Ruminant digestion
for BVSc & AH 1st year

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VPB
Ruminants: 4 stomachs

Rumen:
- Largest (80%)
- Non-glandular
- Covered with papillae
- Content: coarse ingesta and fluid

Functions:
1) Reservoir
2) Site for cellulose digestion
3) Synthesis of vit B complex
4) Production of gases: CO₂, CH₄, H₂S
Reticulum:

- Smallest
- Epithelium: **honey comb** like structure: contents are liquid
- No digestive glands

**Functions:**

1) Reservoir: of swallowed saliva and liquid
2) Regulate passage of food particles from rumen to omasum after rumination (act as a strainer: pushes solid ingesta back to the rumen, liquid ingesta to omasum)

Rumen communicate with reticulum by **rumeno-reticular fold**
Omasum:

- Mem: numerous folds/laminae.
- Received the food directly from the esophagus after rumination

Functions:

- Grind the food particles
- Absorb water, Na, K & VFA

Abomasum: chemical & enzymatic digestion
Advantage/benefits of ruminant digestion:

**Synthesis of high quality protein in the form of microbial protein**: rich in essential aa, from low biological value plant protein & from dietary NPN & from recycled nitrogenous metabolic end product (urea through saliva).

**Synthesis of B vitamins**: Cu should be available for Vit \( B_{12} \).

**Allow utilization of too fibrous food**

**Can utilize cellulose, most abundant plant material**
Disadvantages:

Adequate feed needed

**Ruminants need complicated mechanism** to keep fermentation vat working efficiently

1) addition of large quantity of saliva
2) powerful mixing movement of the stomach
3) mech. Involved in eructation (elimination of gases), rumination (regurgitation of cud), absorption of end products and for onward passage of food to omasum.

4) Food particles leave the rumen- to -reticulum, when size decrease to < 2 mm, most commonly , < 2 mm in length

5) Only p. a. (VFA) is converted to glucose, so high reqmt of feed during lactation and pregnancy (last stages: fetal growth).
Ruminal Microbes:
Bacteria, protozoa and the fungi.

Bacteria are single cell plants (rumen flora).
Protozoa are single cell animals (rumen fauna) and fungi are the vegetative forms.
Protozoa feed on the bacteria and ingested feed.

locations in the rumen: Some microbes adhere tightly to the wall of the rumen, most microbes are associated with feed particles in the rumen or float freely in ruminal liquid.

• Most of the rumen microorganisms are strictly anaerobic, i.e., they live and grow without oxygen.
• Many of the isolated species of rumen microorganisms are sensitive to even small amounts of oxygen.
• But a small proportion of bacteria (facultative anaerobic bacteria) can tolerate small amounts of oxygen and can also use it in their metabolism.
**Rumen bacteria**

$5 \times 10^{10-11}$ / gram of rumen material.

200 species of bacteria with different digestive capabilities have been identified.

Rumen bacteria vary in size and shape:

- Anaerobic, gm +ve or gm –ve,
- Sporeforms, non-sporforms, motile, non-motile,
- Shape: rod, cocci, spirochetes
1) Primary bacteria are those that degrade the actual constituents of the diet and depending on their preference for cellulose or starch are termed **cellulolytic or amylolytic**.

2) Secondary bacteria are the end products of primary bacteria degradations as their substrates. This group includes – 1) lactate utilizing proportionate bacteria which produces some of the propionate and 2) hydrogen utilizing methanogenic bacteria. Although there is some specialization, many bacteria utilize multiple substrates.

Secondary bacteria prevent accumulation of lactic acid by converting it to propionate.
Some of the major groups:

Cellulolytic (digest cellulose)
Hemicellulolytic (digest hemi cellulose)
Amylolytic (digest starch)
Proteolytic (digest proteins)
Sugar utilizing (utilize monosaccharides and diasaccharides)
Acid utilizing (utilize such substrates as lactic, succinic and malic acids)
Ammonia producers
Vitamin synthesizers
Methane producers
• Different types of bacteria are:
  (according to their fermentative property)
1. Cellulolytic bacteria
2. Hemicellulose digesting bacteria
3. Amylolytic bacteria
4. Bacteria utilizing sugars
5. Acid utilizing bacteria
6. Bacteria utilizing protein
7. ,, „aa
8. ,, „methan
9. Lypolytic bacteria
Ruminant diets

Roughage

Cellulose etc.

Concentrates

Starch etc.

