EPITHELIUM-PROPRIA INTERFACE OF RUMINANT FORESTOMACH
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The organization of the ruminant forestomach mucosa has been studied extensively by both light and electron microscopy. Scanning electron microscopy (SEM) has been recently applied to this mucosa, but mostly confined to the observation of its luminal surface. The epithelium-propria interface of mucosa covered with stratified squamous epithelium plays an important role in the function of the mucosa. Direct observation of this interface becomes possible by the SEM observation of separated epithelium. The aim of this report is, therefore, to visualize the configuration of this interface by SEM and DNA-Feulgen microphotometry of epithelial cells at this interface in forestomach mucosae of domestic ruminants with reference to its role in the function of the mucosa and cell population kinetics of the epithelial cells. Several mucosae of other parts of the digestive tract that are covered with stratified squamous epithelium were also observed.

Material and Methods

Mucosae of parts of the digestive tract covered with stratified squamous epithelium were collected from domestic ruminants. They were taken from forestomachs, oesophagus, hard palate and tongue. Fresh tissues were incubated in EDTA-PBS solution to separate epithelium from underlying lamina propria (Klein-Szanto and Schroeder, 1977). Separated tissues were fixed in glutaraldehyde and osmium tetroxide, dehydrated in ethanol and isoamyl acetate, and dried in liquid CO₂ by critical point drying. Gold-coated specimens were observed by a FE-type scanning electron microscope (Hitachi S-700).

Mucosae fixed in 10 % buffered formalin were embedded in paraffin and 5 μ sections were stained with hematoxylin and eosin for light microscopy. Some sections were subjected to Feulgen reaction (Fujita et al., 1973). DNA-Feulgen measurement was done with a microspectrophotometer (Olympus MMSP-TK) at 560 nm.

Results

Two surfaces at the epithelium-propria interface may be provisionally termed as B-face and P-face. B-face is the basal aspect of the epithelium and P-face is the de-epithelialized surface of the lamina propria opposite to B-face. Basal lamina is present between these two faces.

1. SEM view of epithelium-propria interface.

The following three types of the interface configuration were observed.

Type 1. Plateau or low ridges with openings of varying size and arrangement at B-face. Numerous slender papillae (Papilla occuluta : PO) insert into these openings at P-face. Epithelial cells at B-face were elongated and flat.
Type 2. Higher parallel ridges or rows of epithelial cells at B-face and similar PO ridges at P-face. The cells at top of B-face ridges were mostly flat and elongated. Some were rounded in shape.

Type 3. Bulbous epithelial pegs of irregular size and arrangement at B-face. At P-face proprial ridges were often depressed to low networks. The cells at top of the pegs were mostly rounded in shape.

The type 1 interface was found in mucosae of oesophagus, hard palate and tongue. Certain areas of ruminal pillars also showed this type. Type 2 interface was commonly found in the mucosae of reticulum and omasum. When macroscopic papillae were present in the mucosa, the ridges of the two faces were thrown into and continuous to the ridges within the papillae. The type 2 interface at ruminal pillars showed a transition to type 3 pegs when the mucosa became papillated towards the base of pillars. Type 2 interface was also found in the finger-like and conical small papillae and in the periphery of larger, foliate papillae, and to a lesser extent in the mucosa of reticular folds where macroscopic papillae were absent.

Further observation of P-face showed that the three types were not entirely independent. In the oesophagus slender papillae at P-face were essentially the outgrowth of lower type 2-like ridges, while the low networks of type 3 interface could be derived from type 2 ridges when the latter were connected by side-branches. The pattern of winding and branching of these PO suggested that they possibly reflected the pattern of small vessels just below P-face.

2. Light microscopic view of the epithelium-propria interface in sections.

The three types described in Section 1 were also discernible in sectioned mucosa. Type 1 interface in oesophagus, hard palate and tongue was associated with a thick hyperkeratotic epithelium of protective nature. Type 3 interface was associated with developed epithelial pegs of rumen papillae and had relatively thin parakeratotic epithelium. All mucosae examined retained a large number of epithelial cells below the level of the apparent stratum spinosum which runs parallel to the luminal surface of the mucosa. A good proportion of them were basal cells in contact with the basal lamina. They were columnar in shape and had slightly basophilic cytoplasm. Some others, specially in type 1 interface, were judged as immature spinous cells because of the cytoplasmic affinity to eosin and a nucleus similar to those of typical spinous cells. In type 3 interface, intra-peg cells appeared to be similar to basal cells and an occasional mitosis was present among them. They seemingly lacked contact with the basal lamina.

3. DNA-Feulgen microspectrophotometry of epithelial cell populations.

In rumen papillae, the Feulgen-unit (FU) values of basal cell nuclei varied from 8 to 36 FU, with a peak at 15 FU. It was concluded that the nuclei consisted of two types of 15 FU and 30 FU. They corresponded to 2N and 4N nuclei respectively. The 2N nuclei were those of G1 cells of the cell cycle, whereas the 4N ones were those of S and G2 cells of the cycle. The cells at stratum spinosum had 2N nuclei (15 FU). The intra-peg cells had 2N nuclei with a few 4N nuclei. The 4N nuclei at the stratum basale were frequently located at the side of developed pegs.

Discussion

The epithelia covering the digestive tract mucosa have at least two important functions, protective and absorptive. The mucosae are macroscopically developed into various mechanical devices which can affect the flow of contents in the organs. In the ruminant forestomach this function is carried out by several structural devices such as ruminal pillars, reticular cells, reticular and omasal grooves, and omasal laminae with their macroscopic papillae. We observed here that these mechanical devices generally have mucosae with type 2 interface. In contrast well-developed rumen papillae have mucosa of type 3 interface. Such papillae are known to be a highly absorptive apparatus of ruminant forestomach. In connection with this we recently reported the hypertrophy of epithelial pegs, i.e., development of type 3 interface, promoted by the rapid intraruminal administration of butyrate (Sakata and Tamate, 1978). This suggested that the increased absorptive and metabolic activities of the ruminal mucosa may be expressed as the development of type 3 interface at the junction site of epithelium and connective tissues.

It was noted that the configuration of the epithelium-propria interface also reflects the
nature and composition of the epithelial cell population under the stratum spinosum. In the epidermis, a low proliferative rate at the stratum basale results in a thick hyperkeratotic epithelium. In the mucosae of the oesophagus, hard palate and tongue type 1 interface was predominant where they suffer from cell loss due to friction at the luminal surface. We are inclined to think, therefore, that the various configurations of the interface we observed are probably the direct structural expression of mucosal functions in different loci of the digestive tract under different feeding regimes.

As far as we know, the only comparable structure to rumen papillae is the forestomach papillae of the hippopotamus. The histology of the latter papillae suggested that they may have type 2 interface (Langer, 1976). Thus we believe that the rumen papilla with developed type 3 interface is the most advanced structural device for absorption in the forestomach, nearly comparable to the villi of the small intestine.

The configuration of the epithelium-propria interface is determined genetically (Klein-Szanto and Schroeder, 1977). If this is true, evolutional trends towards establishment of the ruminant forestomach, especially of their absorptive device of rumen papillae, could be the result of early mutation(s) which took place in the digestive tract and affected the configuration of the interface as well as the nature of the germinative epithelial cell populations in the forestomach mucosa.

References


