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كلية الطب البيطري بأبو قير

T h e s i s

on the

Morphological structure of the ruminal mucosa of buffalo in dependence of the feeding regime

Presented

by

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(B.V.Sc. 1975)

for

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(Anatomy)

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(قـــــرار لجنـــة الحكـــم والمناقشـــه)

قـــررت لجنـــة الحكـــم والمناقشـــة ترشـــيح الســـيد طبيب بيطـــرى / عبـــد الســـلام كامـــل حمـــــوده للحصـــول علـــى درجـــة الماجســـتير فى العلـــوم الطبيـــه البيطريـــه (تشـــــريح)

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والمشـــرف على الرســـاله

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Dedicated to

my P A R E N T S who were pushing me to this way and

to my D O C T O R F A T H E R who has tought me life and morphology and supervised and guided me.

Also all thanks for Mrs. Berg for her help.

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Content

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1. Introduction

These studies were conducted to render a contribution to the morphology (gross anatomy and microscopic anatomy) of the ruminal mucosa of the Egyptian Water Buffalo, especially of the Beheira breed. From the so far available literature is clear that basic data are still lacking. But exact basic knowledge on the structure and function of the digestive as also reproductive organs is a prerequisite and of eminent importance for the veterinary practice in the animal production, if the efficiency of buffalo husbandry in the Arab Republic of Egypt shall be increased. Before other feedstuffs (f.e. straw pellets enriched with inorganic substances as prevailing in Europe) than traditional ones are tested for their suitability in buffalo-feeding, first the structure and morphologic reaction of the ruminal mucosa under present environmental conditions in the Arab Republic of Egypt must be known. Consequently this thesis gives a first orienting report on the morphology (gross anatomy and microscopic anatomy) of the ruminal mucosa of three groups of buffaloes fed by different regimes:

1. Group: Buffalo-calves, fed by milk-rations.
2. Group: Adult buffaloes, fed by beerseem (green-fodder) and tibn (wheat straw).
3. Group: Adult buffaloes, fed by russian (concentrated fattening feedstuffs) and tibn.

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The results gained by these studies may also be useful in teaching of anatomy and histology of the buffaloes' stomach for undergraduates and postgraduates of veterinary medicine.

These studies are considered as a beginning, they should be extended to other parts of the stomach and digestive tract of the buffalo as also of other ruminants (cattle, sheep, goats) kept in Egypt.

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2. Review of literature:

The buffaloes of the Arab Republic of Egypt are of one breed under the group of African Bos bubalus. They belong to the tribe Bovini, family Bovidae, suborder Ruminants and to the order Artiodactyla. This breed has two vaguely differentiated local types, the Beheiri of the Nile delta and the Saidi of Upper Egypt. Both vary in colour, size and production in accordance with differences in the management and environment (FAO 1974).

The rumen is the largest compartment of the proventricular part of the ruminantial stomach. SENGAR et al. (1970) report that the rumen of the buffalo has a similar topographic position like that of the cattle. It extends from the diaphragm cranially to the pelvis caudally and almost fills the left side of the abdominal cavity (ABDEL MONEIM SALIKH /1976/).
According to different experiments with feeding regimes and diets PIATKOWSKI (1975) is of the opinion that kind, shape and amount of feedstuffs will profoundly affect the structure of the ruminal mucosa. In this regard, of course, the microbial ruminal flora and fauna as an interior specific ruminal environment is excluded from the consideration.

Normal conditions of the ruminal mucosa are those - according to PIATKOWSKI (1975) - which are present

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after normal feeding (not extreme rations). The papillae should densely stud the mucosal surface according to its relief.

HOFMANN (1966, 1973) report that considerable differences are found if the mucosal patterns of different ruminant species, independent of their feeding are compared. Additionally to these differences those ones in race and also a high individual variability is to take into account.

We have found that the following morphologic features of the ruminal mucosa are mentioned in the literature:

- Length, thickness and density of the papillae.
- Superficial structures of the papillae.
- Colour of the superficial structures of the Stratum corneum.
- Kind of Stratum corneum and thickness of the keratine caverings.
- Thickness of the Stratum basale and the Stratum spinosum.
- System of the ruminal pillars.

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2.1 Length, thickness, density and shape of the ruminal papillae

SINCLAIR et al. (1959) and KUNKEL et al. (1959) observe significant positive correlations between the length of papillae in sheep and the uptake of feedstuffs (r = 0,74) and between the length and breadth of the papillae and the daily increase of body weight (r = 0,59; 0,40).

The size of the ruminal papillae of ox may be 2 mm in length x 1 mm in height. The range is till to 9 x 3 mm.
The enlargement of the ruminal mucosal surface by the ruminal papillae is 1,4 - 21,6 fold.
The most extreme density of largest papillae is found in the atrium of the rumen (HAUSER /1929/, KOCH /1970/, SCHNORR and VOLLMERHAUS /1967/).

DYCE (1968) reports that the development of the ruminal papillae depends on chemical, but not physical factors.

MICHEL (1978) observes that the ruminal papillae in the ox cover 80 - 85 % of the mucosal surface. The mucosal membrane of the ruminal pillars as also an extended area in the bovine dorsal ruminal sac of about 7 % in size of the total mucosal surface is devoid of papillae.

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According to SCHNORR and VOLLMERHAUS (1967) as also according to classical textbooks of Veterinary anatomy (ELLENBERGER/ BAUM /1943/, KOCH /1970/) is the height of the ruminal papillae in the individual ruminal compartments different. The highest papillae are found at the reticular aspect of the Atrium ruminis, in the ventral ruminal sac and in the caudal blind sacs.

SCHNORR and VOLLMERHAUS (1967) reveal in the ox 250 000 papillae as a total number covering the ruminal mucosal surface. The papillae are present on 70 - 85 % of the total mucosal surface. The dorsal mucosal surface, the ruminal pillars, and partially the ruminal island are devoid of the papillae or have a scanty number of small papillae. The height measures mostly 3 - 6 mm, the breadth 1 - 2 mm, only in rare cases the height of 13 mm and the breadth of 3 mm were exceeded.
Mostly 10 - 80, maximally till 121 papillae per cm^2 are present.
The total surface magnification factor of the roughly 0,9 m^2 sized ruminal surface is about 7.
This magnification plays an important role for an increased absorption in the rumen.
The highest papillae and the most dense populations of them are found at locations which are characterized by a most intensive digestion and absorption.

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Recent knowledge from MICHEL (1978) records the functional morphology and histological structure of the ruminal mucosa in dependence of the feeding regime of the ruminants. It is reported that the ruminal mucosa in cattle has a higher developed degree than the mucosa of the proventricular part of the horse.
The ruminal epithelium with its fine structure has all prerequisites for an intense absorption and in the same time a fully active protective function. The dense subepithelial capillarisation and the special structure of capillaries there (presence of endothelial pores) are related to intense absorptive activities.

The ruminal mucosa has a highly developed adaptability which is evidenced especially in cases of changing of fodder. Less developed is the adaptability to extreme fodder rations, after applying them, soon reversible, later on irreversible morphologic changes occur, associated with depressed performances of the animals.
Because of the different reaction of the ruminal mucosa to different feeding systems on the base of its high development, also in the future histological studies of the ruminal mucosa should be realized in order to have a high effectivity of the feeding systems. This is especially in need if new feeding systems and feeding technologies, are applied.

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SENGAR et al. (1972) recorded that in the rumen of the buffalo the distribution of the papillae, their length and breadth in the different regions are as follows: In the mid-ventral region of the ventral ruminal sac the largest number of papillae per unit area (1 cm^2) (26,8 papillae per cm^2) is found. Their size is in the Atrium ruminis maximal 10,45 mm in length and 2,43 mm in breadth.
The ventral ruminal sac is followed by regions as the caudal ventral blind sac, caudal dorsal blind sac, cranial ventral blind sac and Atrium ruminis regarding the number of papillae per unit area.
The following ruminal compartments are following the Atrium ruminis : Cranial ventral blind sac, mid-region of the ventral ruminal sac, caudal ventral blind sac and caudal dorsal blind sac in respect of the papillary size.

This may be interpreted to mean that the size and number of the papillae have a reciprocal relationship, and that they are more elaborately disposed in the cranial regions and more densely distributed in the caudal ones.

TAMATE et al. (1962) report similar observations for the interior of the buffalo rumen.

The shape of the papillae differs very much. SCHNORR and VOLLMERHAUS (1967) describe them as papillae-like, tongue-shaped, band-like and leafe-like.

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SENGAR et al. (1970) are of the opinion that the shape of the papillae in the buffalo rumen varies considerably and a variety of forms came across during the course of their study. Mostly they are foliate and conical, sometimes truncated, or filiform and occasionally clubbed and bifurcated.

KAUFFOLD (1974) and PIATKOWSKI (1975) consider mechanical factors like the physical shape and fine structure of the feedstuffs and chemical factors like the increased concentration of the volatile fatty acids (acetic acid, butyric acid and propionic acid) as a cause for the loss of papillae.

2.2. Structure of the papillae:

The ruminal papillae are papillar-like or crest-like elevations which represent a considerable increase of the ruminal surface.
Elevations are possible by Papillae occultae which are branches of the Laminae propriae mucosae and surrounded by epithelium. The papillae can realize its heating function of the food much better. Furthermore they increase the absorptional area and absorptional performance considerably.

DELLMANN (1976) reports that the rumen of the cattle has tongue-shaped papillae which may

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attain a length of 1,5 cm in the adult cattle.
The size and shape of these papillae vary considerably from one region of the rumen to another.
The ruminal epithelium is stratified squamous keratinized one.
The Stratum corneum is of 1 - 2 cell layers to 10 - 20 cell layers in thickness. The cells are squamous with or without stainable nuclei.
The Stratum granulosum is usually one to three cells thick and these cells are distinctly flattened with keratohyaline granules in its cytoplasm.
The cells immediately above the Stratum granulosum often swell and become nucleated vesicles with a cornified wall and a non-stainable cytoplasm.
The Stratum spinosum consists of polyhedral shaped cells which are slightly larger than the basal cells. Its thickness varies from 1 - 10 cells.
The Stratum basale contains columnar cells located on a basement membrane.
The Lamina propria mucosae beneath the epithelium extends into the center of each papilla and consists of dense connective tissue and a dense network of fenestrated capillaries lies just beneath the basement membrane.

BERG et al. (1976) report that the contact of the basal cells to the capillaries is improved by the Papilla-occulta-formation.
The stratified squamous epithelium of the ruminal

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mucosa is featured by different characteristics. They are described light-microscopically by HAUSER (1929). Also detailed explained are the occurring alterations by swellings of the cells in dependence of the ruminal content.
The blood vessels in the Lamina propria mucosae have characteristic terminal branchings in the mucosa (SCHNORR and VOLLMERHAUS /1967/).
In the papillae the afferent arterioles which are present in a different number of different types of papillae, form according to KOZLOV (1965) one central and two marginal vessels and these again a dense subepithelial capillary network with meshes of about 50 - 70 um.

SENGAR et al. (1972) report that the ruminal mucosa in the buffalo has only a limited Lamina propria mucosae which is indistinctly separated from the submucosa. A defined muscularis mucosae is absent. The epithelium is nonglandular and of keratinized stratified squamous type.
The thickness of the epithelium between the basal cells and the cornified layer is greatly variable and it is customary to differentiate the following different layers: Stratum corneum, Stratum transitionale, Stratum granulosum, Stratum spinosum and Stratum basale in succesion from the lumen to the submucosa. The Stratum basale and the Stratum spinosum also considered as the Stratum germinativum.

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The cells of the basal layer are columnar or cuboidal in shape and are usually disposed in a single layer with their long axis almost perpendicular to the mucosal surface.
The basal layer of the mucosal epithelium of ruminal papillae has further foldings to give rise to the papillary bodies. The Lamina propria mucosae and submucosa which form the core of the papillae also have their outpushings into the secondary foldings of the papillary bodies. These have a great functional importance firstly because their formation reduces the distance between the mucosal surface and the absorptive site and secondary because their development increases the absorptive area to a considerable extent. This presumption also finds its indirect support by DOBSON et al. (1956) who have demonstrated a fine capillary network in the region of the ruminal papillae.
The cells of the following two layers, i.e. the Stratum spinosum and the Stratum granulosum are almost sufficient different in their appearance and this makes their identification conspicuous. The Stratum spinosum appears to be better developed than the Stratum granulosum. The nuclei of the cells of both regions are almost spherical and located in the center of the cells. They have their long axis perpendicular to the apical margin.

The inner flattened cell layers with their long axis are almost parallel to the apical border

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representing the Stratum lucidum of the older literature in which two distinct layers are evident. The innermost layer of deeply keratinised cells called the Stratum corneum and the layers first below it which are ready to be keratinised or may have the same degree of keratinization mark the Stratum transitionale.

The Stratum corneum has a single cell layer except at the papillary tips, where it may have two or even 3 cell layers of thickness and may even be altogether missing from same regions.

The Stratum transitionale on the other hand is two to three cell layers thick. The cells of these layers usually have shrunken nuclei which are less effectively stained and get almost invisible in the flattened Stratum-corneum-cells.

The cells of the Stratum transitionale, which usually have a swollen appearance show well defined, centrally located nuclei.

The Lamina propria mucosae lying just below the epithelium, is a relatively thin layer, compared with the underlying submucosa with which it blends. It is difficult to be distinguished because the usual layer of the muscularis mucosae is missing in between them. But the two can however be differentiated on the basis of the more cellular nature of the propria as against the more fibrous feature of the submucosa.

The Lamina propria mucosae therefore forms a very

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thin layer inbetween the basal layer of the epithelium and the submucosa and primarily forms the core of the papillae.
The total thickness of the mucosal covering (including epithelium and Lamina propria mucosae) is more in the interpapillary regions than on the papillae themselves. This may be interpreted to mean that the formation of the ruminal papillae is a device for more effective and efficient absorption.

2.3 Colouration of the superficial structures of the Stratum corneum

According to PIATKOWSKI (1975) the superficial layers of the Stratum corneum are coloured in dependence of the feedstuffs, yellow after feeding of straw, brown after silage, light brown after cereals, dark brown to black brown after beet leafes and black brown to black after molasses (= product of sugar beet processing).
The above mentioned author indicates that only in case of feeding the same rations dates on the thickness of the keratine can be received.

GROTH (1971) says, not only the feedstuffs also managing of the animals as also hygiene affect the colouration of the ruminal mucosa.

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SISSON and GROSSMAN (1955) are of the opinion that the Stratum corneum has a brown colour and according to WARNER et al. (1956) as also FLATT et al. (1958) the end products of the crude fibre digestion and the production of the volatile fatty acids are primarily responsible for this colour.

An almost similar view is held by SINCLAIR and KUNKEL (1959) who are of the opinion that the colour of the mucosa indicates the degree of microbial activity.

SENGAR et al. (1970) report that the colour of the buffalo ruminal mucosa varies considerably from pale white through various shades of pale yellow to dark brown but the pillars are invariably pale white or pale yellow in colour.
As a rule a deep dark brown colour of the mucosa was found to be associated with densly studded papillae and vice versa.

2.4 Kind of Stratum corneum and thickness of keratine

The corneal cells are of three different qualities. They are plate-like, fusiform and balloon-like. According to SCHNORR and VOLLMERHAUS (1967) the plate-like corneal cells are strongly filled with keratine, which may be homogene or in plates.

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Between the cells, maximally a cleft-like lumen is present. The spindle-like corneal cells are characterized by a broad marginal zone of keratine and an increased cellular space filled with amorph and granular content. In both cell types the cell membranes are strongly folded, in consequence of what especially between the plate -like corneal cells an intercellular space is formed.
Balloon-like corneal cells have a thick cornified wall. In their interior centrally a granular material is present. This kind of cell later ruptures into the ruminal cavity.
On the base of the prevalence of a certain kind of cells it is differentiated between the Stratum corneum of the first kind in which mainly plate-like corneal cells are present. The desquamation here is realized by large scales. The more loosely structured Stratum corneum of the second kind is made up of balloon-like cells. In this case only individual epithelia are desquamated.
The thickness of the corneal layer is characterized by a strong keratine layer and a medium desquamation. Strong and thick keratine layers are the result of a depressed desquamation, this again is the result of an excessively solidified keratine. Solidified keratine is identical with an increased Stratum corneum of the first kind and with the absence of vesicle-like increased cells in the Stratum transitionale. By external pressure all

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these conditions may be formed. The pressure in question itself originates from the cover on the papillae which is represented by feedstuffs. This condition fosters the sticking together and clumping of the papillae.

