

Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 24(2) May-August 2026]

Pantnagar Journal of Research

(Formerly International Journal of Basic and
Applied Agricultural Research ISSN : 2349-8765)



G.B. Pant University of Agriculture & Technology
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Comparative histomorphological and histochemical studies on the abomasum of adult Bakerwali goats, non-descript goats and non-descript sheep of the Jammu region

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<https://doi.org/10.67063/pjr.vol.24.issue.02.09>

ABSTRACT: The present study was conducted to investigate the histomorphology and histochemistry of the abomasum in adult Bakerwali goats, non-descript goats (NDG), and non-descript sheep (NDS) of the Jammu region. Histological examination revealed that the abomasum consisted of tunica mucosa, submucosa, muscularis, and serosa. Cardiac glands were simple branched tubular glands, fundic glands contained mucous neck, chief, parietal, and argentaffin cells, while pyloric glands were predominantly mucous and associated with deep gastric pits. Reticular fibers formed a characteristic network around the gastric glands, and lymphoid tissue was evident within the lamina propria. Histochemical studies demonstrated strong Periodic Acid–Schiff (PAS) positivity in the surface epithelium, gastric pits, and glandular cells, indicating the presence of neutral mucopolysaccharides. Acidic mucopolysaccharides were localized mainly in the infra-nuclear regions of glandular cells. Glycogen, proteins, and lipids showed variable distribution within different glandular regions, reflecting their secretory activity. The study provided baseline information on the normal microscopic architecture and chemical composition of the abomasum in indigenous small ruminants of the Jammu region. These findings may serve as valuable reference data for comparative anatomy, pathology, and gastrointestinal research in sheep and goats.

Keywords: Abomasum, Bakerwali goat, Cardiac region, Histomorphology, Parietal cells

Union territory of Jammu & Kashmir is generally provided with an environment and socio-cultural system which is conducive to small ruminant production. When compared to other farm animals, goats have the advantage of not requiring expensive structures or equipment. Furthermore, goats have a high digestion of dry matter and fibre, and can eat inferior woody vegetation that no other animal would eat. As a result, the goat is known as the ‘Poor Man’s Cow’. Similarly, sheep farming is popular among India’s economically disadvantaged people and is seen as a “mortgage lifter” for poor farmers (Poonia *et al.*, 2012). Small ruminants provide meat, milk, wool, and hides. Their ability to produce well in different environments makes them a key part of sustainable livestock farming (Saba *et al.*, 2024; Singh *et al.*, 2025).

On the basis of foraging behaviour, ruminants can be classed as grazers, browsers, or intermediate grazers (Gordon, 2003). Sheep prefer to graze, but goats prefer to browse (Mosavat and Chamani,

2013). Browsers eat high-nutrient twigs and shrubs, while grazers eat lower-quality grasses.

Animal health should be good for better productivity. A better nutrient supply, adequate digestion, and absorption are all necessary for an animal’s optimal health. Ruminants have a digestive mechanism that permits them to use energy from fibrous plant material more efficiently than other herbivores. Ruminants, unlike monogastrics like pigs, have a digestive tract that is designed to ferment feedstuffs and create energy precursors for the animal.

The abomasum is a ruminant’s “true stomach”. It gets the food ready for enzymatic digestion and absorption in the small intestine (Liebich, 2019). The cardiac, fundic, and pyloric gland regions make up the inside of the abomasum as reported by Konig and Liebich (2020). Cardiac glands secrete mucus to protect the abomasal wall from acid damage. Fundic glands secrete acids, electrolytes, and digestive enzymes like pepsin to break down proteins, while the pyloric gland secretes the

hormone gastrin into the abomasum to protect the abomasal wall from acid damage (Banerjee, 1998). Literature is available on the histomorphology of abomasum of goat (Mahesh *et al.*, 2017), sheep (Poonia and Kumar, 2017) and domestic animals (Liebich, 2019). Rasheed and Ibrahim (2025) documented morphological and histochemical evaluation of the abomasum of lambs and goat kids (1–4 months of age). Mahesh *et al.* (2017) reported histochemical studies on the abomasum of goat. However, comparative information regarding histomorphology and histochemistry is unavailable on abomasum of small ruminants of Jammu region which prompted this study. The present study may guide us to a better understanding of the organ and thereby correlate with the digestive physiology of small ruminants. By better understanding how the digestive system of the ruminant works, livestock producers can better understand how to care for and feed ruminant animals. Developing a good understanding of ruminant digestive anatomy and function can help livestock producers better plan appropriate nutritional programs and properly manage ruminant animals in various production systems.

