Part 02: Comparative Anatomy Of The Digestive System

I. Anatomy of the ruminant digestive tract And operating features

1- Basic reminders

- **Anatomical features of the ruminant TD**

– *Three pre-stomachs*: the rumen, a large vat, constantly filled with food representing 10-15% of the animal's weight. The disintegration of food is facilitated by the grinding it undergoes during rumination. A dense and complex microbial population is present there to digest almost all of the food ingested. Cap and foliar, when the particles are reduced to a sufficient size, they can pass through the narrow orifice which separates the cap and the foliar.

– *A stomach*: the abomasum, the only functional compartment in the newborn and remains so as long as the young consume only milk. After weaning, its digestive secretions attack food particles and microbial bodies.

- **The ruminant feeds on the fermentation products of the rumen**

Ruminal fermentations produce:

- gases (carbon dioxide and methane) which are released outside;
- volatile fatty acids (acetic acid, propionic acid and butyric acid) which are absorbed through the rumen wall and provide energy to the ruminant.

- **The ration should contain sufficient fiber to promote balance**

Contractions of the rumen cause the food to churn, induced by the presence of fiber in the food. This increases chewing time and leads to increased salivation, which buffers the pH of the rumen (neutralizing the acids produced by fermentation).

Fermentation → Salivation ↓
↓ Acidification Neutralization

The digestive system ensures digestion, that is to say the set of mechanical and secretory acts which contribute to transforming food into nutrients, that is to say into substances directly assimilated by the body.

In ruminants, the anatomical and physiological adaptations of the digestive tract are essentially linked to the importance of fermentative digestion (absence of*cellulase*In herbivores, the digestion of plant matter corresponds to anaerobic conversions carried out by symbiotic microorganisms.

2- Anatomy of the digestive tract of ruminants and operating characteristics

- The digestive system of each species is adapted to its diet.
- From an anatomical point of view, the digestive system of ruminants consists of the mouth, tongue, teeth, digestive pharynx, esophagus, stomachs, intestines, rectum and anus.
- The stomach of ruminants consists of 4 compartments: reticulum, rumen, folium and abomasum.
- These compartments are particularly suited to the digestion of foods rich in fiber, such as forages.
- The role of digestion is to extract nutrients from food to make them absorbable by the digestive tract and available for metabolism in animal cells. Digestion combines physical and chemical mechanisms.

The mouth and esophagus

- ***The mouth***is limited at the front by the lips which are mobile and play an important role in the grasping of food in horses, small ruminants and rabbits; in large ruminants, the lips are not very mobile, and it is the tongue which is used for grasping.
  - The soft palate is very developed in the horse, so that vomiting must always be nasal, when it occurs accidentally; for the same reason, the administration of medicines is done through the nose.
  - The dentition is adapted to the diet, and its formula per upper/lower half-jaw can be represented by the following table:

	Horse	Ox	Sheep and Goat	Dog	Rabbit
Incisors ……..	3/3	0/4	0/4	3/3	2/1
Canines ……..	1/1	0/0	0/0	1/4	0/0
Premolars ……..	4/3	3/3	3/3	3/3	3/2
Molars ……..	3/3	3/3	3/3	2/3	3/3

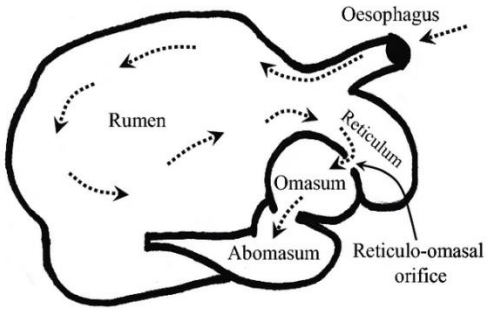
  - The mare does not have canines.
  - They have a thick, rough tongue that allows for optimal gripping of the grass that is pinched between the lower incisors and the gum line.

