Ruminant Nutrition

AS 1124

Outline

• Digestive Tract Anatomy
• Digestion of nutrients

Digestive Tract Anatomy

• Many organic components of feed are in the form of large insoluble molecules, hence has to be broken down

• Depending on the type of feed animals consume, they are classified as
  1- Carnivores – consume meat and meat like products
  2- Herbivores – depend on forages or plant material
  3- Omnivores - consume either plant material or animal product

• Anatomic structure of digestive system vary depending on the feeding habit
  • Carnivores have simple and short
  • Herbivores have most complicated and long
  • Omnivores have intermediated anatomical structure of the gut

• Digestive system include all organs involved directly or indirectly to the process of reception of feed or food particles, digestion of feed or food nutrients, absorption of digested nutrients & excretion or elimination of waste material.

• Depending up on this general definition two groups of organs belong to the digestive system.

1- Alimentary tract, or gastrointestinal tract (GIT), or gut or digestive tract: which is a tube that runs from the mouth to anus (mouth, esophagus, stomach, small and large intestines, and anus).
2- Accessory digestive organs: these organs involve in indirect manner to digestive process. E.g. liver, pancreas that produce enzymes to or have some help to facilitate the digestion process and are essential components of the digestive system.

Digestion
is a process whereby large insoluble feed particles are broken to simple, soluble and absorbable particles.

Absorption
is the passage of the digested nutrients though the mucous membrane into blood circulation or lymph.

Three forms digestion

1- Mechanical digestion: the mechanical activities are mastication and the muscular contraction of the gut. This involves mechanical or physical breakdown of feed particles to decrease particle size.

2- Chemical digestion: this refers to digestion brought about by enzymes secreted by the animal in the various digestive juices.

3- Microbial digestion: this is also enzymatic, but is brought about by the action of bacteria, protozoa and fungi. Microbes are of special significance in ruminant digestion. In monogastrics microbial activity occurs in the large intestine.

• Ruminants can convert fibrous food into meat, milk and fiber
• Do not compete with humans for food supply

Digestive Tract Anatomy

Mouth

• Food is mechanically broken down by chewing (mastication)
• Saliva starts the digestion process and lubricates the food (no carbohydrase in saliva).
• No incisors on the upper jaw
• ruminants chew very little initially but will rechew food later (regurgitate or ruminate)
The relative importance of the mouth and its component teeth, lips, tongue, cheeks, salivary glands, varies with species. The function include:

1- Prehension or bring in feed (lips more important in horses and tongue for cattle)
2- Mastication- mechanical digestion accomplished by teeth
3- Insalivation - mixing the feed with saliva

Mouth

- Ruminants are more efficient in grinding grasses and other forages although much of this occurs during rumination.
- This is due to special modification in that ruminants normally grind the feed by the type of lateral movement of the upper and lower jaw.
- Some ruminants such as cattle usually swallow small grain seeds with very little chewing, so their grain should be ground or cracked before feeding.

Different phases of rumination:
1- Small boluses are brought to the mouth called regurgitation. The content of the rumen are continually mixed by the rhythmic contraction of its wall, and material at the anterior end is drawn back into the esophagus & returned by a wave of contraction to the mouth.
2- Reswallowing liquids. The bolus regurgitated contain liquid and solid portion, liquid will be squeezed and reswallowed
3- Remastication and reinsalivation.
4- Reswallowing of bolus. This decrease feed physical size.

Function of saliva
1- Facilitate effective mastication and swallowing - softens the feed
2- Saliva contains 99% water, the remaining 1% consists of mucin (mucous materials), inorganic salts, enzyme, lysozymes. Ruminants saliva has lipase.
3- The enzyme lysozyme breaks the cell membrane of different species of bacteria - is important disinfectant
4. Buffering effect: help to neutralize fermentation acid – saliva is alkaline and is a source of bicarbonate phosphate buffer which buffer rumen action.

5. Saliva has antifrothing agent. Ruminants require fiber for proper digestion which has get pinching effect on the internal environment of reticulo rumen. When ruminants graze on young clover rich pasture or pasture rich in legumes, there will be high production of gases like CH4, CO2, H2 which may not be lost by eructation and the gas is trapped in the rumen in a foam which may result to bloat and death of the animal.

Mouth

Esophagus

- transports feed from the mouth to the rumen/reticulum.

Esophagus

Ruminant Stomach

- Four compartments
- Rumen
- Reticulum
- Omasum
- Abomasum.