2.5 Thickness of the Stratum basale and of the Stratum spinosum (Stratum germinativum)

The Stratum basale is a single layer of highly prismatic cells, resting directly on a basement membrane. In the lower third of the basal cells are spherical or ovoid cell nuclei.

The Stratum spinosum is represented by 2 - 20 layers of polygonal cells. The cell nuclei are vesiculous. Both layers have a decisive share in the total thickness of the papillary epithelium and so far in the transportation distance from the Stratum corneum to the Lamina propria mucosae.

2.6 System of the ruminal pillars

SENGAR et al. (1970) record the rumen of the buffalo internally as being in cattle. The dorsal and ventral ruminal sacs are separated by nearly a complete circle of pillars, which is formed in the horizontal plane by the right and left longi-

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tudinal and cranially and caudally by the cranial and caudal pillars respectively. The right and left longitudinal pillars are connected with the caudal and cranial pillars at the two ends.
The cranial pillar projects obliquely caudally and dorsally from the ventral wall, while the caudal one is disposed almost horizontally and on either side forming the dorsal and ventral coronary pillars. The two ventral ones are complete and form almost a circle while the dorsal ones fade out gradually dorsally.

SALEH and el-GAAFARY (1976) record that the caudal ruminal pillar of the buffalo constitutes of dorsal and ventral parts which are horizontally placed and separated by a somewhat triangular area covered with ruminal papillae. The right side of this area is limited by the adjoining part of the longitudinal pillar which present papillae extending for a short distance. These features are peculiar to buffaloes.

SISSON and GROSSMAN (1975) report on the interior of the rumen that the Atrium ruminis is limited caudoventrally by the cranial pillar, which is a shelf-like fold, extending obliquely dorsocaudally and on the right and left sides as right and left longitudinal pillars reaching till to the caudal pillar. Dorsal to the right longitudinal pillar is found the right accessory one which joins the right longitudinal at both ends, including thus the ruminal

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islet (Insula ruminis), the left longitudinal one does not reach the caudal pillar and it gives off dorsally an accessory branch.
The caudal pillar at its right end divides into three branches, which are represented by the dorsal coronary pillar, ventral coronary pillar and the continuation with the right longitudinal pillar.
The left end divides into dorsal and ventral coronary pillars.

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3. Material and methods

Totally eleven rumens of buffaloes of different age, sex and feeding regime were used for these studies. All the rumens were taken from buffaloes slaughtered in the abbatoir of Damanhour (Beheira Governorate).

The studies were classified into gross anatomical and microscopic anatomical ones. The first ones comprised the inspection of the fresh ruminal mucosa regarding its colour, condition of the ruminal papillae (counting and measuring) and papillae-devoid areas, the latter ones the condition of the individual layers of the ruminal papillae.

According to their feeding regimes the investigated buffaloes are arranged into the following three groups:

1. Group: Buffalo-calves fed by milk-rations

current Nr.	species	age	sex
III	buffalo-calf	45 days	male
IX	-"- -"-	35 -"-	-"-
X	-"- -"-	40 -"-	-"-

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2. Group: Adult buffaloes fed by berseem (greenfodder) and tibn (bulky food as wheat straw)

current Nr.	species	age	sex
IV	adult buffalo	17-22 monthes	male
V	-"- -"-	42-48 -"-	female
VIII	-"- -"-	42-48 -"-	male

3. Group: Adult buffaloes fed by russian (concentrated fattening feedstuffs) and tibn

current Nr.	species	age	sex
I	adult buffalo	17-33 monthes	male
II	-"- -"-	14-25 -"-	-"-
VI	-"- -"-	17-33 -"-	-"-
VII	-"- -"-	42-48 -"-	female
XI	-"- -"-	12 -"-	male

All investigated buffaloes belong to the Beheira breed. The classification of the animals into groups was implemented on base of the ruminal content and the interrogation of the owner.

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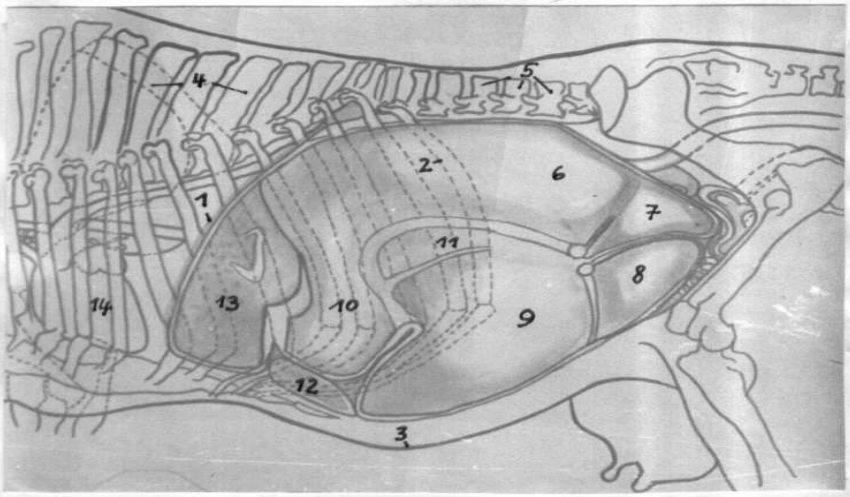

Fig. 1 Position of the buffalo stomach
View from the left side

1	diaphragm
2	13th rib
3	ventral abdominal wall
4	thoracic vertebrae
5	lumbar vertebrae
6	dorsal ruminal sac
7	dorsal caudal blind sac
8	ventral caudal blind sac
9	ventral ruminal sac
10	Atrium ruminis
11	ruminal islet
12	abomasum
13	reticulum
14	heart

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The age estimation of the buffaloes was exerted according to the condition of the teeth.

3.1 Material for anatomical studies:

The 9 samples for counting and measuring of the ruminal papillae were taken according to Fig. 2 and 3

3.2 Material for histological studies: (Fig. 2 and 3)

Also the samples for the histological slides were taken according to the abovementioned diagrams.

3.3 Methods of anatomical studies:

Just after the evisceration of the carcass the reticulum was removed. Beginning from the Plica rumino-reticularis the rumen was opened by making an incision on its dorsal wall. The rumen was emptied and everted to be washed by tap water in big bassins. After this the rumens were transferred into big container with 10 % formaline.
The rumens were identified and the samples taken according to the abovementioned diagram.
Then the samples were divided into small parts and transferred into BOUIN's fluid for histological studies.

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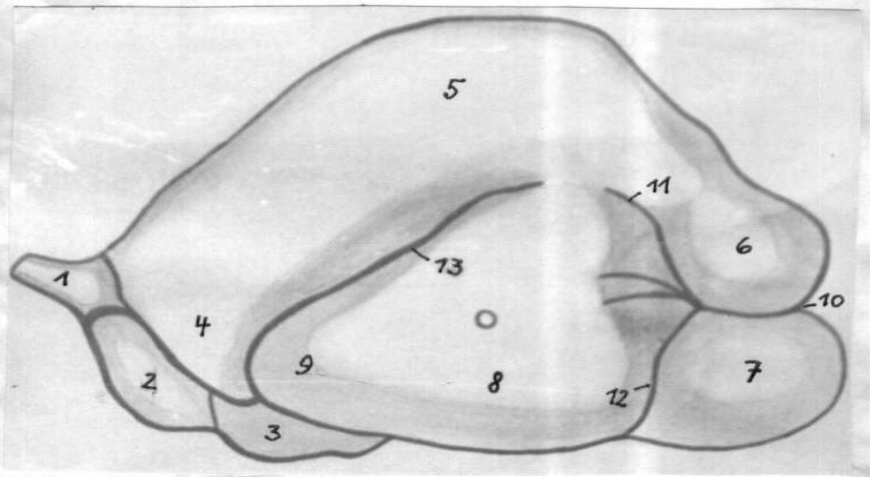

Fig. 2 Stomach of the buffalo
External surface. Left view

1	esophagus
2	reticulum
3	abomasum
4	Atrium ruminis
5	dorsal ruminal sac
6	dorsal caudal blind sac
7	ventral caudal blind sac
8	ventral ruminal sac
9	Recessus ruminis
10	caudal sulcus
11	dorsal coronary sulcus
12	ventral coronary sulcus
13	left longitudinal sulcus
0	site of sample Nr. 3

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The bigger part of the samples was kept in formaline for anatomical investigations.
Now the rumen was completely opened dorsally and the pillar system recorded by the naked-eye and after this illustrated from dorsocranially.
The rumen then was everted for the further description of the ruminal mucosa in each compartment regarding the colour, shape, distribution, height, presence or absence of the ruminal papillae.
Then 1 cm^2 of the ruminal wall was taken from the samples of anatomical studies for counting its papillary content and for measuring of the length and breadth of 40 papillae per sample.
From each rumen 9 samples were taken, i.e. from each rumen 360 papillae were counted and 720 (length and breadth of the papillae) measurements taken. From the 11 buffaloes about 4000 (= exactly 3960) papillae were counted and about 8000 (= exactly 7920) measurements performed.
For these purposes we have used a circle with 2 metall needles and a ruler with half millimeter scale.
For measuring the surface of the ruminal area (papillated and non-papillated ones) and pillar surface area the surface areas were taken first with their outlines on transparent plastic folia and later transferred from here into the paper with square millimeter classification.

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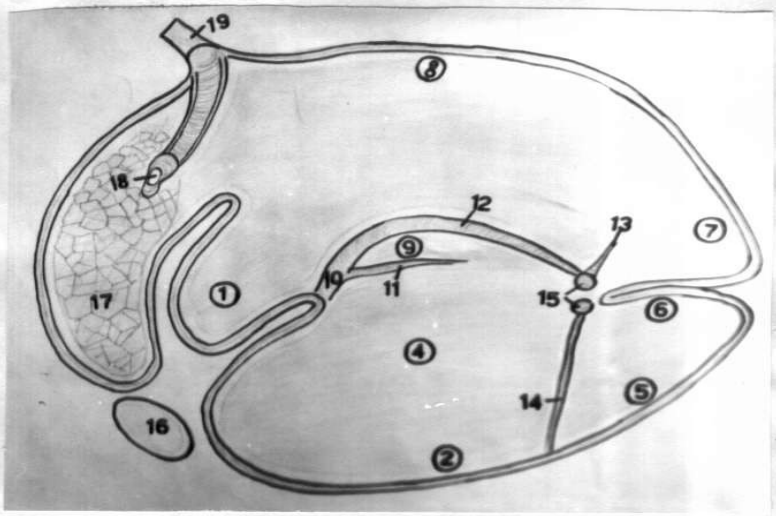

Fig. 3 Stomach of the buffalo
Internal surface. Left view

0 indicate sites of sampling
1 Atrium ruminis
2 ventral wall) of the ventral ruminal sac
4 right wall)
5 ventral wall) of the ventral caudal blind sac
6 dorsal wall)
7 dorsal caudal blind sac
8 dorsal ruminal sac (roof)
9 ruminal islet
10 cranial pillar
11 right accessory pillar
12 right longitudinal pillar
13 dorsal coronary pillar
14 ventral coronary pillar
15 double caudal pillar
16 abomasum
17 reticulum
18 ventricular groove
19 esophagus

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3.4 Methods of histological studies:

The samples for microscopical studies were taken according to the diagrams shown in fig. 2-3 by cutting about 1 cm^2 and then fixed in BOUIN's fluid for 24 hours. After this they were dehydrated by alcohole through increasing grades and cleared in xylene. Then they were cut to be embedded in the paraffin for longitudinal and cross-sections through the papillae and ruminal mucosa at different parts.

The samples are sectioned at 7 µm in thickness and then stained with hemotoxyline-eosine.

The slides were examined with the light microscope and the observation was extended to all aspects of the mucosa.

The standard micrometer was used for measuring the thickness of the Stratum corneum, Stratum granulosum and Stratum germinativum (= Stratum basale + Stratum spinosum).

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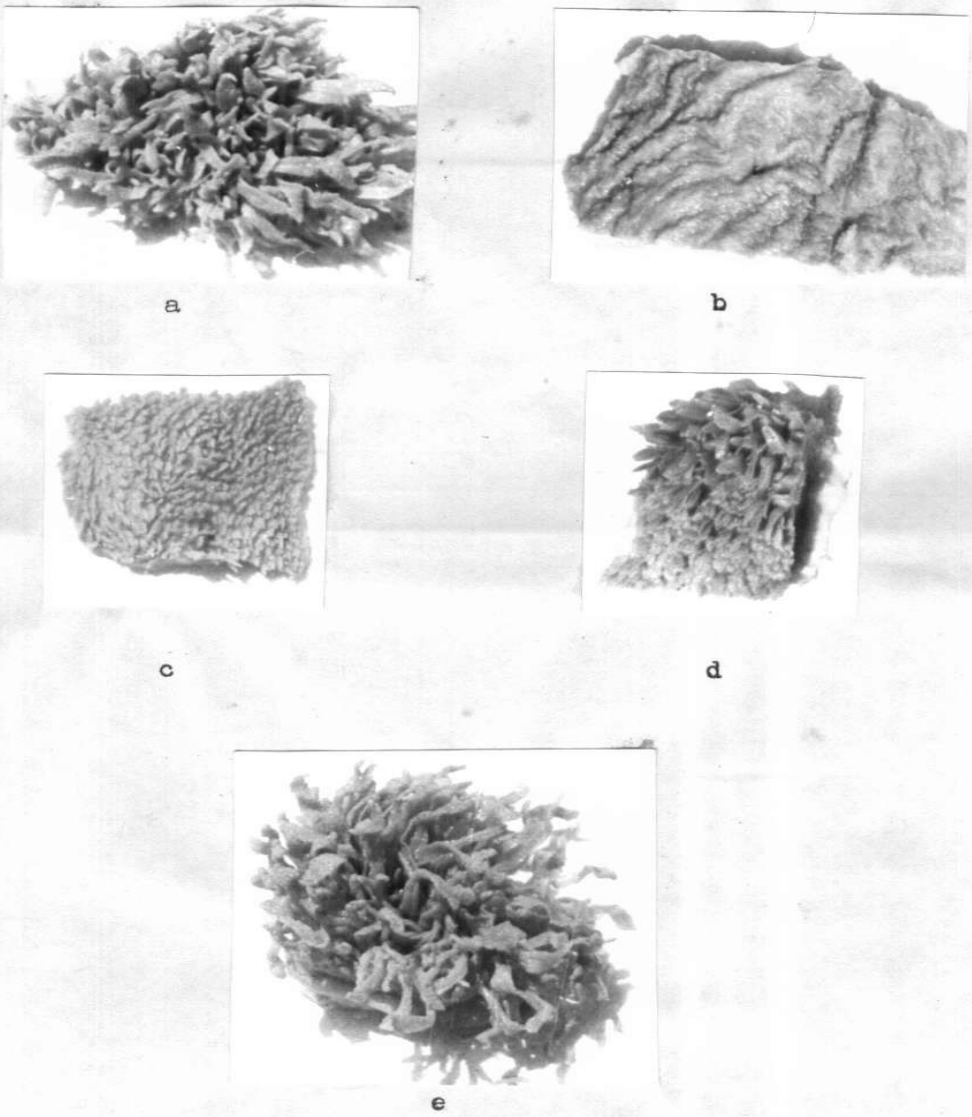

Fig. 4 Ruminal mucosa of the buffalo showing papillated and unpapillated areas

a Dorsal caudal blind sac
b Ventral ruminal sac (midregion)
c Ventral ruminal sac (right side)
d Ruminal islet
e Atrium ruminis

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4. Results

4.1 Results of the anatomical studies (Fig. 4, 5, 6 and 7)

4.1.1 Group 1: Buffalo calves fed by milk-rations

The ruminal mucosa of the buffalo calves has different colours. It is dark or greyish in the ventral ruminal sac and in the blind sacs, more whitish in the dorsal ruminal sac.