- ***The esophagus :*** The ruminant pharynx is a tube that narrows from the pharynx to the rumen (rumen). It transports food to the stomach.
  - Salivary glands are highly developed in herbivores, helping to impregnate the bolus.
  - It is located on the left, has two openings: a very narrow but very extensible inlet orifice, connected to the esophagus: the cardia and a very wide outlet orifice between the rumen and the network : *the neck of the belly.*

Sites of digestion and absorption

- The stomach constitutes the first reservoir of the digestive tract; its importance varies according to the species: very developed in ruminants (lthe largest of the forestomachs (approximately 100 liters in an adult bovine weighing 500 to 600 kg), on the contrary, it is of low capacity in the horse.
- Due to the motor function of this reservoir, the food undergoes a more or less intensive mechanical mixing action at this level and is mixed with an acid secretion: gastric juice.
- ***L'stomach*** ruminants are made up of several compartments and this arrangement has led them to be described as polygastric;
  - Extremely large, it can occupy between half and four-fifths of the abdominal cavity;
  - It comprises four compartments: the "rumen" or rumen, always the largest, the network (Reticulum), the omasum (Omasum) and the abomasum (Abomasum), the only secreting reservoir

- ***The Rumen*Or*Belly***



  - is a large reservoir (about 80% of the total mass of the stomach) is covered with flattened papillae (figure 4).
  - It is located on the left; it has two openings: a very narrow but very extensible entry orifice, connected to the esophagus (the cardia); a very wide exit orifice between the rumen and the network (the neck of the rumen or pylorus).
  - gutter shape which can, by contracting its edges, connect the esophagus to the leaflet: This is the esophageal gutter (13 cm long, 2 to 3 cm in diameter).
  - The rumen is a fermentation reservoir (content of more than 90 kg in a 600 kg cow).
  - Fermentation of fibrous particles is a slow process and they therefore remain in the rumen for 20 to 48 hours before passing into the omasum.

- Epithelium composed of papillae that allow the absorption of volatile fatty acids
- The papillae are keratinized but their epithelium is thin and the products of microbial digestion can diffuse through the epithelial barrier of the papilla, reaching the blood circulation;

- The papillae mainly have the role of absorbing volatile fatty acids but also, thanks to their rich vascularization, of maintaining constant ruminal temperature;
- The rumen has two openings, one, the cardia, corresponds to the end of the esophagus and forms a funnel-shaped orifice, the other is a large opening (18 cm high by 10 cm wide) which connects the rumen with the network and which is called the neck of the rumen.

- ***The Network* Or *reticulum* Or *cap***
  - It is the smallest of the gastric reservoirs (12l in cattle, 1l in sheep, 1 to 2.3l in goats) located near the diaphragm and the heart (2 to 4 cm);
  - its mucosa is non-secreting Andhas the appearance of a honeycomb (figure 5).
  - Inside the network is the esophageal groove, a half-canal connecting the cardia and the network-leaflet orifice and which appears to extend the esophagus to the leaflet. Under these conditions, swallowed food then passes directly from the esophagus to the leaflet and the abomasum, avoiding the first two reservoirs.
  - The network can be compared to a crossroads where the sorting of particles entering the rumen and those leaving it takes place.
  - The food processed in the rumen moves towards the reticulum which acts as a sieve or filter, meaning that the particles that are too large are stopped and the smaller ones continue on their way (particles must be less than 1 or 2 mm in size).Large particles are regurgitated and chewed again, thus, a new rumination

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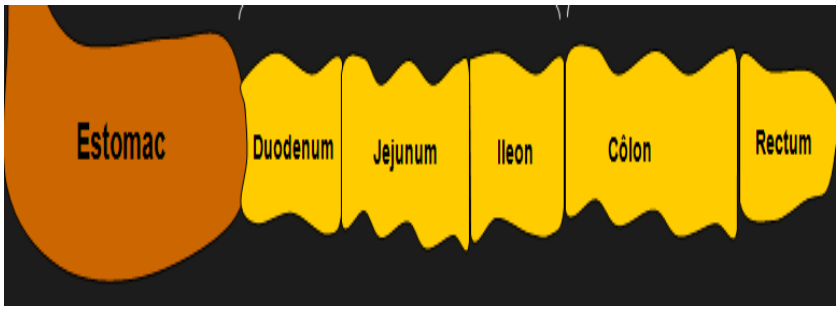
- ***The leaflet*: O*romasum***
  - follows the network, its cavity is partitioned by a series of mucous laminae (figure 6), thin and crescent-shaped;
  - more developed in cattle than small ruminants: 20l in cattle (goat 1.2l, sheep 0.2l) its non-secretory mucosa is formed of laminae arranged in series.
  - composed of parallel blades attached to the large curvature, very large absorption surface
  - The free edges of these blades are oriented towards the network-leaflet orifice. Thus, diluted food reaching the leaflet can easily engage between the blades of this reservoir.
  - This third stomach allows for further fermentation and retains water which then returns to the bloodstream and helps to replenish saliva.
  - Insufficiently divided coarse food will be stopped by the narrowness of the network-leaflet orifice.
  - with a capacity of approximately 10 liters. Despite its small size, this organ has a large absorption capacity. It allows the recycling of water and certain minerals (Na P, etc.)
  - The foliar membrane is a transitional organ between the rumen and the abomasum, which have very different modes of digestion.
- ***The abomasum:*O*rabomasum***
  - It has the shape of a pear stretched backwards, its diameter gradually decreasing as one approaches the beginning of the small intestine.
  - This stomach issimilar to that of non-ruminants. It secretes a strong acid and many digestive enzymes (In non-ruminants, ingested food arrives directly there and is digested):
    - Acid secretion and pepsinogen = protein digestion
    - Secretion of lysozyme which allows the degradation of bacterial walls = digestion of rumen bacteria

