Goat Digestive System

Introduction

In the wild, goats survive by browsing on woody plants such as bushes, shrubs, bramble, scrub, underbrush, and less desirably weeds and grasses. Domestically they are fed hay, alfalfa and grains (fodder) supplemented by free-graze. Goats coexist especially well with other animals because they eat forage not usually preferred by livestock such as sheep, cattle and horses. Furthermore, goats coexist well with man, because they can eat and digest foods humans are unable to consume, therefore goats do not compete for foodstuff man requires. This will become an important agricultural feature of raising goats in the sustainable future.

Goats have been blamed for causing deforestation by overgrazing. Nonetheless, they are very useful for cleaning out heavily forested areas, and lauded as heroes for chomping through undesirable underbrush to create firebreaks by means of managed goat grazing. Goats not only clear undesirable stretches of land but also fertilize and till the land at the same time.

Sound goat management requires the owner to acquire a good working knowledge of ruminant physiology to include the stomachs and digestive processes and their relationship to the food they eat. Nutrition is a key factor in ruminant management because it directly affects overall health, fleece production, and reproduction. Pygora goats are herbivores capable of eating 2-4 pounds of vegetation a day or 3-4% of their body weight in dry matter per day.

Digestive System Overview

Fiber is the goat's main food staple and grains in lesser quantities. Goats have specialized stomachs and intestines or digestive tract to process fiber (cellulose), nitrogen (protein/amino acids) and energy (carbohydrate/fat). Their system ingests digests, absorbs and excretes waste.

Ruminant stomachs and intestinal tract are designed to extract and absorb nutrients for growth, maintenance, lactation, regeneration of cells and reproduction. The four entrained multi-chambered stomachs are called the: reticulum, rumen, omasum and abomasum; essentially, there are three forestomachs and one true stomach. After birth, the size of the stomachs change as the goat matures. The remainder of their digestive system is composed of the small intestine, cecum and large intestine. The cecum is a small compartment joining the small and large intestines.

Unfortunately, much of the research and literature of the ruminant digestive system has been conducted on cows and sheep with little exact references to the goat's digestive processes. However, when possible, the volumes, lengths and facts offered attempt to quote those closest to the anatomy of the pygora goat:

1. Esophagus up to 3 feet long
2. Rumen 3-5 gallons
3. Reticulum up to ½ gallon
4. Omasum ~ ¼ gallon
5. Abomasum ½ - 1 gallon
6. Small Intestines ~36 feet & ~2 gallons
7. Cecum ~¼ gallon
8. Large Intestines ~6 feet long & over 1 gallon

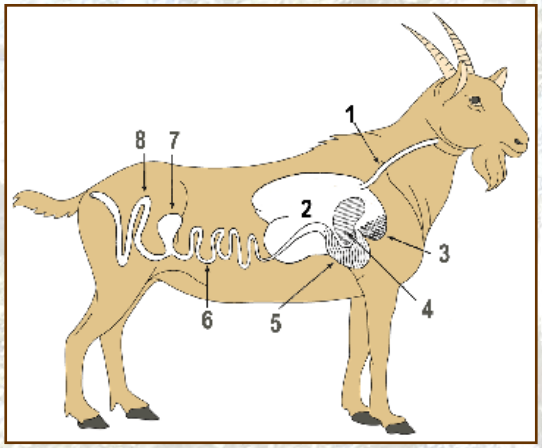

Diagram courtesy of the Alabama Cooperative Extension System (Alabama A&M and Auburn Universities) and the author, Julio Correa.

In reality, the reticulum and rumen are one space positioned on the left half of the abdomen consisting of two distinct inner wall textures carrying out different functions; collectively they are called the reticulorumen. The textural differences are designed to increase the surface area of the stomachs to facilitate more efficient absorption of nutrients. The stomachs occupy almost three-quarters of the abdominal cavity filling all of the left side and extending into the right side.

The reticulum is lined with raised honeycomb-like ridges and is capable of holding only a quarter to a half a gallon of liquid and foodstuff. The reticulum is joined to the rumen by a fold of tissue. The rumen also known as the paunch holds an amazing 3 to 5 gallons of food, water and saliva for an average of about 8 hours. Amazingly, goats can generate up to a quarter pint of saliva per hour.

