Digestive physiology

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UNIVERSITY OF MARYLAND EXTENSION
SMALL RUMINANT PROGRAM

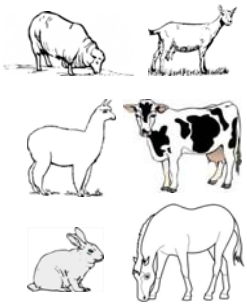
Digestive physiology

- The process by which food is converted to substances that can be absorbed and assimilated by the body.

Classification of digestive systems

HERBIVORE

- Eat primarily plant materials.



CARNIVORE

- Eat primarily other animals.

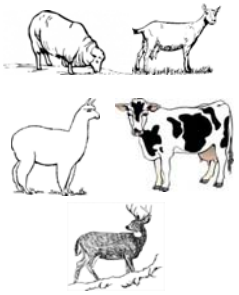
OMNIVORE

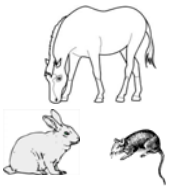
- Eat combination of plant and animal material.

Types of digestive systems

RUMINANT

- Multi-compartment stomach.



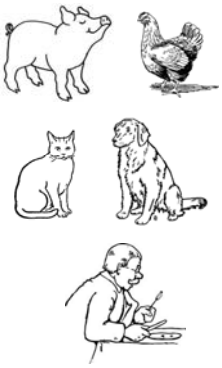


HIND GUT FERMENTOR

- Simple stomach, but very large and complex large intestine.

MONOGASTRIC

- Simple stomach



Digestive system comparisons

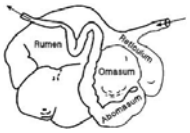
Function	Ruminants	Hind Gut Fermentors	Monogastric
Digest and extract energy from cellulose	Yes (rumen/reticulum)	Yes (large intestine)	Very limited (large intestine)
Utilize dietary sugar sources directly	No (fermented to VFA's)	Yes (absorbed as glucose)	Yes (absorbed as glucose)
Utilize protein from feeds directly	Limited (most converted to microbial protein)	Yes	Yes
Utilize fat from feeds directly	Some (most fermented to VFA's)	Yes	Yes
Utilize microbial protein	Yes (60-80% of AA from microbes)	No	No

Source: Dr. Richard Coffey, University of Kentucky

Organs of digestive system

RUMINANT

- Mouth
- Esophagus
- Stomach
  - Reticulum
  - Rumen
  - Omasum
  - Abomasum
- Small intestines
- Large intestines



Liver
Pancreas

MONOGASTRIC

- Mouth
- Esophagus
- Stomach
- Small intestines
- Large intestines

Liver
Pancreas

Classification of ruminants

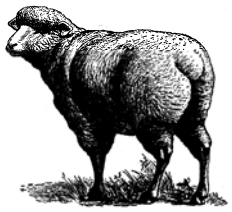
CONCENTRATE SELECTOR

- Select diets of plants that are highly digestible; high in starch, proteins, and lipids; and low in fiber.

INTERMEDIATE

- Consume a mixed diet, based on season and opportunity.

- Prefer concentrate portions of plant parts and will select shrubs and browse, but also possess ability to digest cellulose.

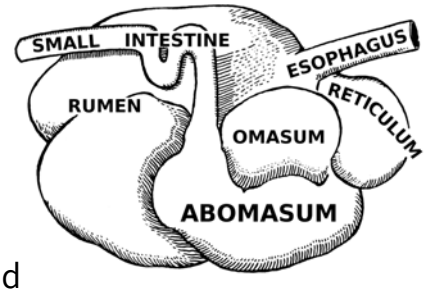


GRASS/ROUGHAGE EATER

- Highly developed fermentation system that enables them to digest cellulose fractions of plant cell walls.

Ruminant stomach

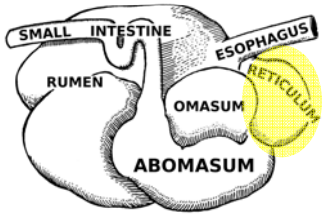
- Four compartments or chambers
  1) Reticulum
  2) Rumen
  3) Omasum
  4) Abomasum



- Llamas and alpacas have a three-chambered stomach: C1, C2, and C3

Reticulum

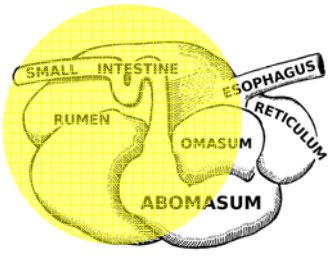
- Holding area for feed after it passes down esophagus.
- Provides additional area for fermentation.
- Contains microorganisms, like rumen
- Collection compartment for foreign objects.
- Helps open and close rumen.
- Minimal separation with rumen.
- Can contract to a fraction of its resting size.