Cellulolytic bac (pH>6.2)

Cellulolytic bac (pH>6.2)

Methanogenic bac (>6.2)

Amylo. Bac (>5.5)

Propionate bac (>6.2)

VFA

CO₂

8H

8H

CO₂

VFA

Lactic acid

CH₄

CH₄

Propionate
• Fungi:
  Little important in fermentation.
Protozoa

• Anerobic
• Feed ruminal bacteria, plant, starch granules & PUFA, linoleic and linolenic acid
• Very sensible, presence: indicator of normality
## Difference between Holotrichs & Entodiniomorphs

<table>
<thead>
<tr>
<th>Holotrichs</th>
<th>Entodiniomorphs</th>
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</thead>
<tbody>
<tr>
<td>1. Entire body is covered with cilia</td>
<td>1. Cilia aggregated in a tuft or syncilia that do not cover much of the body surface</td>
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<tr>
<td>2. Depends on non-structural polysaccharides (starches, soluble sugar)</td>
<td>2. Engulf materials that are attacked by enzyme (enzyme attack cellulose and hemicellulose)</td>
</tr>
<tr>
<td>3. First established</td>
<td>3. Later established</td>
</tr>
<tr>
<td>4. Large size</td>
<td>4. Smaller</td>
</tr>
<tr>
<td>5. Survive for longer period</td>
<td>5. Shorter period</td>
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Role of micro-organism

1. It provides digestion of soluble and insoluble CHO into organic acid, which are readily absorbed—source of energy.

2. Both quality & quantity of dietary protein can be upgraded.

3. Microflora protect the gut from disease both by stimulation of immune system & direct competition with pathogenic micro-organism.
4. Toxic substances in the diet may be attacked by the microbes before they are presented for absorption in the SI.

5. Capable of Vit. B complex synthesis

6. They can digest mucus, bilirubin, GI enzymes, urea, protein and other nitrogenous compound & wide varieties of drugs.

7. They can produce organic acid, CO$_2$, H$_2$, NH$_3$ as well as toxic amines and phenols
- Rumen pH: 5.5 -7
- Diet affects pH: lower pH with concentrate diet
- 25% microbial protein is protozoal in origin.
- Protozoa accounts for ¼ to 1/3 of ruminal fiber digestion
- **Defaunated animals (protozoa free)**: less digestion of organic matter, degradation of dietary protein is less. Less rumen NH₄.
- Using CuSO₄,
- Isolation of young ruminants from faunated animals

- Increased Protozoa conc. --- important: if diet contain excess starch and sugar: protozoa incorporate these into **i/cellular reserve polysaccharide**. So, less lactic acid produced.
• Pathway of fermentation of dietary CHO: (page: 445, duke’s)

1. Hydrolysis of polysaccharides:
   - Starch
   - cellulose
   - fructosans
   - hemicellulose
   - Pectin

2. Anaerob oxidation
   - Glucose → fructose 1,6 bis PH₄
   - xylose

(Embden-Meyerhof pathway)

3. Form of VFA
   - Formate
   - Acetyl co A → pyruvate
   - lactate → oxalo-acetate
   - Aceto acetate
   - Beta-OH-butyrate
   - acrylate
   - succinate
   - CO₂
   - CH₄

4. 8H Acetoacetate CO₂
   - acetate (75%)
   - butyrate (15%)
   - propionate (10%)

Stage 4: microbial digestion : syn. Of new protein
• High starch rich concentrate diet (cereal grains, legume seeds): 70:25:5 (more VFA production with increased conc. of propionate)---low methane prod.

Absorption:
• Most VFAs are absorbed in the rumen (passive/facilitated diffusion)
• Absorp higher when ruminal pH reduced &
• Increased chain length. Eg: b.a > p.a > a.a

• B.a:-ketone bodies; beta-OH-Bu acid
• P.a:- lactic acid (rumen) & oxalo-acetic acid (liver)---glucose
• A.a:- acetyl co-A (liver) & CO$_2$ (rumen); acetyl Co-A reacts with oxalo-acetate and form citrate to use in Kreb’s cycle
• Lactic acid: converted to propionate

• Higher starch rich diet: pH falls: propionate bacteria inactivate;
• Lactic acid accumulates: L.A is stronger acid than other VFA
• Metabolized in the liver to pyruvate, then to glucose and glycogen
• Metabolized acid turn to **metabolic acidosis**
Gases:

- \(\text{CO}_2\) (60%)
- \(\text{CH}_4\) (30-40%)
- \(\text{N}_2, \text{H}_2\text{S}, \text{H}_2 \& \text{O}_2\) (eliminated through eructation)

- Ammonia: deamination of protein (dietary Protein, urea or NPN subs)

Other end products:

aa: high biological value proteins
small amts of lipids (PUFA)
and some vitamins
- Proteolytic bacteria: 12-38%

**Dietary proteins are classified into:**

1. **RDPs**: rumen degradable protein
2. **RUPs**: rumen undegradable protein (protected protein): present in plant (maize) poorly fermented in fore-stomach but are radily digested in the abomesum and intestine

Half of dietary protein: degraded in the rumen

RDPs → RUPs

*heat/ formaline* (prevent microbial dig of high quality protein, so that it is available in the intestine): called **protected protein**

Formalized protein has been used to coat & protect fats from microbial attack to enhance the milk yield & increase amt of unsaturated fatty acid in milk / animal fat.
Fermentation of dietary protein:

Food

→ True protein (CP)

→ Peptide

→ Amino acids

 rumen

→ Amino acid (absorb in lower gut)

→ Microbial protein

→ Protozoan protein

→ NH$_3$

→ NPN

→ some – org acid (VFA)

→ deaminated to NH$_3$

→ CO$_2$

→ Liver

→ NH$_3$ → urea

→ urea (grt part)

→ Kidney

→ excreted in urine

→ Salivary gland

→ saliva

→ NH$_3$
How microbial proteins are produced?