In young ruminants (calves) the 1st two parts are undeveloped and milk reaching the stomach is channelled to omasum & mainly abomasum through a tube like fold of tissue called oesophageal groove or reticular groove. Because fermentation of milk in foregut is not essential.

When young animals start to eat solid food (fibrous feed) the 1st two compartments enlarge until in the adult they comprise 85% of the total capacity of the stomach.

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Rumen and Reticulum

- Located predominately on the left side.
- The largest proportion of the stomach called fermentation bags.
- Rumen and reticulum accounts for more than 50% of the total digestive tract. This large capacity is essential to allow feed retention to give enough time to break cellulose and other complex carbohydrates, done by microbial enzymes.

Rumen and Reticulum

- Rumen and reticulum are only separated by a fold in the wall and there is no specific orifice which joins the two organs together. However, there is a considerable difference in the appearance of the wall of the rumen and reticulum.
- The reticulo-rumen provides a continuous culture system for anaerobic bacteria, protozoa, and some fungi that produce enzymes that hydrolyse various nutrients.

Rumen and Reticulum

- Rumen contents contain 85-93% water on average, but they often exist in two phases. A lower liquid phase, in which fine feed particles are suspended and a drier upper layer of coarse solid material (floating fibrous food).

Rumen and Reticulum

- Bacteria and protozoa are responsible for fermentation in the reticulo-rumen.
  - Bacteria number $10^9-10^{10}$ per ml of rumen content
  - Protozoa number $10^6$ ml rumen
- Number of microbes is variable depending on diet type.
- High concentrate feed decreases number of protozoa due to low rumen pH (5.5 to 6.5 is an ideal pH for bacteria and protozoa)
- Proportion of bacterial species also change with diet type.

Rumen and Reticulum

- The waste products from the bacteria are called VFA's (volatile fatty acids: acetic, propionic and butyric acids), and these are absorbed through the rumen wall (villi) into the animal's bloodstream. These VFA's provide energy for the animal to live on and are the only nutrient absorbed through the rumen.
Rumen and Reticulum

- A by-product of microbial fermentation is methane gas.
- Methane is released by belching but if this process is impeded then bloat occurs.

Rumen and Reticulum

- 50 gallon capacity
  - bolus (cud) is formed by the reticulum
  - cud is forced up the esophagus and back into the mouth
  - cud is thoroughly chewed and reswallowed
  - rumen is pH neutral, so regurgitation is not bitter

Rumen and Reticulum

- Due to the honeycomb structure of the reticulum, foreign objects will lodge there. If these objects puncture the reticulum, then a situation called hardware disease occurs.

Rumen and Reticulum

- Calves, lambs and kids are functional nonruminants.
- Milk flows directly from the esophagus to the abomasum by means of an esophageal groove.
- Rumen fermentation is inefficient use of high-quality feed such as milk.

Rumen contains

- A lot of small infoldings to increase the internal surface area
- Small projections in internal side of rumen called rumen papillae
- Running from side to side across the rumen are a series of muscular pillars capable of contraction.
- The rhythmic movement of these pillars causes the whole rumen to contract and expand leading to a through mixing of its contents.

Reticulum

- Reticulum is most cranial compartment, honeycomb like
- Location is just behind the heart.
- Materials enter the rumen from oesophagus at the junction of rumen & reticulum. For this reason foreign bodies such as stone or nails accumulate in the reticulum & is in a very good position to penetrate into the heart.
- Materials passes freely between the rumen and reticulum, so they are often considered being parts of one large organ, termed the reticulo- rumen.
Omasum

- Digesta leaves the reticulo-rumen though a small passage called the reticulo-omasal orifice, and enters omasum which is about 6% of digestive tract in capacity.
- The omasum is located to right of rumen & reticulum just caudal to liver.

- Contains leaf-like structure or folding (manyplies) that increase the internal surface area.
- Water is absorbed from the digesta as it passes through the omasum. So the content of omasum is dry.
- Omasum contains short, blunt papillae which help in physical degradation as they are in constant motion.

Abomasum

- The omaso-abomasal orifice leads to abomasum from omasum, which is about 8% of gut capacity.
- The abomasum, often called the true stomach, secretes hydrochloric acid, which is a strong acid that begins chemical digestion and also kills bacteria.
- This is more or less equivalent in function to stomach of monogastric animals.
Small Intestine

• The small intestine is where most digestion occurs (by enzymes secreted into the small intestine) of everything except fiber. More importantly, the small intestine is where nutrients such as amino acids are absorbed into the bloodstream. Any nutrients that are not absorbed into the bloodstream are lost in the feces!