  - The products of ruminal fermentation which pass into the abomasum are therefore composed of residual food particles, certain by-products of bacterial fermentation, and a microbial mass (bacteria, protozoa).
  - The abomasum cavity is lined with a glandular mucosa, soft, spongy over its entire extent, presenting numerous folds and always covered with a layer of mucus.

- ***The small intestine***
  - It is very long 40/45 m 70 l cattle, 22 m 65 l horse and 20/28 m sheep goats
  - consists of 3 segments (duodenum, jejunum and ileum).
  - The duodenal loop, which constitutes the first part, receives biliary and pancreatic secretions.
  - The acidic chyme arriving in the duodenum is immediately neutralized by the digestive secretions of the pancreas (pancreatic juice) and the liver (bile).
  - The small intestine is the major site of food digestion and nutrient absorption (monosaccharides, amino acids, dipeptides, monoglycerides, fatty acids).
  - Its lumen is formed by valves which multiply its surface area by 3. The valves are themselves pleated by villi which multiply the surface area by a factor of 30. Finally, the villi have microvilli which multiply the absorption surface area by a factor of 600.



- ***The large intestine***
  - is the part that follows the small intestine. It begins with the ileocecal valve and ends at the anus. It includes: the cecum, the colon and the rectum.
  - A first part of the large intestine called the colon (measuring around ten meters), an irregularly dilated intestine, forming the major part of the large intestine.
  - A final, short, straight portion is called the rectum (intestinum rectum = right intestine) and immediately precedes the anus.
  - It does not produce enzymes, microbial digestion resumes
  - it ends with the rectum: 10 m 30 l cattle; 3 to 4 m 80 to 90 l horse; 4 to 8 m goat
  - for the horse, it constitutes its microbial stomach.

- ***The cecum and the colon***
  - The cecum is a cylindrical sac, 0.9 m 10 l in cattle, 1 m 30 to 35 l in horses and 20 to 35 cm in sheep and goats.

- For ruminants and especially horses, it constitutes a fermentation chamber degrading cellulose into assimilable carbohydrates.
- In horses, the cecum and colon represent 70% of the volume of the digestive tract: cecum (30 L), colon (100 L). It is at this level that microbial digestion will take place.
- More than half of the energy required by the horse will be absorbed at this level (50% of soluble sugars and 100% of cellulose arrive in the cecum). This is also the place where major exchanges for water balance take place.

Liquid feed for ruminants

- At birth, the calf's stomach differs from that of the adult only in the relative size of its different components since all the elements are present but differently developed.
- In the newborn, the abomasum is by far the predominant part since its capacity is more than double that of the ruminoreticulum.
- Since the rumen is not developed or functional, liquids pass directly from the esophagus to the abomasum via the esophageal groove (figure 8).
- Water can enter the rumen because it does not trigger this closure.

Preparatory acts for digestion

Preparatory acts for digestion include:

grasping, chewing, salivation, swallowing of food and its esophageal transit.

The grip

Ruminants have a unique set of teeth: they do not have incisors. This has consequences for gripping herbaceous vegetation.