MATERIALS AND METHODS

The present study was conducted in the Division of Veterinary Anatomy, Faculty of Veterinary Sciences & A. H., SKUAST-J, R. S. Pura, Jammu. The stomach samples (N=06) from apparently healthy adult Bakerwali goat, non-descript goats and non-descript sheep were collected from the slaughter houses in and around Jammu city. The age was estimated based on dentition (Solaiman, 2010). Immediately after collection, the stomach was washed with running tap water and brought to the gross anatomy laboratory for recording the gross morphological and biometrical studies. Immediately after the slaughter of animals, the stomach was separated by cutting at the atrium ventriculi and pylorus in the cranial and caudal directions, respectively. All four compartments were excised for evacuation at the point of their greatest curvature. After thorough cleaning and removal of omental coverings, photography was done to document the

gross morphology of the abomasum.

Tissue samples from abomasum (cardia, fundus and pylorus) of Bakerwali goat, non-descript goat and non-descript sheep were preserved in 10% Neutral Buffered Formalin (NBF) solution. After proper fixation, the tissue samples were washed, dehydrated, and cleared by standard tissue processing schedule (Luna, 1968). The tissue samples were embedded in paraffin wax (58-60 °C). Tissue sections of 5 µm were obtained from these blocks on clean glass slides with the help of rotary microtome. The sections were subjected to following stains.

1. Haematoxylin & Eosin for routine histomorphology
2. Van Gieson's method for collagen fibers
3. Gomori's method for reticular fibers
4. Periodic Acid Schiff's method and Alcian blue (pH 2.5) for neutral and acidic mucopolysaccharides
5. Best Carmine Method for glycogen
6. Bromophenol Blue for proteins
7. Sudan Black B method for lipids

The stained sections were analyzed using an optical microscope (Magnus microscope, MX21i-TrLED) and photography was done.

RESULTS AND DISCUSSION

Histologically, the abomasum of goat and sheep species under study consisted of four different layers, namely tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa (Fig. 1) as earlier reported by Salan *et al.* (2023) in camel and Rasheed and Ibrahim (2025) in lamb and goat kids. Tunica mucosa consisted of lamina epithelialis, lamina propria and lamina muscularis mucosae (Fig. 1). The mucosa extended to three regions namely cardiac, fundic and pyloric gland region as also reported by Mahesh (2008) in goat.

Lamina epithelialis mucosae: The lamina epithelialis mucosae invaginated to form gastric pits which were lined by simple columnar epithelium

similar to the findings of Pachpande (2008) and Mahendrakumar (2017) in goat and Malik (2014) in Gaddi sheep. Trautmann and Fiebiger (2002) observed single layer of high columnar cells lining the abomasum of domestic ruminants. However, Rasheed and Ibrahim (2025) reported simple cuboidal epithelium forming gastric pits in lambs and goat kids of one month age. The mucous secreted by cells of lining epithelium protects the gastric mucosa against acids and enzymes produced by the mucosa itself. The gastric pits were minute depressions present throughout the gastric mucosa (Fig. 2). Poonia and Kumar (2017) reported that mucosa of abomasum of sheep had gastric area separated by small depressions known as gastric pits. They were tubular in shape as observed earlier in goat (Pachpande, 2008). The gastric pits in the mucosa of pyloric part of abomasum were much deeper than the other regions of abomasum.

Cardiac region: The mucosa of the cardiac region showed presence of glands which were short, simple branched tubular glands (Fig. 2) similar to the findings of Mahesh *et al.* (2017) in goat and in contrast to the findings of Kalita and Chandramouly (1995) in Indian buffalo and Aage *et al.* (2007) in cattle (glands were compound, coiled and branched tubular). Pachpande (2008) reported tubular coiled branching cardiac glands in goats. In Gaddi sheep, the cardiac glands were short, simple tubular glands (Malik, 2014). Poonia and Kumar (2017) in sheep reported simple, branched, tubular and coiled cardiac glands.

The cells of the cardiac glands were low columnar to cuboidal cells with elongated nuclei located towards the basal portion (Fig. 3) similar to the findings of Malik (2014) in Gaddi sheep. Poonia and Kumar (2017) in sheep reported that the columnar cells had oval to round nuclei towards the base. These cardiac glands empty into relatively shallow gastric pits formed by the invagination of epithelium into the lamina propria. The gastric pits were the openings for the glands in the mucosa of abomasum. Mucous neck cells and surface mucous cells were mainly observed in the lamina epithelialis mucosae with occasional presence of parietal cells at few

places in the species under study. Similar observations were made by Aage *et al.* (2007) in cattle. Apical blebs were prominent indicating the secretory mode of cardiac glands. The lamina propria had feltwork of collagen, elastic and reticular fibers. Considerable amount of lymphoid tissue was observed in the lamina propria mucosae of cardiac region (Fig. 4). Poonia and Kumar (2017) also reported lymphoid infiltrations in cardiac region of abomasum of sheep.

Fundic region: The fundic glands varied from straight tubular to branched tubular glands in Bakerwali goat and non-descript sheep (Fig. 1) similar to the findings of Balasundaram *et al.* (2007) in Indian buffaloes, Malik (2014) in Gaddi sheep and Mahesh *et al.* (2017) in goat. In domestic ruminants, Banks (1993) observed branched tubular fundic glands whereas Aage (2004) reported straight, branched tubular fundic glands. However, Poonia and Kumar (2017) reported simple branched, tubular and coiled fundic glands. In non-descript goat, fundic glands were tubular coiled organized into distinct lobules (Fig. 5). Pachpande (2008) in goats observed straight, branched, tubular fundic glands.