The rumen has small finger-like protrusions, called papillae that are flattened against the inner wall of the stomach to increase surface area for nutrient absorption. The rumen is a fermentation vat where the majority of usable nutrient uptake occurs.

Plant tissue and cell walls contain approximately 75% carbohydrates, the major source of energy for the goat. There are two general types of carbohydrates the primary and secondary. The primary consists of cell-soluble starches and sugars. The secondary are cell-wall carbohydrates: pectin, cellulose, hemicellulose and lignin.

Pectin is a water soluble carbohydrate found in cell wall and tissue of plants to bind cells together and regulate water in the plant. Cellulose is the structural component of cell walls of green plants; it is a carbon-based indigestible fiber called roughage. Hemicellulose is between cellulose and sugar. Lignin is found in the cell walls of woody plants filling the spaces between the other secondary carbohydrates and plays a major role in conducting water up the stem of the plant.

Protein is the only nutrient to contain nitrogen. The rumen manufactures its own body protein consisting of amino acids from nitrogen. Protein is the basis for all animal tissue. Any excess is burned as energy and the rest is excreted through the kidneys. Protein requirements are between 12% for dry feeding and 16% for growth and milk production. Ruminants receive their daily nitrogen from amino acids released into the abomasum and small intestines by bacterial protein degradation.

Cud Chewing

Rumination is the act of chewing cud and is the origin of the name for the group of animals known as ruminants. Surprisingly enough, the class of ruminant animals also known as even-toed (two-toed) or cloven-toed animals include: goats, sheep, cow, elk, deer, reindeer, antelope, moose, camels, llamas, alpacas, giraffes, whales, bison, hoppopotimus, giraffes, tree sloths, kangaroos and leaf-eating monkeys. Moreover, there are approximately 155 ruminant species with extended stomach fermentation systems.

The word mastication is Greek for "to chew or grind the teeth." It is the process of mashing, grinding and crushing foods by the teeth. Chewing softens, warms, infuses saliva and increases the surface area of the forage to make the food more soluble for enzymes in the saliva and produced by microbes to begin the breakdown of carbohydrates and proteins.

While chewing, the food is formed into a ball called a bolus that is swallowed by way of the esophagus to the reticulorumen to prompt the next step in the digestion. The reticulorumen physically refines the food to expose more surface area for more efficient nutrient absorption at the same time stimulating saliva production to buffer the rumen pH. Cud is the partially degraded bolus that is regurgitated by the reticulum to be chewed and swallowed a second time. This whole process is called rumination and is believe to be a predator avoidance adaptation. Goat's ruminate up to 8 hours per day, mainly at night or at rest.

At regular intervals, the reticulum contracts to push the cud back up into the goat's mouth. Saliva is a natural lubricant rich in bicarbonate to buffer and neutralize the accumulation of acids generated during the rumen breakdown of fibrous plant matter. The pushing action is caused by the stretching of the chest cavity to form a vacuum in the stomach that sucks the semi-liquid contents back up into the esophagus and is then delivered to the mouth by a muscle contraction called retro-peristalsis.

Peristalsis action entails wavelike muscular contractions forcing the reticulum content into the mouth; conversely it also pushes the material through the other stomachs and intestines. These cycles of muscular contractions and relaxation occur one to three times per minute. They are more frequent during feeding and lowest when the animal is at rest. These movements serve to mix the digesting foods, assist with belching and moves the fluids and foodstuff into the omasum. The reticulum has the ability to move food into either the rumen or omasum, as both are capable of absorbing the fermented products of digestion

The goat's small prehensile mouth has no upper front teeth but hosts a rigid dental pad used to tear forage rather than incisors to rip meat; flexible lips; and the tongue. This semi-degraded bolus is pushed against the palate of the mouth with the tongue to remove excess liquid that is then swallowed leaving the solid bolus material left in the mouth to be chewed thoroughly. When the food particles are small enough they are passed into the reticulum.

Stomachs

Heavier objects settle into the reticulum. Foods and liquids are separated in the rumen by density differences into three basic zones. The previous day's food settles to the bottom while leaving the lighter more buoyant freshly eaten foods such as hay and grasses, in the middle while gases rise to the top of the rumen. An adult goat can generate over 1 gallon of gas per hour. It is purported that during belching the gas travel up their esophagus at rates as fast as 5 to 7 feet per second.

