Rumenology 101

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Ruminants are cool. They have a diverse body size from the small mouse deer that weighs 4 to 11 lbs and stands 14 inches tall to the giraffe that can weigh up to 2 tons and stand 20 feet tall. Ruminants are even-toed, hooved mammals that chew their cud, and have complex four-chambered stomachs.

Why ruminants? 40% of the earth's land surface is covered by grassland. Ruminants can utilized the largest carbohydrate source in the world (cellulose) and produce food, fiber, fuel, and other products for mankind. Microbial digestion maintains the carbon cycle as plants fix CO_2 and release O_2.

Rumen microbes are essential for the provision of nutrients to the ruminant animal. The rumen microbes population includes bacterial, protozoa, and fungi. The microbe's generalized function is to digest and utilize the feedstuff presented into the rumen. By digestion and utilization of the feeds, the microbes undergo catabolic processes that benefit the microbe and the host. In the rumen the microbes can occupy one of four physical locations. Microbes adhere to the feedstuffs in the rumen, reducing particle size of the feed. Microbes are found associated with the feedstuffs, where they release enzymes to digest the feed particle and take up the resulting nutrients. Microbes are found freed in the liquid phase where they take up the free nutrients released by other microbes or mechanical distruption of the feed. Finally, microbes are found near the rumen wall, utilizing urea that diffuses across the rumen wall or feeding off of sloughed rumen wall cells.

The microbial population adapts to the specific substrates that are presented to them in the diet. The microbial population is a continuum of the amount and proportion of bacteria, protozoa, and fungi that depends on the diet type. All forage diets encourage the proliferation of cellulytic, hemicellulytic, and pectinolytic bacteria, protozoa, and fungi. Bacteria that are amlyolytic (starch) are also present, but not in prolific amounts. The ratio of cellulytic to amylolytic bacteria would be approximately 60:40. In high-concentrate diets (feedlot) the ration would be 40:60 cellulytic to amylolytic bacteria. Protozoa and fungi do not proliferate in high-concentrate diets. Proteolytic bacteria (protein digesting) are present in all diets.

Ruminant Animal Facts and Figures

- In the pen we have examples of the beginning (feed), middle (rumen), and end (feces).
- Notice how she chews: cows chew side to side, their molars are beveled; chewing after here meal, that is rumination or re-chewing of the food to breakdown particle size, add saliva that contains buffer for rumen fermentation.
- The longer the fiber length and the less digestible the longer the cow will have to ruminate to breakdown fiber size.
- Eructation (belching) occurs. This process removes fermentation gas from rumen. Eructation is done silently because cattle are prey animals and don't want to draw attention. Gasses mainly include methane (CH_4), carbon dioxide (CO_2), and hydrogen sulfide (H_2S).
- Microbes in the rumen include bacteria, protozoa, fungi.
- Break down fiber, carbohydrates, and proteins. Some "escapes" for digestion in abomasum and intestines.
- In the rumen the digesta are stratified into 4 layers (1) fiber mat, (2) liquid under raft, (3) soupy material, (4) boundary layer next to rumen
- Cattle produce 16 to 42 gal/day of salvia depending upon diet type.
- Benefits and Costs of Ruminant Digestion
    - Allows animal to use diets that are too fibrous for non-ruminants
    - Breakdown and use cellulose as nutrient
    - Synthesis of high biological value protein from low biological value plant protein
    - Provides all components of B vitamin complex
    - Spend large part of day chewing
    - Complicated mechanism to maintain fermentation
    - Pathways of intermediate metabolism are specific for products of fermentation
- End-products of ruminal digestion
    - Volatile Fatty Acids – precursor for energy metabolism, transported to liver to create glucose, fat. VFAs are what make contents smell: acetate-vinegar, butyrate-rancid butter, caprice acid-goat stink.
    - Lactic acid
    - Gases: methane, hydrogen sulfide, carbon dioxide
    - Microbial cells – protein source in addition to protein from diet
    - Ammonia from protein breakdown
    - Saturated fat from unsaturated oils