Four types of cells were identified namely mucous neck cells, chief cells, parietal cells and argentaffin cells as also seen in Indian buffaloes (Balasundaram *et al.*, 2007) and goats (Mahesh *et al.*, 2017). However, Malik (2014) in Gaddi sheep and Mahendrakumar (2017) in Surti goat identified only three types of cells i.e., chief cells, parietal cells and mucous neck cells. Mucous neck cells were typical mucous cells with elongated nuclei towards base and finely granular cytoplasm. Aage (2004) in domestic ruminants reported that mucous neck cells had flat nucleus with basophilic cytoplasm towards the base. Mahesh *et al.* (2017) in goats reported that mucous neck cells were cuboidal to pyramidal with flat nuclei towards base. Mucous cells mainly produce protective layer of mucin to line stomach and protect gastric mucosa from injury. The chief cells were cuboidal and were the most numerous cell type of fundic gland. Trautmann and Fiebiger (2002) in domestic ruminants reported cuboidal to columnar or wedge-shaped chief cells. They were present in

clusters towards the basal part. These chief cells were arranged in groups in goat (Mahesh *et al.*, 2017). They had spherical nucleus located towards the base of the cell with singly and eccentric nucleolus. Their cytoplasm was strongly basophilic. Similar observations about chief cells were made by Malik (2014) in Gaddi sheep and Mahesh *et al.*, (2017) in goat. Chief cells contained secretory granules as also observed by Poonia and Kumar (2017) in sheep known as zymogen granules which are rich in proenzyme pepsinogen. Thus, these cells are also known as zymogen cells.

Parietal cells were located in between the chief cells. Aage (2004) in domestic ruminants reported that the chief cells were cuboidal to pyramidal in shape with dense nucleus in centre. Parietal cells were comparatively larger in size than the chief cells and mucous neck cells but less numerous than chief cells. They mostly occurred singly. Their narrow apex bordered the lumen of the gland. Their cytoplasm showed strong eosinophilia. These findings were similar to the findings of Mahesh *et al.* (2017) in goat. The pyramid shaped parietal cells had centrally placed nucleus with one or more eccentric nucleoli (Fig. 6). Aage (2004) reported that in cattle, parietal cells were spherical but in small ruminants, the cells were pyramidal. Argentaffin cells were located towards base with round to oval nucleus similar to the findings of Mahesh *et al.* (2017) in goats. Poonia and Kumar (2017) in sheep reported that argentaffin cells were smaller and present between chief cells and parietal cells. The nucleus was dark probably due to condensation of chromatin material. Some of these cells are involved in amine precursor uptake and decarboxylation and thus are known as APUD cells.

Pyloric region: Pyloric glands were simple, straight branched tubular glands which opened into gastric pits similar to the finding of Al-Saffar (2012) in goats and Malik (2014) in Gaddi sheep. Aage (2004) in ruminants and Poonia and Kumar (2017) in sheep reported branched and coiled pyloric glands. Pyloric glands were composed of mucous acini with flat nuclei towards the base (Fig. 7). Prakash and Chandra (2001), Aage (2004) and Al-Saffar (2012)

observed typical mucous glands in pyloric region of goat. The secretory epithelium composed of tall columnar cells with basally located nuclei. These cells were characterized by foamy cytoplasm and oval to elongated spherical nuclei. This was similar to the findings of Aage (2004) in cattle, sheep and goat. Gastric pits in pyloric region were comparatively deeper as compared to the gastric pits in cardiac or fundic region as also observed by Pachpande (2008) in goat and Malik (2014) in Gaddi sheep. Gastric pits were lined by high columnar epithelium similar to the finding of Al-Saffar (2012) in goats. Apical blebs and luminal secretions were prominent indicating the glandular activity. Aage (2004) in cattle, sheep and goat and Pachpande (2008) in goat reported presence of occasional parietal cells which was absent in present study.

Lamina propria: Lamina propria consisted of loose connective tissue rich in reticular fibers. Numerous mononucleated cells such as lymphocytes and plasma cells were evident as also observed by Pachpande (2008) in goat. The gastric glands penetrated at variable distance into the lamina propria. Cardiac, fundic and pyloric glands were surrounded and encapsulated by reticular fibers forming basket like arrangement around individual gland. Fine and coarse reticular fibers were observed in lamina propria forming meshwork (Fig. 8). Malik (2014) in Gaddi sheep observed that reticular and collagen fibers were seen in between the gastric glands.

