413.51[b]	34.40
5	Tunica muscularis	1104.4[a]	84.06	864.30[b]	77.75
6	Tunica serosa	115.72[a]	10.97	128.79[a]	9.72
7	Primary Crest per Field	1.17[a]	0.21	0.83[a]	0.11
8	Length of primary crest	1256.8[a]	87.58	1436.6[a]	131.88
9	Width of primary crest	496.59[a]	46.69	638.98[b]	56.83

Mean value with same superscript within row do not differ significantly (p>0.05).

(115.72 ± 10.97 µ). Primary reticular crests per field at 40X were higher towards oesophageal groove (1.17 ± 0.21) than at floor (0.83 ± 0.11) though the difference was non-significant. Length and width of primary reticular crests at floor was 1436.6 ± 131.88 µ and 638.98 ± 56.83 µ which was higher than towards oesophageal groove (1256.8 ± 87.58 µ and 496.59 ± 46.59 µ). Width of reticular crest showed significant difference but not the height. In sheep, the length and width of papillae was 1151.6 ± 5.9 µm and 315 ± 9.1 µm (Sultana *et al.,* 2021).

Reticular groove

Gastric groove extends from the level of cardia to the pylorus and was divided into three segments i.e. reticular groove, omasal groove and abomasal groove (Nickel *et al.,* 1979). The reticular groove had two muscular ridges/lips which extended from the cardia to the level of reticulo-omasal opening. The length of reticular groove was 8.70 ± 0.07 cm. It was about 15-20 cm long in ox and 7-10 cm long in small ruminants (Nickel *et al.,* 1979). Both the lips were less developed towards the cardia but were well developed towards the reticulo-omasal orifice. These two lips had separate termination. Towards the level of reticulo-omasal opening, the floor of the groove presented papillae resembling the claws of a small bird (Fig. 8). These were described as *papillae unguiculiformes* by Sisson and Grossman (1953) whereas such papillae were absent at reticulo-omasal orifice in deer (Perez *et al.,* 2015). Teixeira *et al.* (2009) suggested the role of these papillae as filter barrier and check the passage of those particles which were of inappropriate size and not suitable to be forwarded into the omasum and abomasum. The floor of the groove was pale and marked by longitudinal folds (Fig. 8).

The entire reticular groove and its lips were lined by stratified squamous keratinized epithelium. The thickness of epithelium was significantly higher at lips of reticular groove (121.04 ± 9.16 µ) as compared to floor of groove (71.69 ± 6.18 µ). Lamina muscularis mucosae was incomplete and seen mainly in the lips of reticular groove (Fig. 9).

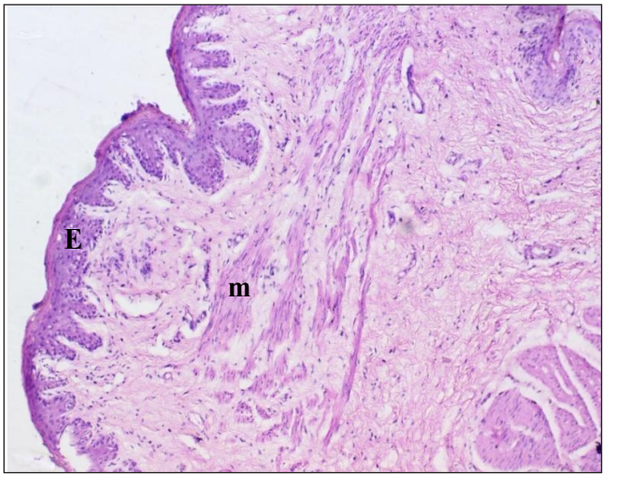

Fig. 9: Photomicrograph of lip of reticular groove showing keratinized stratified squamous epithelium (E), presence of lamina muscularis (m) in lamina propria submucosa. H & E stain, 100x

Lamina propria blended with tunica submucosa which mainly consisted of collagen and elastic fibers. Glands were absent in lamina propria. In the floor of groove, mainly transverse smooth muscle fibers were seen whereas lips contained thick longitudinal smooth muscle fibers. The thickness of lamina propria-submucosa was significantly higher at lips of reticular groove (421.32 ± 20.04 µ) as compared to floor of groove (333.55 ± 15.83 µ). The length and width of papillae were significantly higher at lips of reticular groove (696.97 ± 129.96 µ and 317.91 ± 66.79 µ, respectively) than at floor of reticular groove (393.01 ± 79.57 µ and 242.58 ± 30.02 µ, respectively). According to Pochon (2002), the muscle fibers present in the lips of groove were arranged longitudinally whereas the floor of the groove presented outer longitudinal muscle fibers and inner layer of fibers arranged perpendicular to the long axis of the groove. In yak, tunica muscularis was very thick and included inner oblique muscle and the outer row muscle (Wang *et al.,* 2014).

CONCLUSION

Reticulum was spherical in outline in non-descript goats. Mucosa formed typical honeycomb shaped cells which were smaller near reticular groove as compared to the cells towards the floor of the organ. The cells towards the floor of reticulum were sub-divided by secondary and tertiary crests which were absent from the cells towards the reticular groove. The mean empty weight of reticulum was 12.67% of the total empty weight of the stomach whereas the capacity was 6.53% of the total volume of the stomach. Lamina epithelia consisted of keratinized stratified squamous epithelium. Lamina muscularis mucosae was present only at the tip of primary reticular crests. The thickness of epithelium was significantly higher at floor of reticulum than towards oesophageal groove. Outer muscular layer was thicker than inner muscular layer towards oesophageal groove whereas at floor, inner muscular layer was thicker. The entire reticular groove and its lips were lined by stratified squamous keratinized epithelium. Lamina muscularis mucosae was incomplete and seen mainly in the lips of reticular groove.

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