It bears visible papillae which are velvety to touch, specially on that of the Atrium ruminis, ventral ruminal sac and the two caudal blind sacs, where they are more developed.

The papillae of the Atrium ruminis are more condensed and very smooth. They are here longest at all and may reach 1,5 - 2 mm.

The papillae especially in the ventral wall of the ventral ruminal sac and caudal blind sacs arranged in groups or nests giving the mucosa a retiform appearance.

The papillae are practically absent on the roof of the dorsal ruminal sac which has a much wrinkled mucous membrane.

The pillars are all developed, whitish in colour and correspond externally to the ruminal grooves.

The ventral coronary pillars originate from the caudal accessory one and form a complete circle,

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while the dorsal ones do this not. But they appear relatively more developed in comparison to that of the adult rumen.

The right longitudinal pillar is connected to the caudal and cranial ones while the left longitudinal one reaches not the caudal pillars.

The right accessory pillar is found ventrally to the right longitudinal one and originates at the junction of the latter one with the cranial pillar and faints caudally to limit the ruminal islet (Insula ruminis).

Because of the minimal development of the ruminal papillae in the animals of this group the counting of papillae per cm^2, as also the measurements of their length and breadth were not performed.

Table 1

Size of the ruminal mucosa surface in cm^2

animal Nr.	papillated ruminal mucosa area	unpapillated ruminal mucosa area	ruminal pillar area	total area
III	828 (=89,61%)	-	96 (=10,39%)	924
IX	607 (=94,25%)	-	37 (= 5,75%)	644
X	919,5 (=92,09%)	-	79 (= 7,91%)	998,5

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4.1.2 Group 2: Adult buffaloes fed by berseem and tibn

The colour of the ruminal mucosa of these buffaloes ranges between whitish (Nr. IV) and greyish-green (Nr. V and Nr. VIII). It is studded with differently stained papillae in the individual compartments of the rumen (whitish ⟶ right wall of the Atrium ruminis and dorsal ruminal sac - Nr. IV; light grey-greenish ⟶ ventral ruminal sac, caudal blind sacs of Nr. IV; Atrium ruminis /except bottom/, ventral ruminal sac /except floor/ and caudal blind sacs /except ventral caudal blind sac/ of Nr. V and Nr. VIII).
The pillars show a light yellowish-brown colour (Nr. VIII).
Two buffaloes (Nr. IV and Nr. V) have a light Paramphistomes infestation, especially on the mucosa of the Atrium ruminis.

Atrium ruminis:
The mucosa is studded with long, tongue-shaped papillae.

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Table 2

Length and breadth of the ruminal papillae in the Atrium ruminis

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 9,3 mm	$\bar{x}$ = 2,1 mm
V	$\bar{x}$ = 9,3 mm	$\bar{x}$ = 1,9 mm
VIII	$\bar{x}$ = 27,96mm	$\bar{x}$ = 3,8 mm

In general this compartment of the rumen has the longest papillae. The longest ones were measured with 4,5 cm in the rumen of buffalo Nr. VIII. Also the breadth of the papillae may be considerable, so that the papillae appear to be wrapped in the left wall of the Atrium ruminis. Inbetween these ones shrinked and spiralled papillae may occur (Nr. VIII).

The papillae of the right wall and the bottom are in all cases lighter in colour than those of the left wall. They are unevenly distributed, less dense in the bottom than in the left wall and become more dense toward the right wall and near the cranial pillar.

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Table 3

Number of ruminal papillae per cm^2

animal Nr.	
IV	$\bar{x}$ = 117
V	$\bar{x}$ = 59
VIII	$\bar{x}$ = 36

In two buffaloes (Nr. IV and Nr. V) areas are found in the mucosa of the Atrium ruminis which are partially (Nr. V ⟶ area of about 5 x 2 cm with few long papillae) or completely devoid of papillae (Nr. IV ⟶ an area of 4 x 2,5 cm at the left wall and Nr. V an area of 2 cm^2 also at the left wall).

Dorsal ruminal sac (Saccus dorsalis):
The roof of the dorsal ruminal sac is devoid of papillae (area is in buffalo Nr. IV 20 x 27 cm; in buffalo V 43 x 22 cm) and bears a wrinkled mucosa. The right wall has areas of different size with ill-developed papillae (in buffalo Nr. IV this area measures 20 x 2 cm, in buffalo Nr. V 33 x 7 cm). Cranially to this one regularly an area is found on the right wall which is completely devoid of papillae (12 x 8 cm in buffalo Nr. IV

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and 22 x 11 cm in buffalo Nr. V). The papillae increase in length from the dorsal wall toward the pillars, but on reaching the pillars they become shorter and more dense.

In one case (buffalo Nr. VIII) the left wall at a distance of about 14 cm between the termination of the left longitudinal pillar and the caudal pillar was found to be studded by dense and short papillae, interrupted dorsally by an area of about 2,5 x 3 cm devoid of those.

In the same animal also dorsocaudally on the right wall an area of about 6 x 2 cm is devoid of papillae.

The ruminal islet is a constituent of the dorsal ruminal wall. It is embraced by the right accessory pillar ventrally and the right longitudinal pillar dorsally . The mucosa of this part is papillated and has the following density per cm^2 in the individual animals.

Table 4

Number of the ruminal papillae per cm^2 of the ruminal islet (Insula ruminis)

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 112
V	$\bar{x}$ = 29
VIII	$\bar{x}$ = 26

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The length and breadth of the papillae are the following:

Table 5

Length and breadth of the ruminal papillae of the ruminal islet (Insula ruminis) (in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 3,19 mm	$\bar{x}$ = 1,69 mm
V	$\bar{x}$ = 3,70 mm	$\bar{x}$ = 1,70 mm
VIII	$\bar{x}$ = 5,40 mm	$\bar{x}$ = 2,90 mm

The colour of the ruminal papillae in the dorsal ruminal sac is in general whitish or greyish-green and becomes darker from dorsal to ventral.

Ventral ruminal sac (Saccus ventralis):
The mucosa of the ventral ruminal sac is covered by relatively long, narrow-tongue-shaped papillae. These become more dense, shorter and darker toward the periphery, specially cranially and also on the left wall.
In the center of the floor of its ventral ruminal sac the buffalo Nr. VIII has an area of about 10 x 15 cm which is completely devoid of papillae.

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The mucous membrane is wrinkled and the devoid area surrounded by scores of long and narrow tongue-shaped papillae, inbetween of which are shorter and broader ones.
The transitional stage to the abovementioned lack of papillae in certain areas is that ventral ruminal wall (buffalo Nr. V) bearing a wrinkled mucosa with widely distributed, long, narrow tongue-shaped papillae which increase in number toward the periphery.
The colour of the papillae on the left wall is greyish-green and becomes lighter on the bottom and the right ruminal wall.

Table 6

Length and breadth of the ruminal papillae in the ventral wall of the ruminal sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 2,15	$\bar{x}$ = 0,90
V	$\bar{x}$ = 6,50	$\bar{x}$ = 1,96
VIII	-	-

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Table 7

Length and breadth of the ruminal papillae in the left wall of the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 4,39	$\bar{x}$ = 1,45
V	$\bar{x}$ = 8,70	$\bar{x}$ = 2,50
VIII	$\bar{x}$ =13,03	$\bar{x}$ = 3,70

Table 8

Length and breadth of the ruminal papillae in the right wall of the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 4,83	$\bar{x}$ = 1,45
V	$\bar{x}$ = 6,30	$\bar{x}$ = 1,80
VIII	$\bar{x}$ = 8,20	$\bar{x}$ = 2,50

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Table 9

Mean length and breadth of the ruminal papillae in the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 3,97	$\bar{x}$ = 1,26
V	$\bar{x}$ = 7,16	$\bar{x}$ = 2,13
VIII	$\bar{x}$ = 10,61	$\bar{x}$ = 3,10

Table 10

Number of ruminal papillae per cm^2 in the ventral wall of the ventral ruminal sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 104
V	$\bar{x}$ = 41
VIII	$\bar{x}$ = -

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Table 11

Number of ruminal papillae per cm^2 in the left wall of the ventral ruminal sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 102
V	$\bar{x}$ = 64
VIII	$\bar{x}$ = 27

Table 12

Number of ruminal papillae per cm^2 in the right wall of the ventral ruminal sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 130
V	$\bar{x}$ = 50
VIII	$\bar{x}$ = 34

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Table 13

Mean number of ruminal papillae per cm^2 in the wall of the ventral ruminal sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 112
V	$\bar{x}$ = 51,7
VIII	$\bar{x}$ = 30,5

Dorsal caudal blind sac (Saccus cecus caudodorsalis): The mucosa of the dorsal caudal blind sac is studded with scores of rod-like papillae which are especially distinct in its fundus. They become more dense and tongue-shaped toward the periphery, more dense and shorter near the caudal pillar. In two buffaloes unpapillated areas are found. In the first case (buffalo Nr. V) on the right side of the dorsal caudal blind sac an area of about 5 x 7 cm is devoid of papillae, in the second case (buffalo Nr. VIII) a similar one of about 5 x 12 cm at the roof of the dorsal caudal blind sac. The colour of the papillae on the fundus is lighter than at the periphery.

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Table 14

Length and breadth of the ruminal papillae in the dorsal caudal blind sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 6,40	$\bar{x}$ = 1,20
V	$\bar{x}$ = 10,30	$\bar{x}$ = 2,07
VIII	$\bar{x}$ = 12,70	$\bar{x}$ = 3,40

Table 15

Number of ruminal papillae per cm^2 in the dorsal caudal blind sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 94
V	$\bar{x}$ = 58
VIII	$\bar{x}$ = 40

Ventral caudal blind sac (Saccus cecus caudoventralis): The mucosa bears in its fundus ill-developed or scores of long rod-like papillae which increase in length and density toward the periphery assuming more tongue shape. Near the pillars they become again shorter and more dense.

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The papillae have a lighter colour in the center and darken toward the dorsal peripheral regions. On the bottom of the ventral caudal blind sac of buffalo Nr. IV is a small, ring-like area of about 1 cm^2 which has few papillae and where the smooth musculature seems to lack. Mucosa, submucosa and adventitia are closely associated.

Table 16

Length and breadth of the ruminal papillae of the ventral wall of the ventral caudal blind sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 6,80	$\bar{x}$ = 1,24
V	$\bar{x}$ = 6,40	$\bar{x}$ = 1,70
VIII	$\bar{x}$ = 11,20	$\bar{x}$ = 3,10

Table 17

Length and breadth of the ruminal papillae of the dorsal wall of the ventral caudal blind sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 7,40	$\bar{x}$ = 1,60
V	$\bar{x}$ =11,80	$\bar{x}$ = 1,70
VIII	$\bar{x}$ =20,30	$\bar{x}$ = 3,30

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Table 18

Mean length and breadth of the ruminal papillae of the ventral caudal blind sac

(in mm)

animal Nr.	length	breadth
IV	$\bar{x}$ = 7,10	$\bar{x}$ = 1,42
V	$\bar{x}$ = 9,10	$\bar{x}$ = 1,70
VIII	$\bar{x}$ = 15,75	$\bar{x}$ = 3,20

Table 19

Number of ruminal papillae per cm^2 in the ventral wall of the ventral caudal blind sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 85
V	$\bar{x}$ = 76
VIII	$\bar{x}$ = 21

Table 20

Number of ruminal papillae per cm^2 in the dorsal wall of the ventral caudal blind sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 105
V	$\bar{x}$ = 78
VIII	$\bar{x}$ = 39

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Table 21

Mean number of ruminal papillae per cm^2 in the ventral caudel blind sac

animal Nr.	number of ruminal papillae
IV	$\bar{x}$ = 95
V	$\bar{x}$ = 77
VIII	$\bar{x}$ = 30

An idea on the size of the ruminal surfaces of the buffaloes in the group Nr. 2 give the following measurements:

Table 22

Size of the ruminal surface in cm^2

animal Nr.	papillated ruminal area	ruminal pillar area	unpapillated area	total area
IV	3992 (=77,78%)	381 (=7,43%)	759 (=14,79%)	5132
V	5376,5(=75,75%)	477 (=6,72%)	1244,5(=17,53%)	7098
VIII	7174,5(=76,81%)	5445(=5,83%)	1622 (=17,36%)	9341

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Table 23

Total number of ruminal papillae on the papillated ruminal area

animal Nr.	papillated ruminal area in cm^2 x mean number of papillae/cm^2	total number of papillae
IV	3992 x 106,1	423551,2
V	5376,5 x 56,8	305385,2
VIII	7174,5 x 27,9	200168,6

Table 24

Size of the total papillary surface (in mm^2)/in cm^2/

animal Nr.	length of papillae (= $\bar{x}$) (in mm)	x	breadth (= $\bar{x}$) (in mm)	x 2 x	total number of papillae	total papillary surface
IV	5,60		1,45	x 2 x	423551,2	6878471,5 /=68784,7/
V	7,90		1,90	x 2 x	305385,2	9167663,7 /=91676,6/
VIII	12,34		2,80	x 2 x	200168,6	13832450 /=138324,5/

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Table 25

Magnification of the ruminal absorptive surface by ruminal papillae (in cm^2)

animal Nr.	total papillary surface	total mucosal surface of the rumen	magnification
IV	68784,7	5132	13,40 times
V	91676,6	7098	12,91 times
VIII	138324,5	9341	14,80 times

Table 26

Loss in absorptive surface by unpapillated areas (in cm^2)

animal Nr.	magnification of the ruminal absorptive surface	x	unpapillated area (in cm^2)	lost area cm^2
IV	13403	x	759	10172,87
V	12916	x	1244,5	16073,96
VIII	14808	x	1622	24018,57

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4.1.3 Group 3: Adult buffaloes fed by russian (concentrated fattening feedstuffs) and tibn

The colour of the ruminal mucosa ranges between light greyish-green (buffaloes Nr. VI, VII and Nr. XI), which is more lighter in the Atrium ruminis, greyish-green (buffalo Nr. XI), greyish-brown (buffalo Nr. I) and dark brownish (buffalo Nr. II). The ruminal pillars have a light yellowish-brown to roughly black appearing colour. Two buffaloes of these group (Nr. VI and Nr. VII) show a light Paramphistomes-infection of their Atrii ruminis resp. their caudal blind sacs.

Atrium ruminis:

The mucosa of the Atrium ruminis is studded with long, singly standing and evenly distributed ruminal papillae. They are tongue-shaped or piriform in outline and become more dense but shorter toward the cranial ruminal pillar and the left wall of the Atrium ruminis. The longest papillae are found at the bottom (in buffalo Nr. VII till to 5 cm), the shortest toward the Plica rumino-reticularis. In three buffaloes (Nr. II, VI and VII) areas are found which are devoid of papillae (Nr. II 1 cm^2 at the bottom, Nr. VI 16 cm^2 at the bottom and Nr. VII has three areas: 1 cm^2 on the bottom, 1 cm^2 on the right side and 24 cm^2 /studded only by eight long papillae/).

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Table 27

Number of ruminal papillae per cm^2

animal Nr.	number of ruminal papillae /cm^2
XI	$\bar{x}$ = 54
II	$\bar{x}$ = 63
I	$\bar{x}$ = 61
VI	$\bar{x}$ = 79
VII	$\bar{x}$ = 25

Table 28

Length and breadth of the ruminal papillae in the Atrium ruminis

(in mm)

animal Nr.	length	breadth
XI	12,28	2,1
II	4,60	1,5
I	7,11	1,9
VI	12,50	2,4
VII	24,09	4,5

In general this compartment of the rumen has the longest papillae.

The longest were observed in buffalo Nr. VII having 5 cm!

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The colour of the papillae is greyish-green, greyish-brown or roughly black at the bottom and becomes darker toward the left wall and lighter toward to the right wall.
In buffalo Nr. VI the colour, which is greyish on the left wall, becomes lighter on the bottom and whitish on the right wall.