Lamina muscularis mucosae: A lamina muscularis mucosae was present with variable arrangement. Generally, two to five muscle layers along with reticular fibers formed lamina muscularis mucosae similar to the observation by Pachpande (2008) in goat and Mahendrakumar (2017) in Surti goat. This layer was better developed in pyloric region than cardiac and fundic regions. Similar observation was made by Pachpande (2008) in goat. Mahesh *et al.* (2017) reported thin lamina muscularis mucosae (single layered) in cardiac region of abomasum of goat. However, Poonia and Kumar (2017) observed thin lamina muscularis mucosae in fundic region of sheep and thick in pyloric region (2-3 rows of smooth

muscles).

Tunica submucosa: Tunica submucosa was composed of loose irregular connective tissue containing network of collagen and elastic fibers and infiltrated with adipose cells in all the three regions of abomasum. Blood vessels, lymphatic vessels (Fig. 2) and nerve bundles in the form of submucosal nerve plexus were also observed as earlier described by Trautmann and Fiebiger (2002) in domestic ruminants and Mahesh *et al.* (2017) in goats.

Tunica muscularis: Tunica muscularis was composed of an inner circular and outer longitudinal layer of smooth muscle (Fig. 1) similar to the observation by Mahendrakumar (2017) in Surti goat and Liebich (2019) in ruminants with occasional presence of oblique layer of smooth muscles at few places as described by Trautmann and Fiebiger (2002) in domestic ruminants. Poonia and Kumar (2017) in sheep described the presence of an additional oblique layer in middle at certain locations of fundic region whereas in pyloric region, tunica muscularis had three layers i.e. inner circular, middle oblique and outer longitudinal. The intra-muscular connective tissue was rich in collagen fibers with few reticular fibers.

Tunica serosa: Tunica serosa was the outermost tunic and consisted of mesothelium overlying a layer of loose connective tissue (Fig. 9). Blood vessels were seen in this tunic. Similar observation was made by Trautmann and Fiebiger (2002) in domestic ruminants and Al-Saffar (2012) in goats.

Histochemistry

Histochemical features are important for maintaining tissue structure, protecting the mucosal lining, and supporting normal growth and function (Nikoloudaki, 2021; Ibáñez Cortés *et al.*, 2023).

Neutral mucopolysaccharides: The cardiac and fundic glands towards luminal region of tunica mucosa showed strong PAS reaction whereas glands towards basal region (deeper glands) showed mild PAS reaction (Fig. 10A, 10B). However, in pyloric region, the glands showed strong PAS reaction

irrespective of their location (superficial or deeper glands) (Fig. 10C). Malik (2014) in Gaddi sheep also reported that superficial fundic glands showed strong PAS reaction. The gastric pits of cardiac, fundic and pyloric region showed strong PAS reaction mainly localized in supra-nuclear zone. Poonia and Kumar (2017) in sheep and Mahesh *et al.*, (2017) in goat observed PAS positive material in fundic epithelial lining only in supra-nuclear part. Balasundaram *et al.*, (2007) observed NMPS in surface epithelium and epithelial cells lining the gastric pits in fundic region of Indian buffalo. Lamina muscularis, tunica muscularis and tunica serosa showed weak to moderate PAS reaction and moderate to strong reaction in tunica submucosa. In fundic region, the parietal cells showed moderate PAS reaction. Aage (2004) in cattle, sheep and goats also reported PAS positive reaction in parietal cells and zymogen cells in fundic region indicating the presence of pepsin. Poonia and Kumar (2017) observed strong PAS reaction in columnar cells of surface epithelium of sheep. The cells showed predominance of neutral than acid mucopolysaccharides towards apical part whereas acidic mucopolysaccharides predominated towards gastric pits.

Acid mucopolysaccharides: In cardiac, fundic and pyloric region, the glands towards luminal region of tunica mucosa showed positive reaction for both PAS and Alcian Blue (pH 2.5) whereas the glands towards basal region showed moderate reaction for Alcian Blue (pH 2.5) similar to the findings of Malik (2014) in Gaddi sheep. Pyloric glands showed strong reaction for Alcian Blue towards supra-nuclear zone. Gastric pits and its secretions in all the three regions showed strong PAS reaction in supra-nuclear zone whereas infra-nuclear zone showed strong reaction for Alcian Blue (pH 2.5). Similarly, cardiac, fundic and pyloric glands showed strong PAS reaction in supra-nuclear zone whereas infra-nuclear zone showed strong reaction for Alcian Blue (pH 2.5) (Fig. 11). Chandramouly and Rao (1984) in buffalo reported weak Alcianophilic reaction of surface mucous cells whereas cells lining gastric pits showed moderate reaction. In goats of 90-120 days of age, PAS-AB reaction was weak in epithelium and tunica muscularis, moderate in tunica submucosa and



Fig. 1: Photomicrograph of abomasum (fundic part) of Bakerwali goat showing different layers. Tunica mucosa (T), tunica submucosa (S), tunica muscularis (M), tunica serosa (Se), lamina epithelialis (E) and lamina muscularis mucosae (m). Fundic region showing straight tubular to branched tubular glands. H&E stain 100x