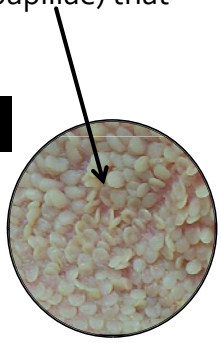

"honeycomb"

Rumen

- Largest of the four components.
- On the left side of the animal.
- Storage site and fermentation vat.
- Houses millions of microorganisms.
- Lined with millions of finger-like projections (papillae) that are needed for absorption.




"paunch"



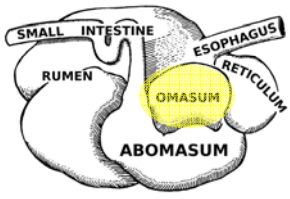
Rumination (cud chewing)

1) Regurgitation
2) Re-chewing
3) Adding saliva
4) Re-swallowing

→ Reduces feed particle size and increases rumen volume, which allows animal to consume more feed.

Omasum

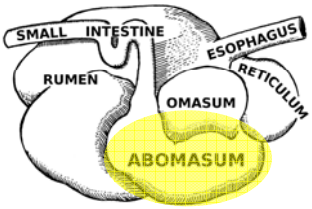
- A heavy, hard organ that has many folds or leaves.
- Little, if any digestive activity.
- Grinds feed particles.
- Removes moisture.



"many piles"

Abomasum

- True, glandular stomach
- Functions similarly to monogastric stomach
- Secretes gastric juices which aid in digestion.



Infected with barber pole worms

Rumen environment

- Anaerobic
- pH between 6 and 7
- Each ml of rumen content contains…
  - 10 to 50 billion bacteria
    - Primary
    - Secondary
  - 1 million protozoa
  - Various numbers of yeast and fungi

Image source: Lock Haven University

Rumen microorganisms

Major groups which contain multiple genera and species

- Microbial populations vary with diet.
  - Digest cellulose
  - Digest hemicellulose
  - Digest starch
  - Digest proteins
  - Sugar utilizing
  - Acid utilizing
  - Ammonia producer
  - Vitamin synthesizer
  - Methane producer

Fermentation

Symbiotic relationship between animal and microorganisms

1) Fermentation of structural carbohydrates into readily absorbable and utilizable sources of energy.
2) Conversion of non-protein nitrogen into utilizable protein sources.
3) Synthesis of vitamin K and B vitamins.

Volatile fatty acids (VFAs)

- Main end products of microbial fermentation.
- Provides up to 80% of the energy needs of the animal.
  - Absorbed by rumen.
- Proportion of VFA's greatly influenced by diet.

Volatile fatty acids

95% of VFAs

ACETIC ACID

- Usually 50 to 60%
- Most abundant VFA in general circulation.
- Prime metabolic substrate
- Used in fat synthesis
- Predominates in high forage diet.
- Mammary gland is most important user of acetate.

↓ Acetic acid
↓ Milk fat

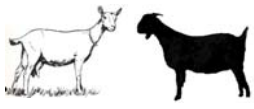
PROPIONIC ACID

- Usually 18 to 20%
- Provides energy for conversion to glucose.
- Used in lactose synthesis.
- Some metabolized to lactic acid.
- Favored in a high-concentrate diet.
- Increased by adding ionophores to diet

↑ Propionic acid
↑Milk production

BUTYRIC ACID

- Usually 12 to 18%
- Metabolized and oxidized to ketones.
- Provides energy to rumen wall.
- Increased in high grain rations.



Protein

- Degradable intake protein (DIP)
  - Broken down by rumen microbes into ammonia, amino acids, and peptides.
    - Microbe growth and reproduction
    - Absorbed as ammonia
- Undegradable intake protein (UIP)
  - Not degraded in rumen

Undegradable intake protein (UIP)

Also called by-pass, escape or protected protein

- Passes intact to the lower digestive tract where it is digested and absorbed.
- Provides protein directly to the animal.
- By-pass proteins tend to be higher quality and more expensive.