In cattle, grass is grasped by the movements of a well-developed tongue. This grasping of the grass is not accompanied by cutting; it is swallowed after a cursory chewing.

Chewing

It is a reflex phenomenon triggered by the presence of food in the oral cavity. The role of chewing is to break up the food and ensure mixing with saliva.

Two types of chewing:

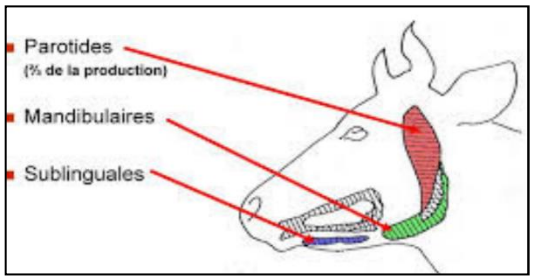
- light chewing when eating to facilitate swallowing;

- careful, nutritious chewing during rumination to facilitate microbial digestion.

Salivation

Salivary secretion is continuous but increases sharply during chewing.

Saliva is a true buffer solution (pH 8.2). Thanks to this power, the acids produced in the rumen are neutralized.



Swallowing

It is a process by which food prepared in the oral cavity is brought into the rumen thanks to the activity of the esophagus which manifests itself in the form of peristaltic contractions.

- *Jaw movements*are varied and provide two types of chewing:
  - a) The actual chewing is basic, the speed of the movements varies depending on the nature of the food (on average 90-95 movements per minute when the animal ingests grains, 70-80 for hay);
  - b) Merycic chewing which follows the regurgitation of the food bolus during the rumination phenomenon. This is a prolonged chewing ensuring grinding and extensive salivation of the food (approximately 55 movements per minute in cattle and 85-110 movements per minute in sheep);
  - The total number of chewing movements per day varies greatly. On average, a cow makes 4,700 movements per day when fed grain and silage, and 10,500 movements per day when fed hay. If we add the 30,000 movements required for squeezing, we see that a cow makes approximately 40,000 jaw movements per day.

- *The salivary glands*are very diversely developed in ruminants and the secretion is continuous; it increases considerably during normal chewing.
  - Saliva, containing bicarbonates and phosphates, has a buffering, food-imbibing, and lubricating role. Saliva production can reach 150 liters per day in a dairy cow (6 to 15 liters for sheep). It depends on chewing, which is itself linked to the fibrousness of the ration.
  - Saliva is actually a mixture from the conglomerated salivary glands: parotid (gland secreting half of the saliva), submaxillary (or mandibular) and sublingual.
  - Saliva is aqueous, alkaline, and contains a significant amount of bicarbonate phosphates. It provides the bases necessary to neutralize the acids resulting from the microbial digestion of cellulose in the gastric reservoirs.
  - The nature of the food in the rumen influences salivary secretion. The presence of coarse food in the rumen excites the cardia area and causes a salivation reflex.

Ingestion and rumination activities

- *Ingestive chewing*mixes the food with saliva and breaks it down to a level sufficient to form a bolus that can be swallowed. Soluble constituents are released and internal tissues are exposed, which will be exposed to invasion by rumen microbes.
- *Mericyc chewing*continues to grind the largest fragments during digestion to bring them to the size that allows it to pass through the reticulo-omasal orifice, namely less than 1-2 mm in sheep and 2-4 mm in cattle. It also damages the tissues and facilitates their degradation.
- The duration of ingestion varies with the quantity and quality of grass available, particularly during the grazing season.

Rumination and mericycal chewing

- For a given animal and ration, there are some 12 to 18 extremely regular daily rumination periods of mericyc cycles of practically constant duration.
- Each cycle begins with the regurgitation of a bolus of ruminose-reticular contents which will be chewed for around sixty jaw movements.
- Chewing frequency is constant throughout the cycle but would accelerate in the seconds before swallowing.
- The duration of the mericyc cycle tends to increase with the fibrosity and wall content of the fodder consumed alone and with the proportion of fodder in the ration; it is thus longer for the stems than for the leaves.
- The relationship between ingestion time and rumination time is very complex. Rumination time can vary in the same direction as rumination time (with grass age or when the amount of grass offered in pasture is restricted), in this case as a result of the decrease in the amount of dry matter ingested. Conversely, rumination time can decrease when the animal extends its ingestion time beyond normal values to maintain its intake.