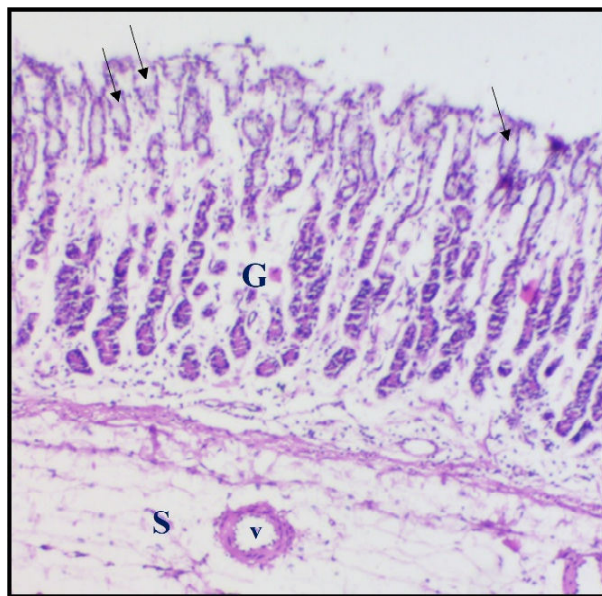


Fig. 2: Photomicrograph of Cardiac region of abomasum of non-descript sheep showing gastric pits (arrow) and simple branched tubular cardiac glands (G). Blood vessels (v) seen in tunica submucosa (S). H&E stain, 100x

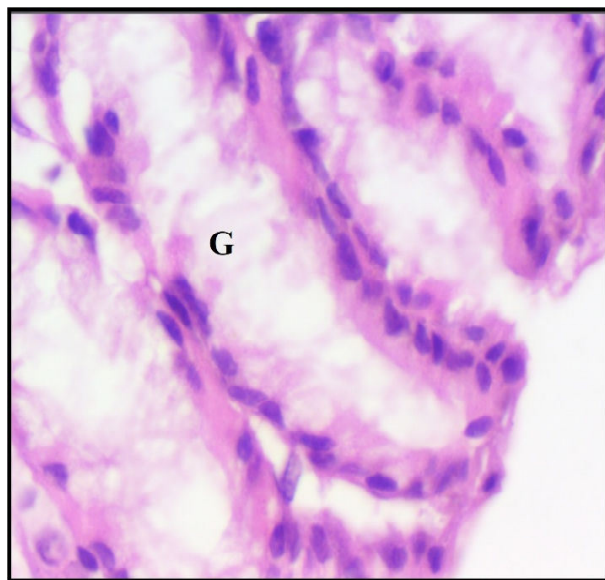


Fig. 3: Photomicrograph of Cardiac region of abomasum of non-descript sheep showing cardiac glands (G) with low columnar to cuboidal epithelium and elongated nuclei towards base. H&E stain, 1000x

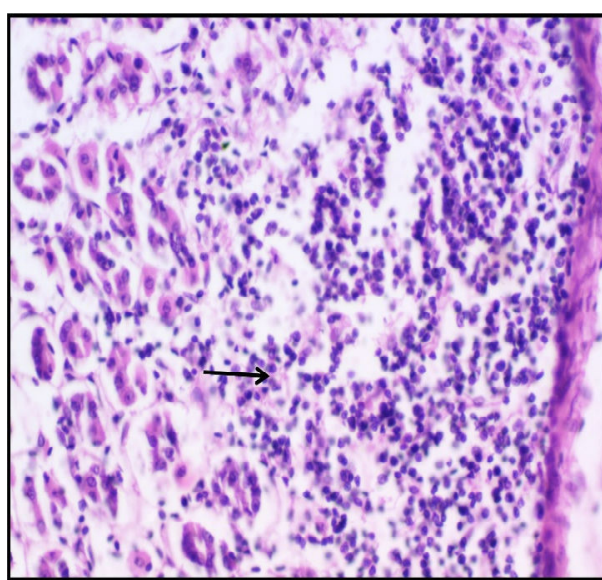


Fig. 4: Photomicrograph of cardia of non-descript goat showing lymphoid tissue (arrow) in the lamina propria mucosae. H&E stain, 400x

serosa and strong in glands (Pachpande, 2008).

Glycogen: In the species under study, cardiac and fundic glands showed strong reaction for glycogen whereas pyloric glands showed moderate reaction.