Dorsal ruminal sac (Saccus dorsalis):
The roof of the dorsal ruminal sac is practically devoid of ruminal papillae and its mucosa shows a wrinkled appearance. The size of this area is different in the individual buffaloes (Nr. XI 10 x 8 cm, Nr. II 12 x 8 cm, Nr. I 15 x 9 cm, Nr. VI 20 x 10 cm).
From dorsal to lateral at the left and right wall of the dorsal ruminal sac the papillae increase in length toward the pillars, but on reaching them they become short again. Also the density increases in the same direction. This is especially visible between the left longitudinal and the caudal pillar as also caudodorsally at the right wall. But on the right wall cranially at the junction of the right longitudinal pillar with the cranial pillar is an area devoid of papillae (about 10 x 12 cm in buffalo Nr. I, 16 x 11 cm in buffalo Nr. VI). Transitions to these areas are such ones with ill-developed ruminal papillae (25 x 10 cm at the right side of the dorsal ruminal wall - buffalo Nr. VI).

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Table 29

Number of the ruminal papillae per cm^2 of the ruminal islet (Insula ruminis)

animal Nr.	number of ruminal papillae
XI	52
II	86
I	64
VI	22
VII	39

Table 30

Length and breadth of the ruminal papillae of the ruminal islet (Insula ruminis)

(in mm)

animal Nr.	length	breadth
XI	$\bar{x}$ = 5,90	$\bar{x}$ = 1,50
II	$\bar{x}$ = 5,90	$\bar{x}$ = 1,85
I	$\bar{x}$ = 3,45	$\bar{x}$ = 1,68
VI	$\bar{x}$ = 5,30	$\bar{x}$ = 2,30
VII	$\bar{x}$ = 5,01	$\bar{x}$ = 2,73

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Ventral ruminal sac (Saccus ventralis):

The characteristic feature of the mucous membrane of the ruminal ventral sac are areas devoid of papillae. They occur in three animals of five in this group (buffalo Nr. I, Nr. XI, Nr. VII) at the bottom of this ruminal compartment and differ in size. They measure 8 x 13 cm in buffalo Nr. I, 15 x 10 cm in buffalo Nr. XI and 26 x 20 cm in buffalo Nr. VII. The area devoid of papillae is replaced by a wrinkled mucous membrane surrounded by a narrow girdle which is studded by scores of extremely long papillae. Toward the periphery the papillae decrease in length and increase in density. The wrinkled mucosa may also show distinct folds bearing few and ill-developed rod-shaped papillae which toward the periphery become more developed, shorter, stronger and tongue-shaped. Especially dense they are toward the cranial pillar and the left wall.

The longest papillae in the ruminal ventral sac are found at its lateral wall, distributed cranio-caudally.

The papillae are of light grey-colour and on the right side more lighter than on the left.

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Table 31

Length and breadth of the ruminal papillae in the ventral wall of the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
XI	$\bar{x}$ = 5,80	$\bar{x}$ = 1,20
II	$\bar{x}$ = 2,30	$\bar{x}$ = 0,94
I	$\bar{x}$ = 2,34	$\bar{x}$ = 0,90
VI	$\bar{x}$ = 4,90	$\bar{x}$ = 1,60
VII	-	-

Table 32

Length and breadth of the ruminal papillae in the left wall of the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
XI	$\bar{x}$ = 12,35	$\bar{x}$ = 1,96
II	$\bar{x}$ = 6,40	$\bar{x}$ = 2,10
I	$\bar{x}$ = 6,11	$\bar{x}$ = 2,16
VI	$\bar{x}$ = 4,90	$\bar{x}$ = 1,76
VII	$\bar{x}$ = 9,21	$\bar{x}$ = 2,16

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Table 33

Length and breadth of the ruminal papillae in the right wall of the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
XI	$\bar{x}$ = 5,93	$\bar{x}$ = 0,93
II	$\bar{x}$ = 5,40	$\bar{x}$ = 1,80
I	$\bar{x}$ = 3,38	$\bar{x}$ = 1,66
VI	$\bar{x}$ = 5,10	$\bar{x}$ = 1,70
VII	$\bar{x}$ = 8,01	$\bar{x}$ = 2,03

Table 34

Mean length and breadth of the ruminal papillae in the ventral ruminal sac

(in mm)

animal Nr.	length	breadth
XI	$\bar{x}$ = 8,02	$\bar{x}$ = 1,36
II	$\bar{x}$ = 4,70	$\bar{x}$ = 1,61
I	$\bar{x}$ = 3,94	$\bar{x}$ = 1,57
VI	$\bar{x}$ = 4,96	$\bar{x}$ = 1,68
VII	$\bar{x}$ = 8,61	$\bar{x}$ = 2,09

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Table 35

Number of ruminal papillae per cm^2 in the ventral wall of the ventrel ruminal sac

animal Nr.	number of ruminel papillae
XI	$\bar{x}$ = 32
II	$\bar{x}$ = 95
I	$\bar{x}$ = 100
VI	$\bar{x}$ = 47
VII	-

Table 36

Number of ruminal papillae per cm^2 in the left wall of the ventral ruminal sac

animal Nr.	number of ruminal papillae
XI	$\bar{x}$ = 93
II	$\bar{x}$ = 97
I	$\bar{x}$ = 82
VI	$\bar{x}$ = 45
VII	$\bar{x}$ = 79

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Table 37

Number of ruminal papillae per cm^2 in the right wall of the ruminal wall

animal Nr.	number of ruminal papillae
XI	$\bar{x}$ = 93
II	$\bar{x}$ = 109
I	$\bar{x}$ = 99
VI	$\bar{x}$ = 76
VII	$\bar{x}$ = 78

Table 38

Mean number of ruminal papillae per cm^2 in the wall of the ventral ruminal sac

animal Nr.	number of ruminal papillae
XI	$\bar{x}$ = 72,67
II	$\bar{x}$ = 100,33
I	$\bar{x}$ = 93,66
VI	$\bar{x}$ = 56,00
VII	$\bar{x}$ = 78,50

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Dorsal caudal blind sac (Saccus cecus caudodorsalis):
The papillae are brownish-grey coloured and at the bottom are somewhat lighter than on the right and left wall. In buffalo Nr. VII the fundus has an area of about 15 x 6 cm which bears few but long papillae and which is surrounded by extreme long papillae. The latter ones decrease in length and become more dense toward the periphery. In general the papillae are piriform and tongue-shaped.
The longest found in the center of the fundus and near the caudal pillar. Traced dorsally and laterally they become shorter.

Table 39

Number of ruminal papillae per cm^2 in the dorsal caudal blind sac

animal Nr.	number of ruminal papillae
I	$\bar{x}$ = 82
II	$\bar{x}$ = 112
VI	$\bar{x}$ = 77
VII	$\bar{x}$ = 11
XI	$\bar{x}$ = 63

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Table 40

Length and breadth of the ruminal papillae in the dorsal caudal blind sac

(in mm)

animal Nr.	length	breadth
I	$\bar{x}$ = 4,87	$\bar{x}$ = 1,52
II	$\bar{x}$ = 3,30	$\bar{x}$ = 1,18
VI	$\bar{x}$ = 5,90	$\bar{x}$ = 1,40
VII	$\bar{x}$ = 26,34	$\bar{x}$ = 3,60
XI	$\bar{x}$ = 10,80	$\bar{x}$ = 1,33

Ventral caudal blind sac (Saccus cecus caudoventralis):

The colour of the papillae appears somewhat lighter than in the dorsal caudal blind sac, especially at the periphery (the tips of the papillae are lighter).

The center bears either short papillae in the center or is devoid of them as in rumen Nr. VII and Nr. XI. Toward the periphery they become more dense and concentrated.

The papillae are tongue-shaped.

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Table 41

Number of ruminal papillae per cm^2 in the ventral wall of the ventral caudal blind sac

animal Nr.	number of ruminal papillae
I	$\bar{x}$ = 24
II	$\bar{x}$ = 88
VI	$\bar{x}$ = 67
VII	$\bar{x}$ = 76
XI	$\bar{x}$ = 43

Table 42

Number of ruminal papillae per cm^2 in the dorsal wall of the ventral caudal blind sac

animal Nr.	number of ruminal papillae
I	$\bar{x}$ = 82
II	$\bar{x}$ = 95
VI	$\bar{x}$ = 81
VII	$\bar{x}$ = 80
XI	$\bar{x}$ = 62

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Table 43

Mean number of ruminal papillae per cm^2 in the ventral caudal blind sac

animal Nr.	number of ruminal papillae
I	$\bar{x}$ = 53
II	$\bar{x}$ = 91,5
VI	$\bar{x}$ = 74
VII	$\bar{x}$ = 78
XI	$\bar{x}$ = 52,5

A surview on the length of the ventral caudal blind sacs give the following tables.

Table 44

Length and breadth of the ruminal papillae of the ventral wall of the ventral caudal blind sac

(in mm)

animal Nr.	length	breadth
I	$\bar{x}$ = 1,9	$\bar{x}$ = 1,09
II	$\bar{x}$ = 2,16	$\bar{x}$ = 0,91
VI	$\bar{x}$ = 7,40	$\bar{x}$ = 1,50
VII	$\bar{x}$ = 6,80	$\bar{x}$ = 2,60
XI	$\bar{x}$ = 20,60	$\bar{x}$ = 2,20

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Table 45

Length and breadth of the ruminal papillae of the dorsal wall of the ventral caudal blind sac

(in mm)

animal Nr.	length	breadth
I	$\bar{x}$ = 6,12	$\bar{x}$ = 1,70
II	$\bar{x}$ = 6,04	$\bar{x}$ = 1,98
VI	$\bar{x}$ = 7,70	$\bar{x}$ = 1,40
VII	$\bar{x}$ = 13,30	$\bar{x}$ = 3,50
XI	$\bar{x}$ = 13,35	$\bar{x}$ = 2,22

Table 46

Mean length and breadth of the ruminal papillae of the ventral caudal blind sac

(in mm)

animal Nr.	length	breadth
I	$\bar{x}$ = 4,01	$\bar{x}$ = 1,39
II	$\bar{x}$ = 4,10	$\bar{x}$ = 1,44
VI	$\bar{x}$ = 7,75	$\bar{x}$ = 1,45
VII	$\bar{x}$ = 10,05	$\bar{x}$ = 3,05
XI	$\bar{x}$ = 16,97	$\bar{x}$ = 2,21

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An idea on the size of the ruminal surfaces of the buffaloes in the group Nr. 3 give the following measurements.

Table 47

Size of the ruminal surface in cm^2

animal Nr.	papillated ruminal area	ruminal pillar area	unpapillated area	total area
XI	5334 (=88,12%)	346 (= 5,72%)	373 (= 6,16%)	6053
II	3177,5 (=83,91%)	390 (=10,30%)	219,5 (= 5,79%)	3787
I	5653 (=87,41%)	455 (= 7,03%)	359 (= 5,56%)	6467
VI	4253,5 (=81,10%)	324,5 (= 6,19%)	667,5 (=12,71%)	5245,5
VII	4273 (=66,30%)	675 (=10,47%)	1497 (=23,23%)	6445

Table 48

Total number of ruminal papillae on the papillated ruminal area

animal Nr.	papillated ruminal area in cm^2	x	mean number of papillae /cm^2	total number of papillae
XI	5334	x	61,50	328041
II	3177,50	x	93,13	295920,6
I	5653	x	74,25	419735,3
VI	4253,50	x	61,80	262866,3
VII	4273	x	48,50	207240,5

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Table 49

Size of the total papillary surface (in mm^2) /in cm^2/

animal Nr.	length of papillae (=$\bar{x}$) (in mm)	x	breadth (=$\bar{x}$) (in mm)	x2x	total number of papillae	total papillary surface
XI	9,6	x	1,7	x2x	328041	10707258,2 /=107072,58/
II	4,5	x	1,5	x2x	295920,6	3994928,2 /=39949,28/
I	4,5	x	1,6	x2x	419735,3	6044188,4 /=60441,88/
VI	6,7	x	1,8	x2x	262866,3	6340335,2 /=63403,35/
VII	11,6	x	2,6	x2x	207240,5	12500747 /=125007,47/

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Table 50

Magnification of the ruminal absorptive surface by ruminal papillae (in cm^2)

animal Nr.	total papillary surface	total mucosal surface of the rumen	magnification
XI	107072,58	6053	17,68 times
II	39949,28	3787	10,54 times
I	60441,88	6467	9,34 times
VI	63403,35	5245,5	12,08 times
VII	125007,47	6445	19,39 times

Table 51

Loss in absorptive surface by unpapillated area (in cm^2)

animal Nr.	magnification of the ruminal absorptive surface	x	unpapillated area (in cm^2)	lost area cm^2
XI	17,68	x	373	6594,64
II	10,54	x	219,5	2313,53
I	9,34	x	359	3353,06
VI	12,08	x	667,5	8063,40
VII	19,39	x	1497	29026,83

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Table 52

Number of ruminal papillae /cm^2 of all investigated buffaloes

animal Nr.	sample Nr. 1 (Atrium ruminis)	2 ventral wall of the ventral ruminal sac	3 left wall	4 right wall	5 ventral wall of the caudal blind sac	6 dorsal wall of the ventral blind sac	7 dorsal caudal blind sac	8 dorsal wall of the dorsal ruminal sac	9 ruminal islet	$\bar{x}$
I	61	100	82	99	24	82	82		64	74,25
II	63	95	97	109	88	95	112		86	93,13
III	-	-	-	-	-	-	-		-	-
IV	117	104	102	130	85	105	94		112	106,1
V	59	41	64	50	76	78	58		29	56,8
VI	79	47	45	76	67	81	77		22	61,8
VII	25	-	79	78	76	80	11		39	48,5
VIII	36	-	27	34	21	39	40		26	27,9
IX	-	-	-	-	-	-	-		-	-
X	-	-	-	-	-	-	-		-	-
XI	54	32	93	93	43	62	63		52	61,5
$\bar{x}$	61,8	52,4	73,6	83,6	60	77,8	67,1		53,8	

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Table 53

Length (l.) and breadth (b.) of ruminal papillae (in mm) of all investigated buffaloes

animal Nr.	$\bar{x}$ 1 l.	b.	$\bar{x}$ 2 l.	b.	$\bar{x}$ 3 l.	b.	$\bar{x}$ 4 l.	b.	$\bar{x}$ 5 l.	b.	$\bar{x}$ 6 l.	b.	$\bar{x}$ 7 l.	b.	$\bar{x}$ 8 l	b	$\bar{x}$ 9 l.	b.	$\bar{\bar{x}}$ l.	b.
I	7,11	1,9	2,34	0,9	6,11	2,16	3,38	1,66	1,9	1,09	6,12	1,7	4,87	1,52			3,45	1,69	4,5	1,6
II	4,6	1,5	2,3	0,94	6,4	2,1	5,4	1,8	2,1	0,91	6,04	1,9	3,3	1,18			5,9	1,85	4,5	1,5
III	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-
IV	9,3	2,1	2,15	0,9	4,39	1,45	4,83	1,45	6,8	1,24	7,4	1,6	6,4	1,2			3,19	1,69	5,6	1,45
V	9,3	1,9	6,5	1,96	8,7	2,5	6,3	1,8	6,4	1,7	11,8	1,7	10,3	2,07			3,7	1,7	7,9	1,9
VI	12,5	2,4	4,9	1,6	4,9	1,76	5,1	1,7	7,4	1,5	7,7	1,4	5,9	1,4			5,3	2,3	6,7	1,8
VII	24,09	4,5	-	-	9,21	2,16	8,01	2,03	6,8	2,6	13,3	3,5	26,34	3,6			5,01	2,73	11,6	2,6
VIII	27,96	3,8	-	-	13,03	3,7	8,2	2,5	11,2	3,1	20,3	3,3	12,7	3,4			5,4	2,9	12,3	2,8
IX	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-
X	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-
XI	12,28	2,1	5,8	1,2	12,35	1,96	5,93	0,93	20,6	2,2	13,35	2,2	10,8	1,33			5,9	1,5	9,6	1,7

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Table 54

Size of the ruminal surface (in cm^2) of all investigated buffaloes

animal Nr.	papillated ruminal area	ruminal pillar area	unpapillated area	total area
I	5653	455	359	6467
II	3177,5	390	219,5	3787
III	828	96	-	924
IV	3992	381	759	5132
V	5376,5	477	1244,5	7098
VI	4253,5	324,5	667,5	5245,5
VII	4273	675	1497	6445
VIII	7174,5	544,5	1622	9341
IX	607	37	-	644
X	919,5	79	-	998,5
XI	5334	346	373	6053
$\bar{x}$	3780,8	345,9	612,9	4739,6