Small Intestines

• The microorganisms (bacteria and protozoa) that pass from the rumen and destroyed by the strong acids in the abomasum are digested in the small intestines.
• The digested microorganisms provide amino acids and energy

Cecum

• In the cecum, fiber can be fermented (digested) if it was not digested the first time in the rumen. That means ruminants have "two shots" at digesting fiber! Fiber digestion in the cecum is also by microbes; no animals can digest fiber unless microbes are there to do it for them.

Cecum

Large Intestine

• In the large intestine, some fermentation occurs. Mostly what happens is that water is absorbed back into the animal's body.
A lot of digestion take place in the ruminant stomach, as well as at different sites of the gut. To study these processes researchers do surgical modification or surgical opening at different sites of the gut.

Such studies will help to understand how digestion takes place, and to device means for more efficient digestion and better productivity.

1. Rumen fistulation

Make small hole or opening on the rumen and fix it with fistula. Make opening between the hip bone and lumbar vertebrae which you find rumen. This special point is called paralumbar fossa.

Open skin next rumen, join the side of the outer skin and the rumen and fix the outer skin to internal rumen. When fixed it is permanent opening to be used for study.
2. Oesophageal fistula

This is fistula on the oesophagus. Farm animals are selective eaters. We find many plant species on grazing land. To exactly know what type of plant species animal eat & their nutritive value, when animal grazes & swallows representative samples could be taken through oesophageal fistula.

3. Tracheal fistula

Fermentation in the reticulo-rumen produce different gases. To study the quantity of these gases, measure gas exhaled through nose and mouth. But the gases coming through mouth and nose are mixture from reticulo-rumen and lungs. To separate gases of the two origin, tracheal fistula is made, whereby the trachea leads to lungs and oesophagus to GIT. Gas from lungs goes through opening while gases from oesophagus goes through mouth and nose.

4. Abomasal and intestinal cannulas

Are tubes fitted to any part of gut. You may fit one point of cannula at the abomasum other at the duodenum or you may fit both points in the small intestine and can measure different things such as flow of digesta across the gut, how much nutrients digested, etc.

Digestion of carbohydrates in the reticulo-rumen (Fermentation of carbohydrates)

• This is important as ruminants depend upon diets rich in carbohydrates, thus carbohydrate degradation impact utilisation of feeds.
• Carbohydrates in diet of ruminants include cellulose, hemicellulose, starch & water soluble carbohydrates (fructans, pentosans, xylans)

Type of carbohydrates

• **Structural Carbohydrates**
  - Include cellulose, and hemicellulose
  - It is the support structure of the plant
• **Nonstructural Carbohydrates**
  - Composed primarily of sugar, starch, and pectin.

Digestion of carbohydrates in the rumen may be divided into two stages.

1. Digestion of complex carbohydrates into simple sugars

   Cellulose  Hemicellulose  Starch  Pectin

   Glucose
2. The simple sugars are metabolised by intracellular enzymes of micro-organisms.

Simple sugars $\rightarrow$ Pyruvate

- Under aerobic condition pyruvate oxidised to $\text{CO}_2$ and $\text{H}_2\text{O}$
- Under anaerobic environment of the rumen, pyruvate is oxidised to VFA.
- The main VFA are acetic, propionic and butyric acids, and gasses CO2 and methane.

**Volatile Fatty Acids (VFA’s)**

- Much VFA (>90%) is absorbed through rumen, reticular and omasal walls. Rest through lower gut
- Acetic acid is used as a source of energy and synthesis of fatty acids.
- Propionic acid is mainly changed into glucose in the liver may serve for energy and fatty acids synthesis.
- Butyrate also serves as source of energy and fatty acids synthesis.

**Digestion of protein in the reticulo-rumen**

- Rumen microbes synthesise protein from proteins, non protein nitrogen (NPN) such as urea, uric acid, etc.
- Monogastric animals could only utilise true protein

**Digestion of protein in the reticulo-rumen**

- Ammonia + small peptides + amino acids is utilised to synthesise microbial proteins.
- Microbes are carried through to the abomasum and small intestine, will be digested and absorbed as amino acids.
- Microbes synthesize essential and nonessential amino acids, thus the host not need dietary supplies of the former.

**Digestion of protein in the reticulo-rumen**

- Because of forgut fermentation, ruminants are provided with two major sources of proteins.
  1. The protein synthesised by the microbes (microbial protein)
  2. The UDP, which escapes microbial digestion in the rumen.
- Digestion of these two mixtures of microbial protein & UDP in the abomasum and small intestine supplies the amino acid for the host animal.