Lamina muscularis and tunica muscularis showed weak reaction for glycogen. In fundic region, parietal cells showed negative reaction but chief cells showed strong reaction for glycogen (Fig. 12). The pyloric region of abomasum of sheep showed positive

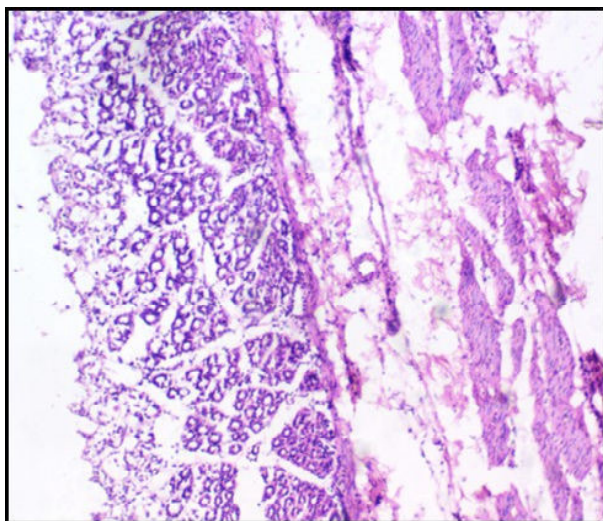


Fig. 5: Photomicrograph of fundus of non-descript goat showing tubular coiled glands organized in distinct lobules. H&E stain, 100x

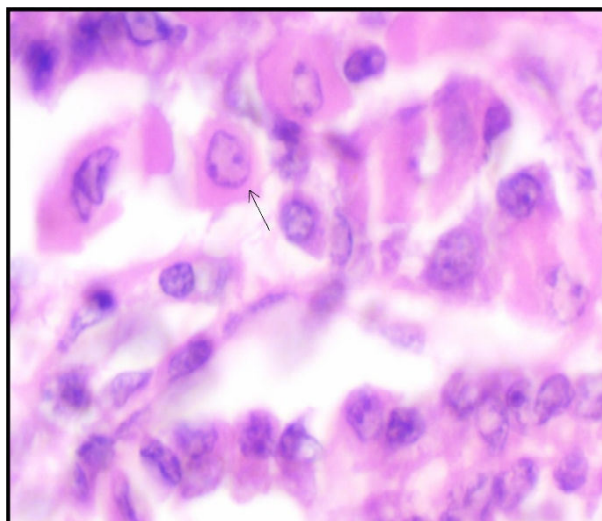


Fig. 6: Photomicrograph showing parietal cells (arrow) with more than one nucleoli in fundic part of abomasum of Bakerwali goat. H&E stain, 1000x

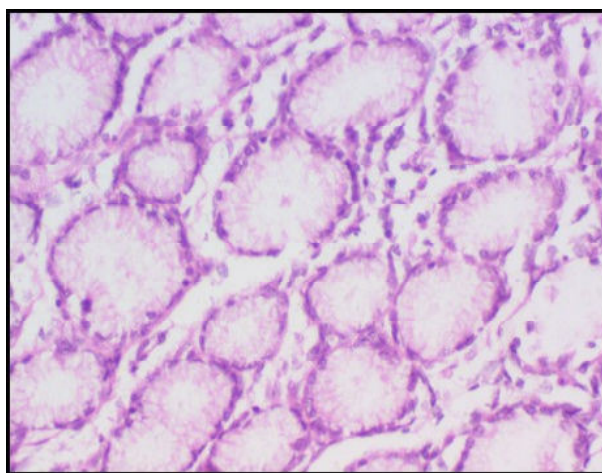


Fig. 7: Photomicrograph showing pyloric glands (mucous acini) of abomasum of Bakerwali goat. H&E stain, 400x

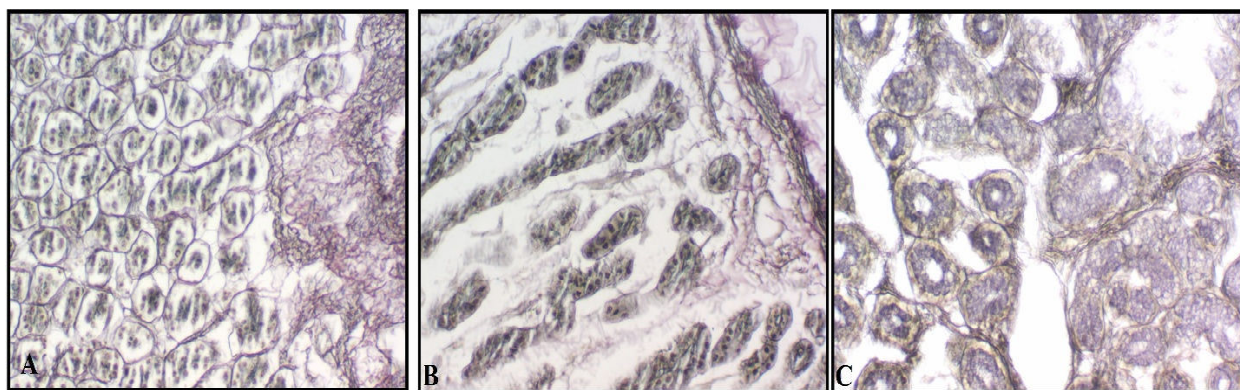


Fig. 8: Photomicrographs of lamina propria of cardia (A), fundus (B) and pyloric (C) region of abomasum of non-descript goat showing presence of reticular fibers. Gomori stain, 400x