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Table 55

Location of the unpapillated areas in the rumens of all investigated buffaloes

animal Nr.	Atrium rumini	dorsal ruminal sac	ventral ruminal sac	dorsal caudal blind sac	ventral caudal blind sac
I	-	x	x	-	-
II	x	x	-	-	-
III	-	-	-	-	-
IV	x	x	-	-	-
V	x	x	-	x	-
VI	x	x	-	-	-
VII	x	x	x	-	x
VIII	-	x	x	x	-
IX	-	-	-	-	-
X	-	-	-	-	-
XI	-	x	x	-	x

x = found

- = not found

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Table 56

Total number of the ruminal papillae in all investigated buffaloes

animal Nr.	papillated ruminal area in cm^2	x	mean number of papillae / cm^2	total number of ruminal papillae
I	5653	x	74,25	419735,3
II	3177,50	x	93,13	295920,6
III	828		-	-
IV	3992	x	106,1	423551,2
V	5376,50	x	56,80	305385,2
VI	4253,50	x	61,80	262866,3
VII	4273	x	48,50	207240,5
VIII	7174,50	x	27,90	200168,6
IX	607		-	-
X	919,50		-	-
XI	5334	x	61,50	328041

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Table 57

Size of the total papillary surface in all investigated buffaloes

(in mm^2)

animal Nr.	2 x	length of papillae ($\bar{x}$) (mm)	x	breadth ($\bar{x}$)(mm)	x	total number of papillae	=	total papillary surface
I	2 x	4,5	x	1,6	x	419735,3	=	6044188,4
II	2 x	4,5	x	1,5	x	295920,6	=	3994928,2
III		-		-		-		-
IV	2 x	5,6	x	1,45	x	423551,2	=	6878471,5
V	2 x	7,9	x	1,9	x	305385,2	=	9167663,7
VI	2 x	6,7	x	1,8	x	262866,3	=	6340335,2
VII	2 x	11,6	x	2,6	x	207240,5	=	12500747,0
VIII	2 x	12,34	x	2,8	x	200168,6	=	13832450,0
IX		-		-		-		-
X		-		-		-		-
XI	2 x	9,6	x	1,7	x	328041	=	10707258,2

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Table 58

Magnification of ruminal absorptive surface by ruminal papillae of all investigated buffaloes

(in cm^2)

animal Nr.	total papillary surface (1)	total mucosal surface of the rumen (2)	enlargement (1 : 2)
I	60441,88	6467	9,34 times
II	39949,28	3787	10,54 times
III	-	-	-
IV	68784,7	5132	13,40 times
V	91676,6	7098	12,91 times
VI	63403,35	5245,5	12,08 times
VII	125007,47	6445	19,39 times
VIII	138324,5	9341	14,80 times
IX	-	-	-
X	-	-	-
XI	107072,58	6053	17,68 times

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Table 59

Loss in absorptive surface by unpapillated areas of all investigated buffaloes

(in cm^2)

animal Nr.	enlargement of surface	x	unpapillated area	
I	9,34	x	359	= 3353,06
II	10,54	x	219,5	= 2313,53
III	-		-	-
IV	13,403	x	759	= 10172,87
V	12,916	x	1244,5	= 16073,96
VI	12,08	x	667,5	= 8063,40
VII	19,39	x	1497	= 29026,83
VIII	14,808	x	1622	= 24018,57
IX	-		-	-
X	-		-	-
XI	17,68	x	373	= 6594,64

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4.1.4 Pillar system of the rumen of the buffalo (Fig. 5, 6, 7)

The investigation of the ruminal pillar system of the buffalo attracted us because some variations from the ox could be observed. If not specially mentioned then relations are found as in ox.

1. Group (buffaloes Nr. III, IX and X): (Fig. 5) All the ruminal pillars are developed and correspondingly to them also all the ruminal grooves externally. Special attention has been paid to the caudal pillar, because a caudal accessory pillar, ventral to the proper one, is present. From this caudal accessory pillar the ventral coronary pillars originate and form a complete circle. The dorsal coronary pillars - although relatively stronger developed than in the adult rumen - form no circle.

The right longitudinal pillar is connected to the caudal and cranial one, but not the left longitudinal pillar; this does not reach the caudal one. In buffalo Nr. IX the left dorsal coronary pillar is somewhat more developed than the right dorsal one and is nearly meeting the left longitudinal pillar.

The right accessory pillar is ventral to the right longitudinal one and originates at the junction of the latter with the cranial pillar and faints caudally to limit the ruminal islet.

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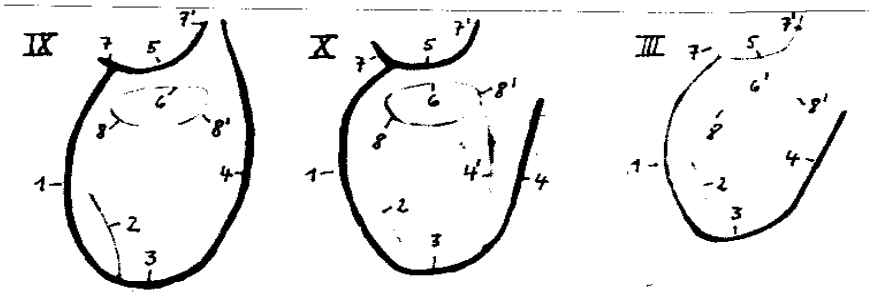

Fig. 5 Pillar system in the buffalo's rumen
First group. Craniodorsal view
III rumen Nr. III, IX rumen Nr. IX
X rumen Nr. X

1 Right longitudinal pillar
2 Right accessory pillar
3 Cranial pillar
4 Left longitudinal pillar
4' Left accessory pillar
5 Caudal pillar, dorsal part
6 Caudal pillar, ventral part
7 Right dorsal coronary pillar
7' Left dorsal coronary pillar
8 Right ventral coronary pillar
8' Left ventral coronary pillar

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The quantitative studies on the ruminal pillar area in the animals of this group revealed a value of 8,01 % of the total ruminal mucosal area.

2. Group (buffaloes Nr. IV, V, VIII): (Fig. 6)
Beside the caudal pillar all buffaloes have also an accessory caudal pillar. Both embrace an area which is densely studded with papillae. For example this area measures in buffalo Nr. IV 2,5x5 cm and has well developed papillae on the left side. On the right side it is devoid of them. Also in buffalo Nr. V is an area on the right side and measures 15 x 8 cm. In the rumen of buffalo Nr. VIII the caudal accessory pillar has a cranial extention to the right longitudinal pillar, which is not clear in rumen Nr. IV. Between both the area is papillated.

The right and left ventral coronary pillars originate from the caudal accessory one and are long to form nearly a circle, which is only interrupted for a short distance on the floor and bears short papillae.
Variant is the development of the dorsal coronary pillars, which take origin from the caudal proper one. In buffalo Nr. IV the left dorsal coronary pillar measures 6 cm in length, the right one only 4 cm. In rumen Nr. V the left one is well developed and of about 10 cm in length, meanwhile the right one is completely absent. In the buffalo

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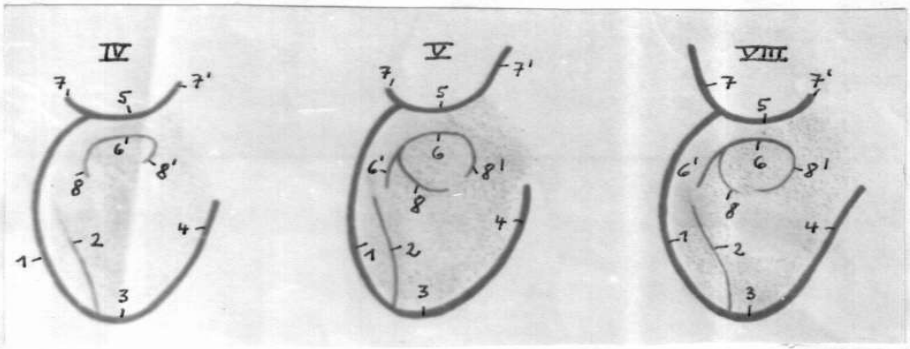

Fig. 6 Pillar system in the buffalo's rumen

Second group. Craniodorsal view

IV rumen Nr. IV V rumen Nr. V

VIII rumen Nr. VIII

1 Right longitudinal pillar
2 Right accessory pillar
3 Cranial pillar
4 Left longitudinal pillar
5 Caudal pillar, dorsal part
6 Caudal pillar, ventral part
6' Cranial extension of the caudal pillar, ventral part
7 Right dorsal coronary pillar
7' Left dorsal coronary pillar
8 Right ventral coronary pillar
8' Left ventral coronary pillar

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Nr. VIII we find the right dorsal coronary pillar also more developed (of about 15 cm in length) than the left one (about 7 cm in length).
The same variations are present in case of the connection of the left dorsal coronary and left longitudinal pillar. Meanwhile in buffalo Nr. V the left longitudinal pillar meets the termination of the left dorsal coronary one, but it fades out in buffaloes Nr. IV and VIII at a distance of about 14 cm before reaching the proper caudal pillar resp. the left dorsal coronary one, leaving a papillated area between them with short and dense papillae.

The right accessory pillar is ventral to the right longitudinal one and meets or points on the cranial extension of the caudal accessory pillar, nearly at a level of the middle of the right longitudinal pillar. In rumen IV f.e. the right accessory pillar extends for about the cranial third of the right longitudinal one, in buffalo Nr. VIII for about half of the length of the right longitudinal one. The quantitative studies revealed 6,72 % of the total ruminal surface as ruminal pillar surface.

3. Group (buffaloes Nr. I, II, VI, VII, XI): (Fig. 7)
The ruminal pillars of these animals are considerably developed.
The cranial pillar is extending on the left side of the rumen as the left longitudinal pillar which

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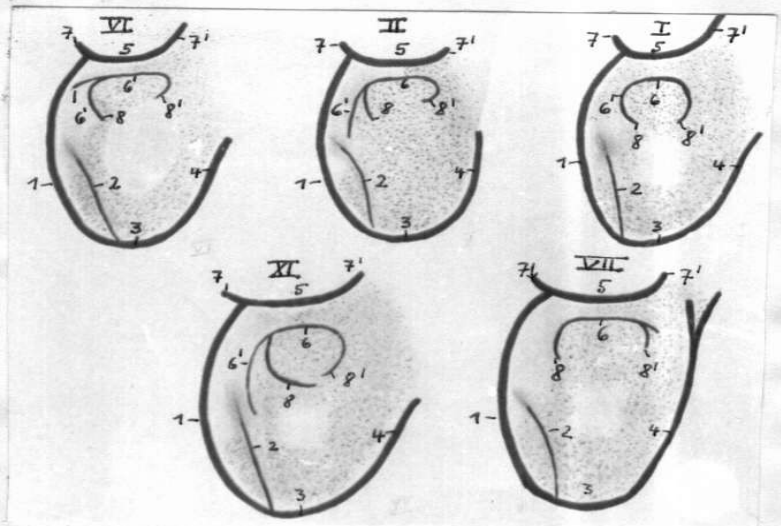

Fig. 7 Pillar system in the buffalo's rumen

Third group

I	rumen Nr. I	VII	rumen Nr. VII
II	rumen Nr. II	XI	rumen Nr. XI
VI	rumen Nr. VI		

1	Right longitudinal pillar	7	Right dorsal coronary pillar
2	Right accessory pillar	7'	Left dorsal coronary pillar
3	Cranial pillar	8	Right ventral coronary pillar
4	Left longitudinal pillar	8'	Left ventral coronary pillar
5	Caudal pillar, dorsal part		
6	Caudal pillar, ventral part		
6'	Cranial extension of the caudal pillar, ventral part		

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terminates caudally at about 4 - 16 cm cranial to the proper caudal pillar, i.e. it reaches the caudal pillar not. This area, not covered by this terminal pillar end, is studded densely by ruminal papillae. In rumen Nr. VII the caudal termination of the left longitudinal pillar is only 4 cm away from the proper caudal pillar, that means, it reaches this practically (termination by two short branches).

At the junction of the cranial pillar with the right longitudinal one the right accessory pillar originates, and courses caudally, ventral to the right longitudinal pillar, to end at the caudal third of the right ruminal wall, enclosing between them the ruminal islet. In rumen Nr. VI the right accessory pillar extends only till to the cranial third and in the rumen Nr. VII till to the cranial half of the length of the right longitudinal pillar.

On the right ruminal wall runs the right longitudinal pillar. It is fully developed and connected with the cranial and caudal one. It is situated dorsally from the right accessory pillar.

The caudal pillar is in all buffaloes of this group doubled, i.e. it consists of the proper caudal pillar, which is located dorsally, and the accessory caudal one, found ventrally. Both are transversely located and separated by at a distance of about 3 cm. The enclosed area is bearing

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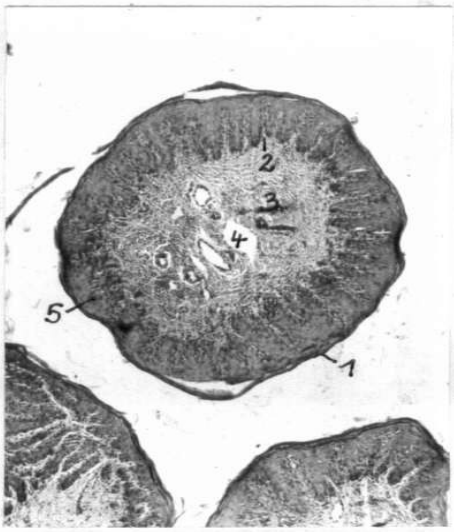

Fig. 8 Transverse section through a ruminal papilla of the right wall of the ventral ruminal sac. Buffalo-calf Nr. IX. 1st group
H & E-stain. Objective: 3,2; Ocular: 5:1K.

1 Stratum corneum, smooth type
2 Papilla-occulta-formation
3 Lamina propria mucosae
4 Central venule
5 Lamina epithelialis

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short papillae, which are more dense on its left half. The accessory caudal pillar gives off at its ends the ventral right and ventral left coronary pillars which fail to complete the circle. Only in rumen Nr. XI this is practically complete (interrupted still on a small part toward the left).

The left and right dorsal coronary pillars are given off by the proper caudal pillar. In general the left one is longer (rumen Nr. I, II, VI, VII, XI) than the right one. They never complete a circle.

Quantitatively the pillar area comprises 7,94 % of the total ruminal mucosa.

4.2 Results of the histological studies (Fig. 8 - 18)

4.2.1 Group 1: Buffalo-calves fed by milk-rations (Fig.: 8, 9, 10, 11)

The ruminal papillae consist of a Lamina epithelialis and a Lamina propria mucosae.

Lamina epithelialis: It is made up of a cornified stratified squamous epithelium, which consists of the following three strata:

1. Stratum corneum: It is composed of 2 - 5 cell layers, from which the most upper one is of the smooth type. The outer 1 - 2 cell layers are mostly detached (Stratum disjunctum).

The Stratum corneum has a light reddish or yello-

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Fig. 9 Transverse section through a ruminal papilla of the ventral wall of the ventral caudal blind sac.
Buffalo-calf Nr. III, 1st group
H & E-stain. Objective: 20; Ocular: 5:1K

1 Individual granulosar cells in the Stratum corneum
2 Stratum germinativum with clear intercellular spaces
3 Central venule
4 Capillaries

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wish red respectively a dark reddish colour (rumen IX). The upper 1 - 2 cell layers are somewhat darker in coloration. The cells are squamous and contain still pyknotic, elongated and flattened nuclei. The mean thickness is about 17 µm.

A hyperkeratosis of this Stratum corneum is found on the floor of the ventral ruminal sac of the rumen X.

2. Stratum granulosum: It follows proximally to the Stratum corneum and contains one cell layer which is in some cases difficult to differentiate from the proximally following Stratum germinativum, but it is relatively easy possible in rumen IX and X.