Protein entry into the rumen

Attached by microbial proteases (majority are endopeptidases)

Digest

Short chain peptides

Immediately absorb in the microbial cells &

Degraded to aa

Esterified for the formation of

Microbial protein
• Remember it:

**Feeding excess protein** --------- wasteful input-------leads to overproduction of NH\textsubscript{3}, which takes energy to convert to urea (liver)-------- leads to ammonia toxicity.

Protozoa mostly engulf bacteria for nitrogen source. Convert bacterial protein to protozoan protein

Each protozoa can engulf about 60-700 bacteria / hour
• **LIPID DIGESTION:**

• **Source:**
  1) *leaves of forage plants* (cell membranes) that contain lipid: phospholipid, f.a., palmitic, linoleic, linolenic acids.
  2) *oil seeds*: free fatty acids, palmitic, linoleic, linolenic acids

![Diagram of lipid digestion]

Dietary lipid

\[\xrightarrow{\text{hydrolysed by rumen microbes}}\]

Stearic acid

VFA \[\xrightarrow{\text{microbial lipids}}\]

microbes
• Protozoa plays an important role in lipid metabolism

  Absorb PUFA (Polyunsaturated Fatty acid), protect them from hydrogenation,

  Then flow out from rumen to the intestine

  Release their content
Concentrations

- **Bacteria:** $10^9 – 10^{10}$/ml rumen liquor
- **Protozoa:** $10^5 – 10^6$/ml rumen liquor
- **Fungi:** $2 \times 10^3 – 3 \times 10^4$/ml rumen liquor
Holotrichs
Entodiniomorphs
Reticulo ruminal motility:
an orderly pattern of ruminal motility
contractions occurs **1 to 3 times per minute**.
highest frequency ---- during feeding
lowest --- animal is resting.

Motility centers in the brainstem: **dorsal vagal nucleus of the brainstem**
control both the **rate and strength of contraction** via vagal efferents.
Two types of contractions are identified:

**Primary contractions:**
Originate in the reticulum and pass caudally around the rumen mixing of the ingesta (mixing contractions).
This process involves a wave of contraction followed by a wave of relaxation

**Secondary contractions:**
Occur in only parts of the rumen usually associated with eructation (Eructation contractions)
Rumination: (chewing the cud)

- regurgitation of the ingesta (cud) from the reticulum followed by remastication, reinsalvation and redeglutition.

- It provides for effective mechanical breakdown of roughage and thereby increases substrate surface area to fermentative microbes.

- Rumination is a unique characteristic of the true ruminants and pseudoruminants.
Vomition: (Emesis)

- It can be defined as the **forceful expulsion of contents of the stomach and often small intestine out of the mouth**.

**Causes:**
- Presence of irritating contents of GIT-stimulate nerve fibre.
- Mechanical stimulation of pharynx.
- Inflammation of intestine.
- Nauseating sight, odor or taste.
- Unusual stimulation of labyrinthine apparatus (vestibular apparatus) as in the case of sea sickness, air sickness, car sickness or swinging.
- Direct stimulation of **medulla** etc.
**MOVEMENTS OF GI TRACT**

“Cutting of food particles or substances into a smaller particles and grinding them into a soft bolus” is known as mastication.

**MOVEMENTS OF STOMACH**

The movement of empty stomach is related to the sensation of hunger, so called hunger contraction.
MOVEMENT OF SI

Movement of SI is essential for mixing the chyme with juices, propulsion of food and absorption.

1. Mixing movement:
   • Segmental contraction:
     Common type in a rhythmic fashion. The contractions occur at regularly spaced intervals along a section of intestine. The segments of intestine between the contracted segments are relaxed.

     All the segments (both contracted and relaxed) give a ring-like appearance resembling the chain of sausage.

   • Pendular movement:
     Intestinal loop move like the pendulum of the clock.
2. Propulsive movement:

• Peristaltic movement:

Peristalsis means the wave of contraction followed by wave of relaxation/sequently timed contraction of longitudinal and circular muscle.

• Peristaltic rush:

• Sometimes, the SI shows a powerful peristaltic contractions.

• caused by excessive irritation of intestinal mucus membrane or extreme distension of the intestine.

• begins in duodenum and passes through the entire length of SI and finally reaches the ilocecval valve within few minutes.

• This sweeps the content of intestine into colon. Thus, it relieves the SI off either irritant or excessive distension.
• MOVEMENT OF LI

1. Mixing Movement – segmented contraction


• Segmented contraction: Large circular constriction, appears in the colon, are called mixing segmentation.

• Mass peristalsis: or mass movement propels the faces from colon towards anus. Usually, this movement is developed only a few times everyday.