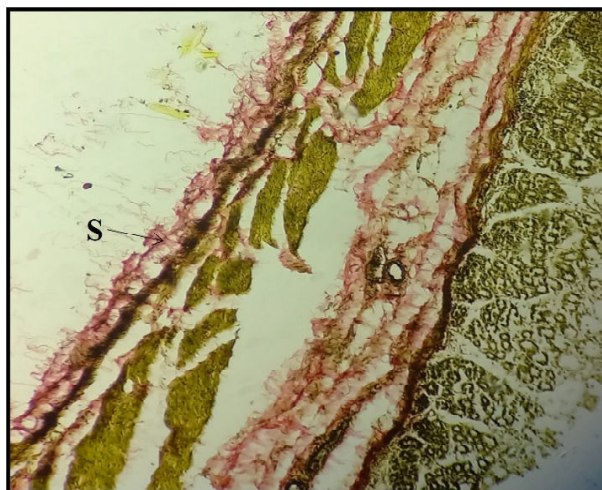


Fig. 9: Photomicrograph showing collagen fibers (pink) in tunica serosa (S) of fundus of adult non-descript goat. Von Gieson stain, 100x

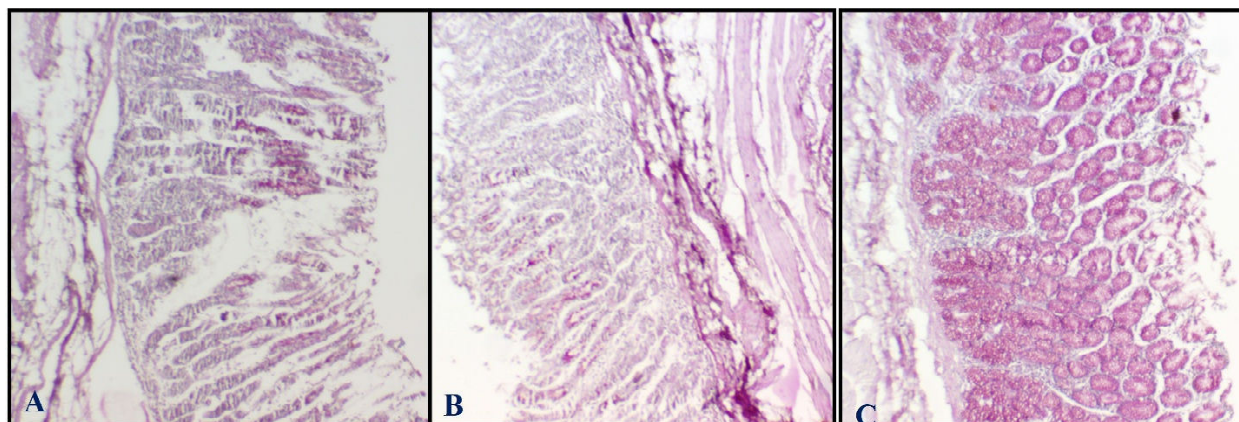


Fig. 10: Photomicrograph showing PAS reaction in cardia (A), fundus (B) and pylorus (C) of abomasum of Bakerwali goat. 100x

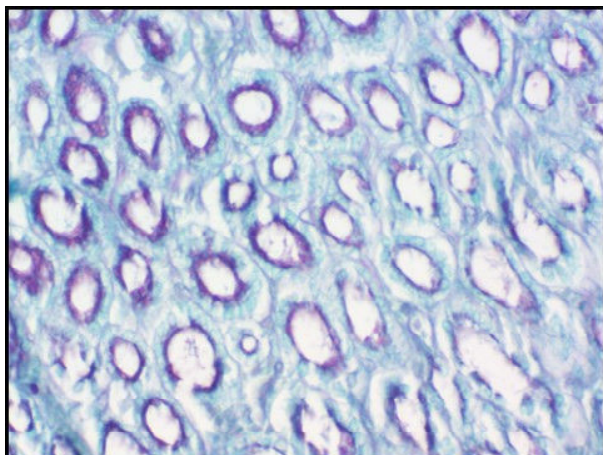


Fig. 11: Photomicrograph of pyloric glands of abomasum of non-descript goat. glands showed strong PAS reaction in supra-nuclear zone whereas infra-nuclear zone showed strong reaction for Alcian Blue. PAS-AB stain, 400x

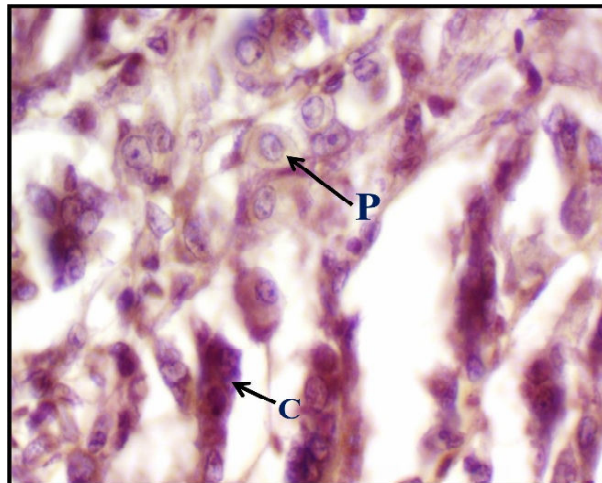


Fig. 12: Photomicrograph of fundus of non-descript goat. parietal cells showed negative reaction but chief cells showed strong reaction for glycogen. Best Carmine stain, 1000x