Table 1. Digestive tract anatomy comparison of ruminant and monogastric

Part	Ruminant	Monogastric	Comparison
Mouth / Teeth	No upper incisors, only upper molars, dental pad in front, use tongue to scoop/grip	Upper and lower complete set of teeth, cut and grind, think about human teeth	Ruminants don't have upper incisors so they grip forage with tongue and tear against lower incisors, molars are beveled for grinding. Mouth is the first place that digestion starts: with saliva and chewing mechanical and enzymatic. Ruminants secret buffers in saliva for use in rumen.
Esophagus	Striated muscle to move bolus up and down	Striated muscle moves bolus down (up)	Ruminant moves bolus up and down for swallowing and rumination
Reticulum	1st compartment of ruminant stomach – honeycomb. Reticular groove in young to shunt milk away from rumen.	Do not have this structure	Functionally part of the rumen. Contains opening to esophagus and omasum.
Rumen	Largest compartment of stomach. Fermentation by microbes is the digestive function. Main site of absorption of microbial digestion. Papillae are the absorptive structures.	Do not have this structure	Rumen develops with age. Urea can be recycled back to rumen for microbial use. Slightly acidic pH as a result of fermentation byproducts.
Omassum	Round ball-like shape. Interior has leaf-like structure-"many plys"	Do not have this structure	Main function is absorption of water as rumen contents leave rumen
Abomasum	True stomach. Acid, enzyme digestion occurs here.	True stomach. Acid, enzyme digestion occurs here	Similar function, size differs between ruminants and monogastrics, and within monogastric. Very low pH because of acid secretion.
Small Intestine	Long, enzymatic digestion and absorption.	Long, enzymatic digestion and absorption	Ruminant is longer than monogastric, pig longer than horse.
Large Intestine Colon/Cecum	Shorter than small intestine, greater in volume, absorption of nutrients.	Shorter than small intestine, greater in volume, absorption of nutrients	Monogastric larger than ruminant because fermentation occurs here in monogastric. Equine much larger because of forage-based diet, microbial fermentation occurs here.
Rectum	Last stop, holds digesta prior to defecation	Last stop, holds digesta prior to defecation	Larger in roughage consuming species (cow/equine) than concentrate feeders (pigs)

Here is how I would describe protein and urea metabolism in a mildly technical way.

1. Feed source proteins and non-protein nitrogen (NPN) enters the rumen and is broken down by microbial digestion to amino acids, ammonia, and carbon dioxide.
2. Depending on the specific bacterial species the microbes will use some of this ammonia or urea to make more microbes, urea is used assuming that rumen ammonia concentration is low and there is available energy for protein synthesis.
3. Microbial protein produced and microbes are then passed out of the rumen into the lower gastrointestinal tract for digestion.
4. Excess ammonia in the rumen as a result of digestion is absorbed across the rumen wall and transported to the liver via the blood.
5. Excess ammonia not used in the liver, is metabolized to urea and sent back out of the liver into circulation where it has 3 fates
    a. Secreted in the saliva of the animal to return to the rumen. Urea is slightly basic so it also functions to buffer the rumen.
    b. Absorbed back across the rumen to supply ammonia for microbial metabolism, see step 2 and 3.
    c. Excreted by the kidneys in urine if there is excess urea in the system.
6. The ability of the ruminant to shuttle urea back and forth across the rumen wall is what allows us to provide protein supplements on a non-daily basis. The ruminant can put urea back into the rumen when ruminal ammonia concentrations are low, supplying the microbes with the nitrogen source they need for metabolism.
7. The provision of energy (sugars from starch, molasses, etc.) with the NPN source provides the necessary energy for the microbes to metabolize the ammonia into microbial cells which provides the ruminant with a consistent source of protein regardless of dietary protein for digestion in the small intestine.
8. Protein digested in the small intestine (either microbial or rumen undegraded protein) will result in ammonia, amino acids, di-, tri-, and other peptides which are transported to the liver for further metabolism.
9. Liver metabolism of the digested protein will also result in some amount of urea that is available for steps 5a ,b, c.

I hope this walk through and the pictures help with your explanation.

Figure 1. Digestion and metabolism of nitrogenous compounds in the ruminant animal.