It lies immediately under the Stratum corneum, sometimes it is characterized by individual cells embedded in the Stratum corneum as in rumen III, one or two squamous cells beneath it.

The cells are larger than the Stratum-corneum-cells and have a oval shape. They are somewhat flattened and have a lighter not stained cytoplasm. The cell nuclei are elongated and flattened, sometimes also crescentic in shape. They are surrounded by an irregular envelope, located centrally or pushed peripherally and are of a dark basophilic colour. The nuclei are surrounded by very fine basophilic stained granules and measure about 5 µm in diameter.

3. Stratum germinativum: Stratum spinosum and Stratum basale are considered as one Stratum germi-

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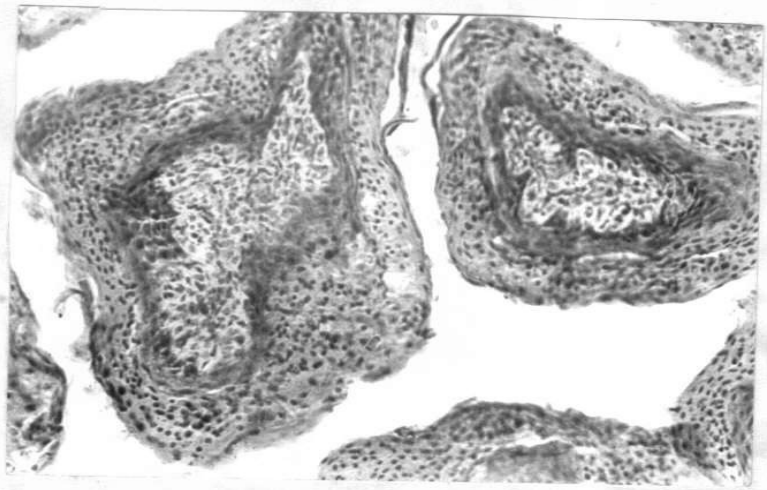

Fig. 10 Transverse section through ruminal papillae of the mid-region of the ventral ruminal sac showing parakeratosis

Buffalo Nr. X. 1st group

H & E-stain. Objective: 10; Ocular: 5:1K

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nativum. It is difficult to be separated light-microscopically and is formed by several layers of large, rounded or polyhedral cells with a large spherical or sometimes oval nucleus.
The deepest cell layer consists of smaller cells with correspondingly smaller and darker basophilic stained nuclei. Both are smaller than the upper ones. It may occur that some cell nuclei are surrounded by an unstained zone. They are more often to observe in the cells of the papillary tip-region.
The Stratum germinativum contains a type of cells which is vacuolated and contains flattened or crescentic nuclei, and which are pushed to the periphery. This type of cells is less numerous in the rumen III than in rumen IX and rumen X.
In both latter ones they are relatively numerous only in the papillary tip region.
Furthermore in this stratum some lymphocytic infiltrations are present. Intercellular spaces are clearly visible.
The Stratum germinativum measures about 10 µm in thickness.

Lamina propria mucosae: It is formed from relatively densely arranged connective tissue, heavily infiltrated with connective tissue cells and lymphocytes which form aggregations in the form of solitary lymphnodes in the rumen IX. It sends its papillary bodies peripherally into the epithelium. They are less branched than in the rumens of the adult

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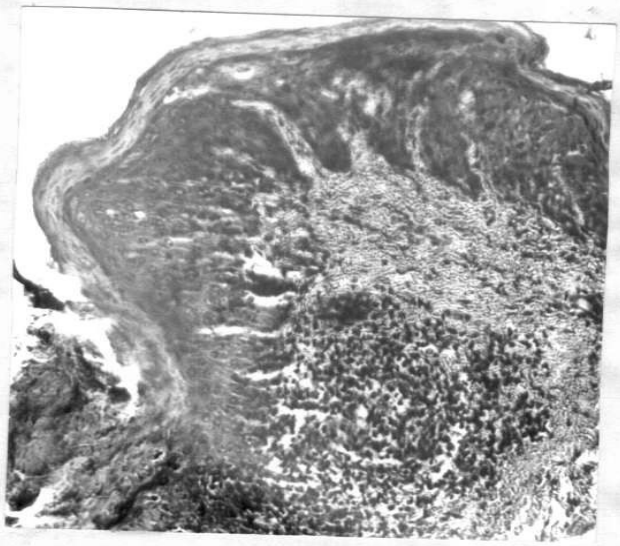

Fig. 11 Longitudinal section through a ruminal papilla in the caudal ventral blind sac showing a lymphocytic aggregation in the Lamina propria mucosae

Buffalo Nr. IX. 1st group

H & E-stain. Objective: 10; Ocular: 5:1K

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buffaloes. The Lamina propria mucosae is less denser in the center of the papillae than in the peripheral parts. In the middle of the Lamina propria 1 - 2 venules are found which are surrounded by many of capillaries. It is thicker than the Lamina epithelialis. The ratio between the thickness of the Lamina propria mucosae and the Lamina epithelialis ranges from 1,5 : 1 to 4 : 1.

4.2.2 Group 2: Adult buffaloes fed by berseem and tibn (Fig. 12, 13, 14)

Lamina epithelialis: It is characterized by a three-layered cornified stratified squamous epithelium.

1. Stratum corneum: It consists of 1 - 4 cell layers in thickness. The cells are squamous and contain elongated, flattened and pyknotic nuclei. The colour of the corneum layer is yellowish red or dark reddish. The Stratum corneum is of the smooth type, despite of the fact that the outer cell layer is mostly detached and giving the surface a serrated appearance.
Its thickness measures about 15 µm.

2. Stratum granulosum: It is following immediately under the Stratum corneum and is formed from 1 - 2 cell layers in thickness. The granulosar cells are large and ellipsoidal in shape, having large nuclei. The lightly or not stained cytoplasm

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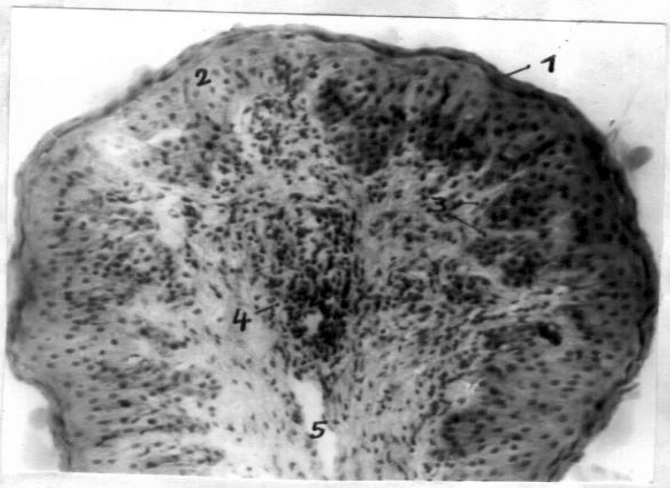

Fig. 12 Longitudinal section through a ruminal papilla. Ventral wall of the ventral ruminal sac. Adult buffalo Nr. V. 2nd group
H & E-stain. Objective: 10; Ocular: 5:1K

1 Stratum corneum of the smooth type. Cell nuclei are distinctly visible
2 Stratum germinativum
3 Papilla-occulta-formation
4 Lymphocytic infiltration
5 Central venule in the Lamina propria mucosae

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contains granules of the same basophilic colour as the nucleus. Sometimes the latter ones are somewhat darker and the large oval flattened cells contain large pyknotic nuclei and unclear granules. The diameter of the cells is about 10 µm.

3. Stratum germinativum: The Stratum germinativum is formed from several layers of polyhedral cells which have large spherical nuclei and fairly clear intercellular spaces. The cells may be somewhat flattened or compressed with correspondingly oval nuclei.
The nuclei of the upper cell layers are larger and lighter in its basophilic colour and contain two clear nucleoli, while the most deeper ones are smaller and darker. The vacuolated cells with peripherally pushed nuclei are less numerous.
The thickness of the Stratum germinativum measures about 70 µm.

Lamina propria mucosae: It is formed from relatively densely arranged connective tissue, which is richely infiltrated with lymphocytes, especially in the rumen V. It sends its papillary bodies peripherally into the Lamina epithelialis. They are more numerous than in calves and very well developed. The large ones contain clear peripheral venules in many of them, especially in the rumen VIII.
The Lamina propria mucosae may be of the same

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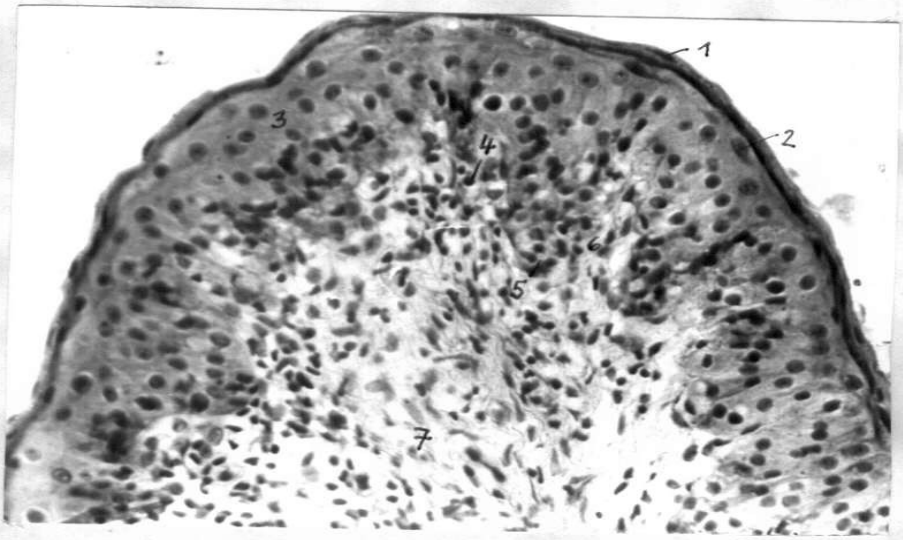

Fig. 13 Longitudinal section through a ruminal papilla of the ventral wall in the ventral ruminal sac of the adult buffalo
Nr. IV. 2nd group
H & E-stain. Objective: 20; Ocular: 5:1K

1 Stratum corneum with flattened nucleus. Smooth type
2 Stratum granulosum
3 Stratum germinativum. Nucleoli clearly visible
4 Lymphocytes
5 Epithelial plug
6 Papilla occulta
7 Lamina propria mucosae

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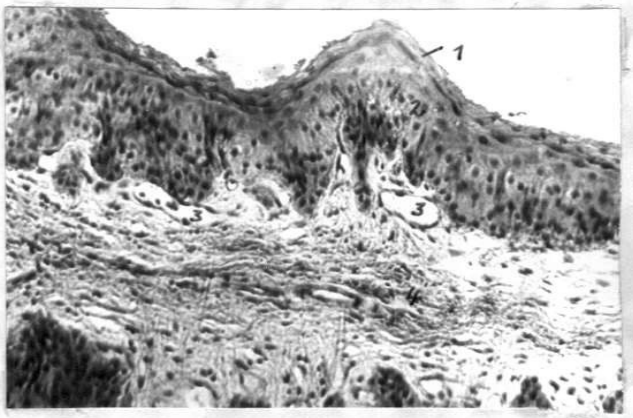

Fig. 14 Longitudinal section through a ruminal papilla in the ventral ruminal sac showing large venules in the Papillae occultae. Buffalo Nr. VIII. 2nd group
H & E-stain. Objective: 10; Ocular: 5:1K

1 Stratum corneum of smooth type
2 Stratum germinativum
3 Large venules in the Papillae occultae
4 Lamina propria mucosae denser in the center

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thickness as the Lamina epithelialis or less. The ratio between both may range between 3 : 1 and 1 : 3 (Lamina epithelialis : Lamina propria mucosae).

4.2.3 Group 3: Adult buffaloes fed by russian and tibn (Fig. 15 - 18)

Lamina epithelialis: The Lamina epithelialis consists of a cornified stratified squamous epithelium composed of three strata.

1. Stratum corneum: It may appear as consisting of 2 layers (rumen II, VI, XI). The most upper one is characterized by 1 - 4 layers of keratin and of a yellowish-brown (rumen II and XI) or brownish-yellow colour as in rumen VI. The nuclei may be present. The type of the cornified stratified squamous epithelium is either smooth or detached (Stratum disjunctum). Exceptionally it may be also of a serrated type or totally missing in some parts. The second layer is formed from 2 - 4 squamous cell layers with cells containing flattened, elongated and somewhat pyknotic nuclei and a dark cytoplasm.
If the Stratum corneum appears only one-layered (rumen I and VII) then this one may contain 2 - 6 cell layers of a somewhat homogenous reddish coloration, from which the most outer 1 or 2 cell layers are of a more yellow colour (Stratum dis-

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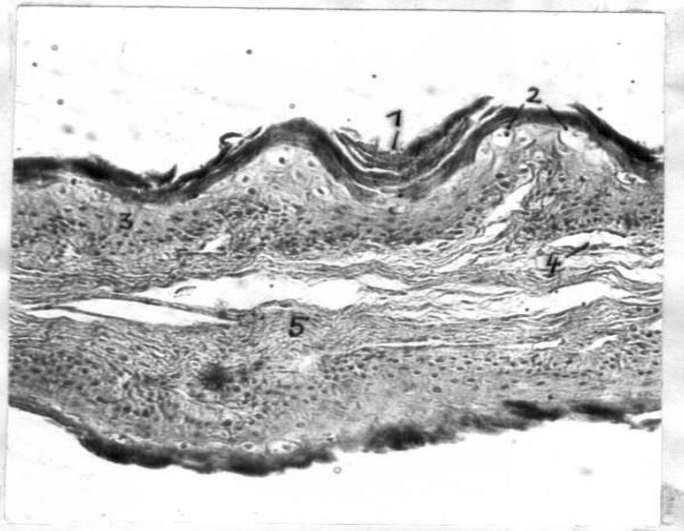

Fig. 15 Longitudinal section through a ruminal papilla. Atrium ruminis. Rumen of buffalo Nr. II. 3rd group
H & E-stain. Objective: 10; Ocular: 5:1K

1 Hyperkeratotic, disjunctive masses of the Stratum corneum
2 Large Stratum-granulosum-cells
3 Stratum germinativum
4 Venule
5 Lamina propria mucosae

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junctum).
The thickness of the Stratum corneum varies from 10 - 37 µm.

2. Stratum granulosum: It is following immediately under the Stratum corneum and is formed from 1 - 2 cell layers. The cells are large, oval, somewhat flattened or ellipsoidal in shape and contain an unstainable cytoplasm. The nuclei may be peripherally located and of rounded shape or somewhat flattened respectively crescentic. The cell nucleus is surrounded by small granules or particles having the same colour as the nucleus or appear somewhat darker basophilic than the latter one.
The granulosar cells may appear as being inbetween the Stratum-corneum-cells. This is the result of the most outer germinativ. cells which become flattened and elongated. They contain dark flattened nuclei (rumen VI). The thickness of the Stratum granulosum varies from 7,5 - 17 µm.