Feed stuff	CP	UIP
Fish meal	66	39.6
Feather meal	86	62.8
Meat meal	56	35.8
SBM	44-49	17-19
Distiller's grains	28-32	14-20
Cottonseed meal	46-48	20-23
Corn gluten meal	41	26.7
Corn gluten meal	60	40.2
Brewer's grains	25-27	13-14

Effect of diet on rumen function

HIGH ROUGHAGE DIET

- Lots of chewing
- Slower passage
- More rumination
- Higher pH
  (normal is between 6 and 7)
- Fiber-digesting bacteria
- Acetate production

HIGH CONCENTRATE DIET

- Less chewing
- Less saliva
- Faster passage
- Less rumination
- Lower pH (more acidic)
- Starch-digesting organisms
- Propionic fermentation pathways

Overfed with, or abrupt shift to grain

or other readily-fermented carbohydrate

- Lactic acid accumulation in rumen (and blood).
  - Ruminal pH drops.
  - Drastic shift in microbial population from normal rumen microbes to more acid-tolerant lactobacilli.

  → can be fatal!

Gas production

- Gases are the primary by-product of rumen-reticular fermentation.
  1) Carbon dioxide (60%)
  2) Methane (35%)
  3) Others (5%)
- These gases must be eliminated from the body to maintain the health and even life of the ruminant.
  1) Eructation (belching)
  2) Respiration

Eructation reflex --belching--

- Quiet, almost inaudible, well-developed reflex mechanism.
  - Ruminal contractions
  - Increased intra-esophageal pressure
  - Closure of nasopharyneal sphincter.
- Failure to expel gas can results in bloat and death.

Methane (CH_4)

- Methane is a greenhouse gas.
- Domesticated ruminants account for up to 28% of global methane production.

↑ Feed consumption	↑ methane production
↑ Feed digestibility	↓ methane production
↑ Per animal productivity	↓ methane production

Other methods ↓ methane production: immunization, feed additives, genetics

Altering the rumen fermentation

- Ionophores
  Rumensin®, Bovatec®
- Microbials
  probiotics, yeast
- Essential oils
- Plant extracts
- Protected nutrients
  protein and lipids
- Buffers
  Sodium bicarbonate

The young ruminant

- Baby ruminants are born with a very small, non-functioning rumen.

Fore stomach - solid food

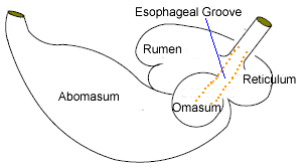
Abomasum - milk

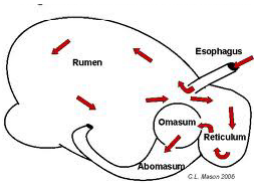
- Size of abomasum = rumen + reticulum + omasum

Esophageal groove reflex

Correct term: ventricular groove

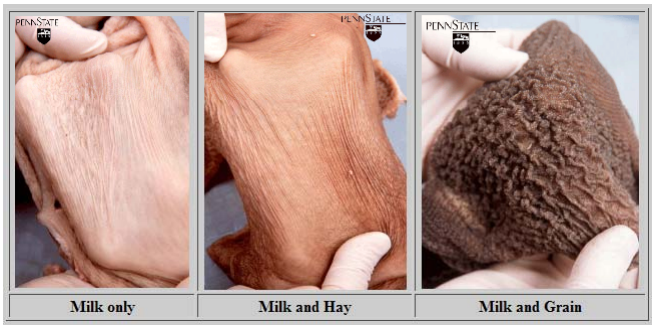
- Stimulated by act of sucking or drinking
  - Not by drinking to quench thirst
- Causes milk or any other liquid to pass directly through esophageal groove (tube) into the abomasum.
- Can occur in adult animals (concern with deworming)





Young ruminants

- As the young ruminant eats solid food, the rumen will develop and become populated with bacteria.
- The rumen will develop faster if the young ruminant is fed grain (vs. milk only or milk + forage).



4-week old calf

Next webinar – Thursday, 1/19, 7:30 p.m. EST
Topic: Nutrients and nutrient requirements

Thank you for your attention.

Any questions?

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