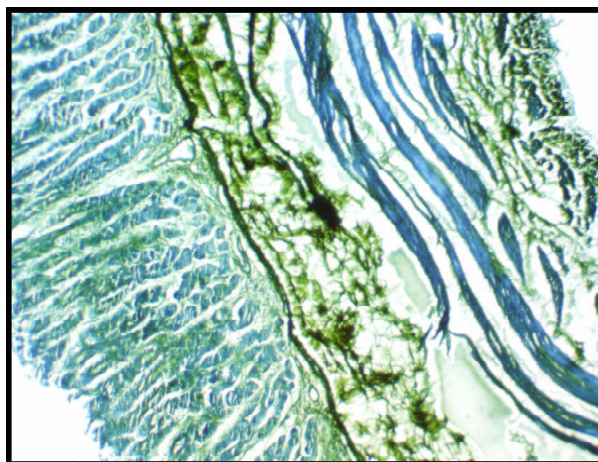


Fig. 13: Photomicrograph of fundus of abomasum of Bakerwali goat. Glands and tunica muscularis showed moderate to strong reaction. Bromophenol Blue stain, 100x

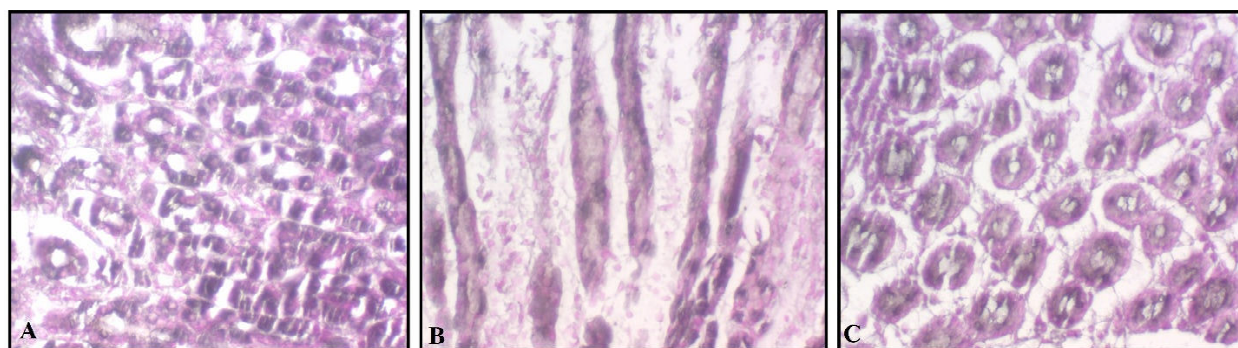


Fig. 14: Photomicrograph of cardiac (A), fundic (B) and pyloric glands (C) of abomasum of non-descript sheep showing strong reaction of glands to lipids. Sudan Black B stain, 400x

reaction for glycogen which was mainly localized in the supra-nuclear zone (Poonia and Kumar, 2017). In goats of 90-120 days of age, all the tunics showed negative reaction for Best Carmine (Pachpande, 2008).

Basic proteins: In the species under study, cardiac and fundic glands showed moderate to strong reaction for basic proteins. In pyloric region, the superficial zone of gastric glands showed moderate to strong reaction whereas basal/deeper glands showed weak reaction. The pyloric glands exhibited moderate reaction for basic proteins in infra-nuclear zone. Lamina muscularis and tunica muscularis showed moderate to strong reaction (Fig. 13).

Lipids: In all the three species, cardiac, fundic and pyloric glands showed strong reaction for lipids in supra-nuclear zone and glandular secretions were

moderately to strongly positive for lipids (Fig. 14). Malik (2014) in Gaddi sheep reported negligible Sudan Black B reaction of surface epithelium of cardiac region and in fundic region, cells of gastric pits showed moderate reaction and cells of fundic glands were strongly positive for Sudan Black B. In pyloric region, cells of gastric pits showed strong reaction for Sudan Black B.

CONCLUSION

From the study, it was concluded that the abomasum of indigenous small ruminants of Jammu region exhibited a similar histological organization with distinct regional glandular specializations and characteristic histochemical distribution of mucopolysaccharides, glycogen, proteins, and lipids. These findings provided baseline reference data on

the normal microscopic structure and secretory activity of the abomasum, which might be useful for comparative anatomical, pathological, and gastrointestinal studies in small ruminants.

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Received: July 03, 2026

Accepted: July 30, 2026