3. Stratum germinativum: The Stratum spinosum and Stratum basale form together the Stratum germinativum because it is difficult to separate both light microscopically. It is composed from several layers of large rounded or polygonal cells with large spherical nuclei which are more deeply stained in the deepest located cells. Somewhat larger are the cells of the outer layers and their nuclei are of a lighter staining. They may contain 1 - 2 clear nucleoli and 2 - 5 dark heterochromatin spots

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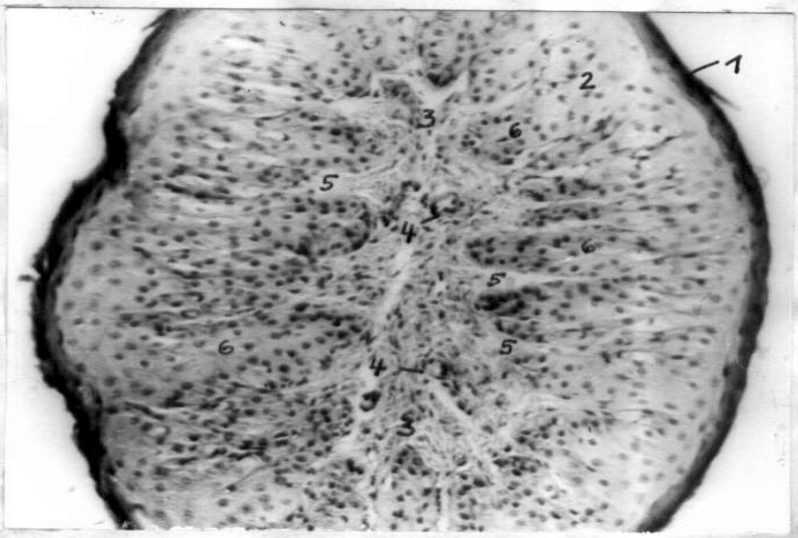

Fig. 16 Transverse section through a ruminal papilla. Dorsal caudal blind sac. Rumen of the adult buffalo Nr. II. 3rd group
H & E-stain. Objective: 10; Ocular: 5:1K

1 Stratum corneum. Smooth type
2 Stratum germinativum
3 Loosely arranged Lamina propria mucosae
4 Capillaries
5 Papilla-occulta-formation
6 Epithelial plugs

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(rumen VI). Lymphocytic infiltrations (as in rumen XI and VII) reach the Stratum germinativum. Somewhat clear intercellular spaces occur in rumen VII. In some cells the nucleus is surrounded by an unstainable zone and in other ones peripherally pushed having a crescentic shape. These vacuolated cells are relatively numerous in rumen I.
The thickness of the Stratum germinativum varies from 30 - 100 µm.

Lamina propria mucosae: It is formed from relatively densely arranged connective tissue which may be somewhat less dens toward the papillary tip and the center of the papillae (rumen II, I and X). Vice versa it can be also denser in the center than in the periphery, except around the blood vessels (venules)(rumen VI and VII). It sends strandlike interdigitations (papillary bodies) into the Lamina epithelialis between its plugs to carry the vessels and nerves. In the middle part of the papillae 1 - 2 medium sized venules are found, surrounded by many capillaries.
Lymphocytic infiltrations occur which may be arranged as subepithelial lymphocytic aggregations as in the rumen VI.
The ratio between the Lamina epithelialis and Lamina propria mucosae may range between 3 : 2 and 1 : 3.

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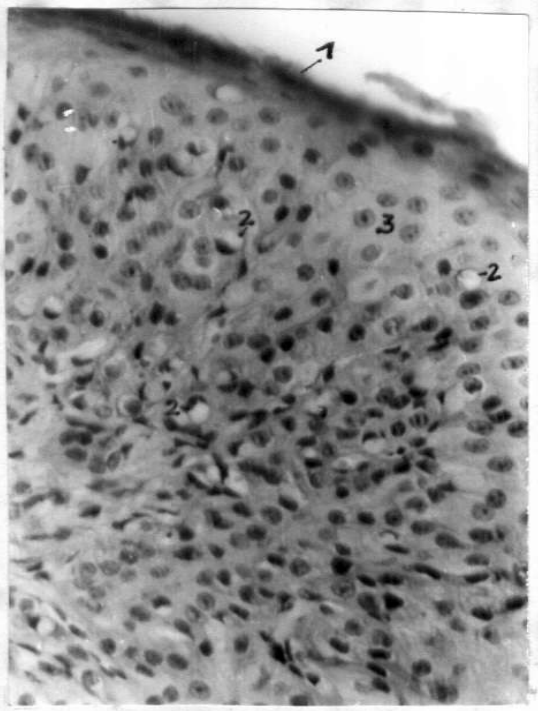

Fig. 17 Longitudinal section through the tip of a ruminal papilla. Dorsal caudal blind sac. Rumen of buffalo Nr. II. 3rd group
H & E-stain. Objective: 20; Ocular: 5:1K

1 Stratum corneum
2 Vacuolated cells
3 Stratum germinativum
1 - 3 nucleoli are clearly visible

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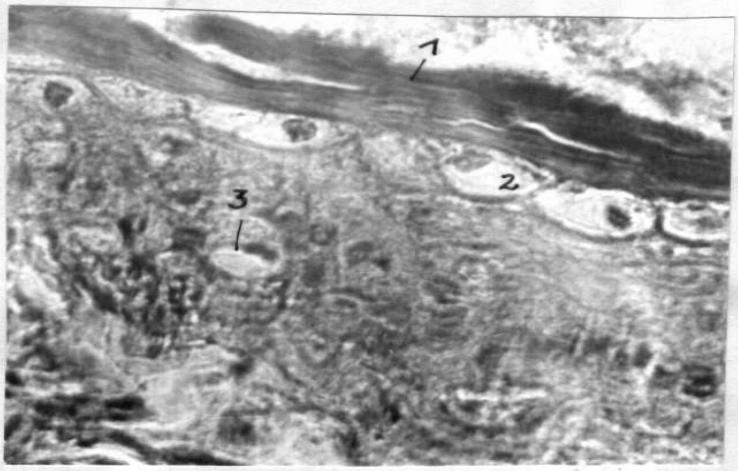

Fig. 18 Longitudinal section of the ruminal papilla. Atrium ruminis. Rumen of the adult buffalo Nr. II. 3rd group
H & E-stain. Objective: 40; Ocular: 5:1K

1 Stratum corneum. Smooth type
Partially disjuncted
2 Stratum-granulosum-cells
3 Vacuolated cell

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5. Discussion

Our studies resulted in a lot of important and very interesting facts which will be discussed now in regard to the buffalo species, to the different feeding regimes and to the comparison with ox and sheep.

Our investigations revealed a gross anatomical structure of the rumen of the buffalo (Beheira breed) as consisting of the Atrium ruminis, Saccus ventralis with Recessus ruminis and Saccus cecus caudoventralis and finally Saccus dorsalis with Insula ruminis and Saccus cecus caudodorsalis. This, of course, we expected and it is also in accordance with the description of the Indian buffalo by SENGAR et al. (1970) and of the ox in the classical textbooks by KOCH (1970) and by SISSON and GROSSMANN (1975). But somewhat creative and new are our findings on the ruminal pillar system of the buffalo even if SALEH and EL-GAAFARY (1976) have already mentioned the double caudal ruminal pillar (dorsal proper and ventral accessory one) in the Egyptian Water buffalo. It is astonishing for us that SENGAR et al. (1970) are mentioning nothing on this problem. The double caudal pillar in buffalo is considered by us as

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the more primitive stage in the development of the ruminal pillar system which later on becomes united to one pillar in the phylogenetically more advanced Pecora as the ox. This indicates also a different physiological pattern of contractions in both the caudodorsal and caudoventral blind sacs of buffalo in comparison to those of ox. On the contrary to the reports of KOCH (1970) and of SISSON and GROSSMANN (1975), we find the right accessory pillar ventral to the right longitudinal one and not dorsal. This finding is a confirmation of the description of the right accessory pillar position in ox by BERG (1973). Also, we don't agree with the description of the left longitudinal pillar by SENGAR et al. (1970) which - according to them - is connecting the cranial and caudal pillar. Exactly in not one case we observed this. As it is described in ox by SISSON and GROSSMANN (1975) also in the buffalo the left longitudinal pillar never reaches the caudal one on the left side. The distance between them measured 4 - 16 cm in the cases investigated by us.

The behaviour of the coronary pillars resembles to that in ox except the origin, i.e. the ventral ones forming roughly a complete circle, the dorsal ones on the contrary to this are not strongly developed.

Meanwhile in ox dorsal and ventral ones are originating from the uniform caudal pillar, in buffalo

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the dorsal coronary pillars originate from the proper caudal pillar, the ventral coronary ones from the accessory caudal pillar. The instable factor in the coronary pillars are the dorsal ones. They are differently developed, the left dorsal one generally being longer (group 1: the left dorsal coronary pillar is always longer; group 2: in two cases the left one is longer, in one case the right dorsal coronary one; group 3: all left dorsal coronary pillars are stronger developed). The explanation of this fact we find in the behaviour of the left longitudinal pillar. Because this never reaches the proper caudal pillar on its left end (distance 4 - 16 cm) it is compensated by a longer left coronary pillar. At the right side the right longitudinal pillar always reaches the caudal pillar proper, but the right accessory pillar never.

The quantitative development of the ruminal pillar system differs in ox and buffalo. In ox it is about 12 % (SCHNORR and VOLLMERHAUS 1967), in buffalo 7,58 % (group 1: 8,01 %; group 2: 6,72 %; in group 3: 8,01 %) of the total ruminal mucosal surface.

A different effect of the feeding regime on the qualitative and quantitative development of the ruminal pillar system in the individual groups was not recognizable. No statistically significant differences could be found.

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Within and between the groups the absolute, but not the relative size of the ruminal pillar area increases (group 1: 37 - 96 cm^2 or 5,75 - 10,39 %; group 2: 381 - 544,5 cm^2 or 7,43 - 5,83 %; group 3: 346 - 675 cm^2 or 5,72 - 10,47 %) with increasing age resp. with the increasing surface of the rumen.

The absorptive capacity of unpapillated areas of the ruminal mucosa is only one third of the papillated one. So the ruminal pillar area is to calculate in this regard.

According to SCHNORR and VOLLMERHAUS (1967) as also MICHEL (1978) the mucosal surface of the bovine rumen is covered in 80 - 85 % by papillae. Our studies in this regard can be considered as representative because samples of totally nine different sites of the rumen were taken.

Our results are somewhat similar to those of the abovementioned authors. In average 83,38 % of the total ruminal mucosal surface in buffalo of Beheira breed is papillated. The tendency is decreasing with increasing age (group 1: Ø = 91,98 %; group 2: Ø = 76,78 %; group 3: Ø = 81,37 %). Surely also the feeding regime is affecting the size of the papillated area of the rumen. Milk-fed buffalo calves have the largest papillated areas of the rumen, because no metabolic substances are accumulated in the rumen to this time as for example volatile fatty acids or parasitic infestations

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by paramphistomes occured causing a decrease of the ruminal papillary population. Later on when the feeding regime has shifted to berseem and tibn resp. russian and tibn, concentrations of volatile fatty acids (acetic acid, propionic acid and butyric acid) develop in such a degree which clearly diminishes the papillated area especially in the ventral ruminal sac (BERG et al. /1976a/, BERG et al. /1976b/, ABRAHAM et al. /1977/ and GLISZCZYNSKI et al. /1977/). This will be more distinct by a simultaneous parasitic infestation. It can be summarized that adult buffaloes on the base of the abovementioned factors have a diminished papillated ruminal area and comprises now only 77 - 81 %. Physiologically unpapillated areas in the rumen are the pillars because of their mechanical function (contraction) and the roof of the dorsal ruminal sac because of the site of the ruminal gas bubble. According to our findings in the buffalo-calves it can be concluded that here practically no unpapillated area - except the pillar area - occurs. This is explainable by the weak development of the rumen during this phase on the base of the milk-feeding. Later on, after finishing the milk feeding regime and starting the berseem and tibn resp. russian and tibn feeding pathological sites of unpapillated areas may occur in the mid-region of the ventral ruminal sac. These will be increased by unpapillated areas in the Atrium ruminis and

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caudal blind sacs by paramphistomes infestation. According to our experience the paramphistomes only found in areas with highest metabolic activities and not pathological concentrations of volatile fatty acids as in the Atrium ruminis and the caudal blind sacs, what is to conclude from the highest density of the ruminal papilla per cm^2 in these regions as also by the longest and broadest papillae here. Despite of the fact that this is only a side - effect of our studies it shall be stressed that the paramphistomes-infestation in adult buffaloes is a factor of diminishing the ruminal papillae and in this way of the absorption in the rumen and of the total performance of the buffalo which is to be calculated. Unpapillated areas of Beheira buffaloes in the Atrium ruminis and caudal blind sacs are typical for paramphistomes infestations, in the ventral ruminal sac typical for high concentrations of volatile fatty acids.

The unpapillated area of the rumen, which practically plays no role in the milk fed calves of group 1, measures in average 16,50 % of the total ruminal surface in group 2 and 10,69 % in group 3. The loss of absorptive capacity (unpapillated areas in the dorsal and ventral ruminal sac as also in the Atrium ruminis and the caudal blind sacs) in the rumens of the buffaloes of group 2 is in average 16755,13 cm^2, in those of group 3

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in average 9870,29 cm^2. The roughly double amount of lost surface in group 2 must be reduced to paramphistomes-infestation.

According to SCHNORR and VOLLMERHAUS (1967) totally 250000 papillae are covering the ruminal surface in ox. Our studies in the buffalo of Beheira revealed in average a totality of 309701 papillae in group 2 and of 302760 papillae in group 3 (counting of papillae in buffalo calves were on reason of the impossibility to exert this neglected). That means firstly a slightly higher number of papillae occurs in the rumens of the buffaloes in comparison to oxes and practically the same total number occurs in both groups with a different feeding regime. From this is to conclude that the applied feeding regimes as also the age of the buffaloes are practically not decisively affecting the total number of ruminal papillae between these groups.

The absorptive capacity of a rumen depends in a high degree on the density of the papillae and their length and breadth. These three parameters are different in the individual ruminal compartments and between the studied buffalo groups. The first group, including the milk-fed calves, was neglected in estimating the abovementioned datas but despite of this it is visible that the ruminal papillae are longest in the Atrium ruminis.

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In group 2 and group 3 the greatest density (number of ruminal papillae per cm^2) of papillae is found in the ventral ruminal sac, especially in its left and right wall. The density in the buffaloes rumen is subjected to considerable variations. The following values were found:

1. Ventral ruminal sac 69,9 papillae per cm^2
   (left wall of ventral ruminal sac, 73,6 -"- -"- -"-
   right wall of ventral ruminal sac, 83,6 -"- -"- -"-
   ventral wall of ventral ruminal sac) 52,4 -"- -"- -"-

2. Ventral caudal blind sac 68,9 papillae per cm^2
   (dorsal wall of the ventral caudal blind sac, 77,8 -"- -"- -"-
   ventral wall of the ventral caudal blind sac) 60,0 -"- -"- -"-

3. Dorsal caudal blind sac 67,1 papillae per cm^2

4. Atrium ruminis 61,8 papillae per cm^2

5. Ruminal islet 53,8 papillae per cm^2

The relative low number of papillae per cm^2 in the ventral wall of the ventral ruminal sac and the ventral wall of the ventral caudal blind sac is to consider in close association to the diminishing of the papillae by high concentrations of volatile fatty acids resp. of paramphistomes infestations here.

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The density and the length of the ruminal papillae have a reciprocal relation, i.e. the longer the papillae the less their density.
Within the groups a decrease of the number of the ruminal papillae with increasing age is clearly visible (f.e. from 117 to 36 papillae per cm^2 in the Atrium ruminis of group 2 or from 54 to 25 papillae per cm^2 in the Atrium ruminis of group 3). This is to explain by the extension of the ruminal mucosal surface because of growth and in the same time by the maintenance of the number of papillae.
If we compare the density of ruminal papillae between the individual groups than it can be concluded an influence of the feeding regime at least as far as the ventral wall of the ventral ruminal sac is concerned.
SCHNORR and VOLLMERHAUS (1967) report the density of papillae in the ox as being 10 - 60 per cm^2 (maximally 121 papillae), meanwhile in buffalo we found 52,4 - 83,6 papillae per cm^2. Astonishing low values are given by SENGAR et al. (1970) for the density of papillae in adult Indian buffaloes. They found in the Atrium ruminis 21,11, Recessus ruminis 21,92, mid-region of the ventral ruminal sac 26,80, ventral caudal blind sac 24,76, and in the dorsal caudal blind sac 24,20 per cm^2 ruminal mucosa. Our values are double resp. four times of those in the Indian buffalo. From this

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it can be concluded a much higher absorptive capacity of the rumen and a higher performance in the buffalo of Beheira breed. Our results in the buffalo of Beheira breed are more adapted to those of the European cattle.

Contradictious is also the result on the density of the ruminal papillae in the ventral ruminal sac of the Indian buffalo. SENGAR et al. (1970) are describing that the mid-region of the ventral ruminal sac has the largest number of papillae per cm^2 (26,80 papillae per cm^2) of all compartments. In the buffaloes of Beheira breed on the contrary to this the ventral ruminal sac has in its mid-region the least number of papillae per cm^2 in comparison to the other ruminal compartments (52,4), but this is still absolutely double as much as that in the Indian buffalo. Because the ruminal papillae are very plastic structures these differences can be explained by differences in the species, feeding system and hygienic conditions.

The sheep has in comparison to ox and buffalo a higher density of its ruminal papillae. According to ABRAHAM et al. (1977) in sheep 93,5 papillae per cm^2 in the Atrium ruminis were found (=Beheira breed of buffalo: 61,8, Indian buffalo 21,11 ruminal papillae per cm^2). This already indicates that the absorptive processes in the rumen are very active. But the total absorptive capacity is

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profoundly affected by the length and breadth of the papillae.

The length and breadth of the ruminal papillae vary from animal to animal; the length ranges in the investigated buffaloes from 4,5 mm (14 months of age) to 12,34 mm (42 months of age), the breadth from 1,5 mm (buffalo 14 months of age) till 2,8 mm (42 months of age). In ox it is much lower, the length is about 3 - 6 mm (SCHNORR and VOLLMERHAUS 1967) resp. 6,8 - 14,2 mm in the Atrium ruminis or 5,7 - 6,5 mm (length) resp. 5,7 - 6,5 mm in the Recessus ruminis /ABRAHAM et al. 1977/. The length of the papillae in the Atrium ruminis of the sheep ranges between 2,5 - 7,0 mm (ABRAHAM et al. 1977). GLISZCZYNSKI et al. (1977) report the length of the papillae of the Atrium ruminis of ox as being 8,00 - 9,48 mm, and 4,48 - 8,96 mm in the Recessus ruminis.

From this elucidates that the buffaloes have among the above mentioned ruminants the longest ruminal papillae. Positively correlated with the length is the breadth of them, i.e. the longer the papillae the broader they are. The papillary length increases with age and body weight. Furthermore it was observed that length and breadth of the ruminal papillae are in a reciprocal relation to the density of the papillae per cm^2 (buffalo Nr. II: Ø = 93,13 papillae per cm^2 and Ø = 4,5 mm x 1,6 mm /length x breadth/; in comparison buffalo

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Nr. VIII: Ø = 27,9 papillae per cm^2 and Ø = 12,34 x 2,8 /length x breadth/). In the literature we did not find datas on this phenomenon.

Comparison of the length of the ruminal papillae between both groups of buffaloes

	Group 2	Group 3
Atrium ruminis	15,52 mm	12,12 mm
Ventral ruminal sac		
left wall	8,70 mm	7,79 mm
right wall	6,44 mm	5,56 mm
ventral wall	4,32 mm	3,83 mm
Dorsal ruminal sac	4,09 mm	5,11 mm
Dorsal caudal blind sac	9,80 mm	10,24 mm
Ventral caudal blind sac	10,65 mm	8,58 mm

This comparison gives evidence that the longest papillae are found in the Atrium ruminis followed by both caudal blind sacs. From the principle that structure and function are an unit follows that these mentioned ruminal compartments are the most active ones in absorption. From this reason also the parasitic infestations by paramphistomes takes place especially in the Atrium ruminis and the caudal blind sacs.
Except in the dorsal ruminal sac, in group 3 (russian and tibn) the papillae are shorter in the individual compartments than in group 2 (berseem). May be that this is caused by the different applied diets. Furthermore also the ruminal

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surface in the buffaloes of the third group is smaller (Ø = 5599,5 cm^2) than that in the buffaloes of the second group (Ø = 7190,3 cm^2).
The mean size of the ruminal surface in adult buffalo measures 0,64 m^2 in comparison to 0,9 m^2 in european cattle (SCHNORR and VOLLMERHAUS /1967/) resp. 0,82 m^2 in european cattle also (GLISZCZYNSKI et al. /1977/).
The same trend becomes visible if one compares the total number of ruminal papillae. This is 309701,6 papillae in the rumens of the group 2 and 302760,6 papillae in rumens of group 3. The value is about 250000 for the european cattle (SCHNORR and VOLLMERHAUS 1967) resp. 228146 papillae in european cattle also GLISZCZYNSKI et al. (1977). Consequently the total papillary surface is larger in the buffaloes of the group 2 (Ø = 99595,26 cm^2) than in those of group 3 (Ø = 79174,86 cm^2). The magnification factor for the ruminal surface by the papillae in buffalo is 13,75 times (group 2: 13,70 times; group 3: 13,80 times) on the contrary to ox where it shall be only 7 (SCHNORR and VOLLMERHAUS /1967/) resp. 15,42 (GLISZCZYNSKI et al. /1977/). It supposes to us as the value by GLISZCZYNSKI et al. /1977/ is more realistic than that by SCHNORR and VOLLMERHAUS (1967).

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The histological studies resulted in the finding of a colour in the Stratum corneum, which depends on the colour of the food, i.e. lighter in the second group (berseem) than in the third one (russian and tibn).
In all buffaloes the type of the Stratum corneum is of the smooth one. This proves firstly a normal turnover of the cells in the Stratum corneum, but secondly also the disadvantage of the increased possibility of sticking together and not being disjuncted as seen in the 3rd group.
As hyperkeratosis we define the presence of an increased number of layers with excessive keratine formation in the Stratum corneum without being disjuncted or disjuncted in scales. First symptoms of this we have seen in buffaloes of the group of russian and tibn feeding (fig. 15). They may be the results of higher concentrations of volatile fatty acids in the rumen of these animals.
On the contrary to this we found in the calves first symptoms of parakeratosis in the ruminal papillae (fig. 10), i.e. an increase of the layers in the Stratum corneum with cells having not lost their nuclei as in case of hyperkeratosis and without keratine. Also the physical characteristics of the food affects the development of parakeratosis respectively hyperkeratosis (milk in calves and roughage in adult buffaloes).

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Our histological studies gave evidence for the occurrence of the vacuolated or branched cells (fig. 17) also in the buffalo.
According to STEVEN and MARSHALL (1972) they are a normal component of the epithelium of the forestomach and certain other ruminants. It seems to them probable that branching cells are derived from the leucocytes of circulating blood and are active in a defensive manner. In normal circumstances the cells of the Stratum corneum appear to act as a bacterial filter (HENRIKSON /1970/, STEVEN and MARSHALL /1970/), but minor defects in the absorption barrier of the Stratum granulosum could well allow small quantities of antigenic material to pass into the intercellular spaces of the deeper epithelial layers (fig. 9). Branched cells are thus ideally placed to intercept such material and to prevent its wider dissemination into the subepithelial space.
Thus the stratified squamous epithelium of the rumen of the buffalo resembles to a high degree to that one of the ox.
The Lamina propria mucosae is the vital part of the ruminal papilla facilitating the vessels and nerves to reach the stratified squamous epithelium. It is relatively densely arranged with numerous blood vessels. The pattern of arrangement of the blood vessels similars to that of the

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ox described by KOZLOV (1965) (fig. 8).
One or two large venules are found in the center, surrounded by several capillaries. But they may also occur in the Papillae occultae themselves respectively at their bases (fig. 14) thus facilitating the drainage of metabolites diffusing into them from the epithelial basal surface, which is increased by the Papilla-occulta- and epithelial-plug-formation. The ratio between the thickness of the Lamina propria mucosae and that of the Lamina epithelialis in buffalo calves (1,5 : 1 - 4 : 1) is different from that of the adult buffaloes (3 : 1; 1 : 3; 2 : 3). This is based on the decrease of the number of cell layers of the stratified squamous epithelium immediately after birth (ARIAS et al. /1978/).
The lymphocytic infiltrations in the Lamina propria mucosae are found in all three groups, but they seem to us associated to physiological as also pathological conditions (fig. 11 and 12). The latter ones we detected in cases of beginning of a para- and hyperkeratosis in buffaloes of the group 1 and group 3. Here the lymphocytes are arranged in lymph nodules in the Lamina propria mucosae.
But clear effects of the diets we could not detect in the structure of the Lamina propria mucosae of the buffaloes in the different groups and also

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not in the ratio between the thickness of the Lamina propria mucosae and the Lamina epithelialis.

Compared with the histological structure of the ruminal papillae in ox we find the principally same structure in buffalo.

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6. Conclusions

1. The rumen of the buffalo has the same compartments as in ox, and is studded with papillae in an area of 83,38 % of the total ruminal mucosa. It is largest in the first group (91,98 %) because no greater concentrations of volatile fatty acids occur in the rumen to this time.

2. The unpapillated area measures about 16,56 % in the 2nd group and 10,69 % in the 3rd group. In the 1st group this area plays no role because practically only the pillars are unpapillated. The double lost surface in the 2nd group is caused by the paramphistomes-infestation.

3. The ruminal pillar system of the buffalo offers peculiarities in comparison to that of the ox (double caudal pillar, right accessory pillar ventral to the right longitudinal one, the left longitudinal pillar does not reach the caudal piller). This means also a different contraction pattern of the rumen in buffalo.

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4. The size of the pillar's area in buffalo (7,58 %) is smaller than in ox (12 %). That means the loss in the papillated surface area by the pillars is less in buffalo than in cattle.

5. The total number of the ruminal papillae in the rumen of the buffalo is larger (306231) than in ox (250000).

6. The magnification factor for the ruminal surface by the papillae in buffalo is 13,75 times, in ox 7 - 15 times.

7. The ruminal surface in buffaloes of the 2nd group (Ø = 7190,3 cm^2) is larger than in the 3rd group (Ø = 5599,5 cm^2) and consequently the total papillary surface is larger in the buffaloes of the 2nd group (Ø = 99595,26 cm^2) than in the 3rd group (Ø = 79174,86 cm^2).

8. The density of the papillae in buffalo is 52,4 - 83,6 papillae per cm^2 (maximally 130 papillae per cm^2) and in ox 10 - 60 papillae per cm^2 (maximally 121 papillae per cm^2).
The least number of papillae is found in the mid-region of the ventral ruminal sac, followed by the Atrium ruminis, ventral caudal blind

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sac, dorsal caudal blind sac and the walls of the ventral ruminal sac.

9. The buffalo having among the other ruminants the longest and the broader papillae. They vary from 4,5 mm - 12,24 mm (maximally 5 cm) in length and from 1,5 - 2,8 mm (maximally 6,5 mm) in breadth. The longest papillae are found in the Atrium ruminis, followed by the caudal blind sacs, and the ventral ruminal sac.

10. The length and breadth of the papillae have a positive correlation and are in reciprocal relation to the density of the papillae per cm^2.

11. The length and breadth and also the density of the papillae in the Atrium ruminis and the caudal blind sacs indicate the high absorptive activity which are the attractive sites of paramphistomes-infestations.

12. From the beforementioned points it is indicated that the absorptive capacity of the rumen in the buffalo is higher than in the ox. Inbetween the studied groups of buffaloes it is higher in the berseem group than the russian group.

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13. The measurement of the length and breadth of the papillae in the rumen of the buffalo calves was neglected for its smaller size. But with changing of the feeding system from milk to russian or berseem they increased in size and the papillary density decreased with increasing of the ruminal mucosal surface.

14. The mucosa of the mid-region of the ventral ruminal sac is either unpapillated or studded with long, rod-like and widely scattered papillae. Apparently this is the result of the accumulation of the metabolic products as f.e. fatty acids.

15. The more distinct development of the Papillae occultae in the 2nd group and the presence of larger venules are indications for the more absorptive capacity of the rumen in this group.

16. The Lamina epithelialis is structured like in ox. The presence of the vacuolated or branching cells indicate that the Stratum germinativum has the same absorptive-barrier-function like in ox.

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17. The Lamina propria mucosae is somewhat dense like in ox having central venules and lymphocytic infiltrations under physiological conditions which turn to subepithelial lymphocytic aggregations in the form of lymph nodule under certain pathological conditions which may be explained by the presence of parakeratosis and hyperkeratosis where such aggregations are present.

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7. Summary

The studies on the morphology of the ruminal mucosa in buffalo in regard to the feeding regime have been carried out by the investigation of 11 rumens, classified into three groups.
The first group contains the rumens of calves fed by milk, the 2nd group contains the rumens of adult buffaloes fed by berseem, and the 3rd group contains the rumens of adult buffaloes fed by russian and tibn.
The rumen of the buffalo has a greater absorptive capacity than that in ox, and the rumens of the 2nd group again have a greater absorptive capacity than those of the 3rd one.
The rumen of the buffalo has same peculiarities of its pillar system which concern the double caudal pillar, which is separated by a papillated area, the presence of the right accessory pillar ventral to the right longitudinal one, and the not reaching of the left longitudinal pillar to the caudal one.
The longest papillae are in the Atrium ruminis from 4,5 - 12,24 mm (maximally 5 cm), followed by those of the caudal blind sacs and finally by those of the ventral ruminal sac. The length and breadth of the papillae are in a positive corre-

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lation, and both with the density of the papillae in a reciprocal relation.

The mid-region of the ventral ruminal sac has either an unpapillated area or widely scattered rod-like papillae.

The histological structure of the ruminal mucosa in buffalo is like that of the ox. The Lamina muscularis mucosae is absent. The Lamina epithelialis has three layers. The Stratum corneum is of the smooth type. It is followed by the Stratum granulosum and Stratum germinativum in which some vacuolated or branching cells with peripherally pushed nuclei are found. The Lamina propria mucosae is like in ox. It has well developed Papillae occultae which carry the vessels and nerves inbetween the epithelial plugs.

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ملخص عربي

لقد أجريت دراساتنا المورفولوجية للغشاء المبطن للحجرة الأولى من معدة الجاموس وعلاقاتها بنظام التغذية بفحص عدد احدى عشر كرش مقسمة الى ثلاث مجاميع :

المجموعة الأولى : تحتوى على عدد ٣ كرش أخذت من عجول جاموس تم تغذيتها باللبن .
المجموعة الثانية : تحتوى على عدد ٣ كرش أخذت من جاموس بالغ تم تغذيتها بالبرسيم .
المجموعة الثالثة : تحتوى على عدد ٥ كرش أخذت من جاموس بالغ تم تغذيتها بسليقه مركزه وتبن .

ولقد وجد من هذه الدراسات أن كرش الجاموس له قدرة امتصاصية أكثر منها فى البقر ووجد من البحث أيضا أن المجموعة الثانية لها قدرة امتصاص أكثر من مثيلتها فى المجموعة الثالثة ولقد وجد من البحث أن جهاز الدعامات فى كرش الجاموس له نظام خاص به يختلف عنه فى البقر .

وملخصه الآتى : ازدواج الدعامة الخلفية وفصل جزأيها العلوى والسفلى بمنطقة بها بروزات الكرش ، وجود الدعامة اليمنى المساعدة أسفل الدعامة اليمنى الطولية ، عدم وصول الدعامة اليسرى الطولية الى الدعامة الخلفية المستعرضة .

ووجد أن أطول بروزات (حلمات) الكرش يوجد فى مدخله وطولها من ٥ر٤ — ٢٤ر١٢ مم (بحد أقصى ٥ سم) ويليها الحقائب الخلفية العمياء ، وأخيرا حقيبة الكرش السفلى ووجد أن طول هذه البروزات فى علاقة طردية مع عرضها بينما طولها وعرضها فى علاقة عكسية مع كثافتها .

ووجدت المنطقة الوسطى من الحجرة السفلى للكرش أما أنها لاتحتوى على بروزات أو بها بروزات عصوية الشكل واسعة الانتشار .

ومن ناحية التركيب النسيجى للغشاء المبطن لكرش الجاموس وجد أنه مماثل لزميله فى البقر لايحتوى على الرقيقة العضلية للغشاء المبطن ووجد أن الغلاف الخلوى (الظهاره) مكونة من ثلاث طبقات . الطبقة القرنية ناعمة النوع ، طبقة الخلايا الحبيبية وطبقة الخلايا المولده ويهذه الطبقة أيضا خلايا بها فجوات ونواه طرفية .

والصفيحة الدعامية المستوية للغشاء المبطن كما هى فى البقر وبها أجسام حلميه حسنة النمو لتحمل الأوعية الدموية والأعصاب بين سديدات (بروزات) الظهاره .

المنارة للاستشارات
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