The rumen is the largest stomach where the majority of the fermentation and digestion of foods is conducted by a number of microbes: bacteria, protozoa and fungi. The rumen hosts billions of

these microorganisms. The microbes synthesize digestive enzymes to hasten the breakdown of unrefined roughage. Protozoa population is much less than the bacteria population, but they are much larger and can equal the volume occupied by the bacteria.

Over a dozen main bacteria produce enzymes to breakdown plant cellulose and starch-filled grains into sugars attained through the fermentation process in the rumen. In particular, Frobacter succinogens, Ruminococcus albus and Ruminococcus flavenfaciens specialize in fiber digestion from cellulose-based plants. Ammonia generated during the metabolic breakdown is used as a major source of nitrogen to biosynthesis microbes.

The fermentation process using microbes is called anaerobic respiration or in more simple terms; it is the breakdown to sugars in the absence of oxygen to release energy. The chemical energy of the carbohydrates is released in a series of metabolic steps involving the consumption of chemical oxygen and the liberation of carbon dioxide, methane and hydrogen. The oxygen is metabolically removed by both the bacteria and protozoa. Microbes in the rumen convert fiber and starch into three major short-chained volatile fatty acids: acetate (~70%), propionate (~20%) and butyrate (~10%) acids to be absorbed throughout the digestive system. Fatty acids supply over 70% of energy to the goat.

These small microorganisms have a big job building useable proteins called amino acids (nitrogen-based proteins), fatty acids and manufacturing vitamin B complexes, and K that are produced by the rumen while vitamin C is produced by the body tissues. Goats need vitamins and minerals in small amounts, and what they do not manufacture, must be supplemented in their diet such as vitamin A, D, E, calcium, copper, magnesium, manganese, iron, iodine, salt and most importantly selenium. Vitamins can be supplemented through a weekly herbal feeding program or by a free choice salt blocks designed specifically for goats.

Balancing the pH of their stomachs is one of the most important factors of ruminant digestion as well as constant temperature and adequate mixing. The fiber digesting microorganisms in a goat's rumen prefer a pH of 6.5 to 6.8 where as a pH less than 6 begin to kill the microbes resulting in a sick animal that cannot digest crude plant matter. The starch/sugar digesting microbes prefer a pH of 5.5 to 6.0. If goats are fed diets of high grains or starches and sugars, this offsets the balance of fiber decaying microbes to starch-utilizing microbes that are not efficient for fiber digest. Any diet change should be done gradually, so the microbes can adjust their populations to their new environment.

After the size of the food particles is reduced by physical mastication and enzyme/microbial destruction, the fermenting particles are passed through the reticulo-osmasal opening into the omasum. The omasum is also known as many-plies because it has approximately 35 folds (with papillae) that are assumed to assist in grinding the remainder of the useable nutrients while removing the liquid and absorbing fatty acids. It is surmised that electrolytes and inorganic minerals such as potassium and sodium are also absorbed in the omasum. It's believed rhythmic contractions knock flakes of material from the plies for passage into the abomasums. However, the function of the omasum is still poorly understood.

The abomasum is located on the abdominal floor and functions just like the human stomach using gastric juices in the abomasum to facilitate the digestion of protein while eradicating the no longer needed microbes at a pH of around 2.0 to 2.5. The abomasum has a capacity of 1 gallon or less. As to not injure the stomach from the low pH, it is lined with a mucous barrier as in human stomachs; this is accomplished by a mucous secretion released by the abomasum.

Enzymes and hydrochloric acid are the only active fluids in the abomasum, the fourth and last stomach. The enzyme pepsin is activated by the hydrochloric acid and breaks down carbohydrates and proteins that escaped digestion in the reticulorumen and are absorbed into the bloodstream, through the walls of the small intestines. The abomasum secretes an enzyme called lysozyme that breaks down the cell walls of bacteria. It is believed that some poisonous plants are less toxic to ruminants because the microbes can attack the toxins before they are exposed to the gastric digestion process before absorption.

Kid Stomach Development

At birth, goats do not have the ability to ferment foods. Initially, the abomasum is located on the left side adjacent to the diaphragm, as the animal grows, the abomasum moves to the right in the abdomen and gets proportionately smaller. However, throughout the life of the goat, the abomasum works just like a human stomach, that's why it is commonly referred to as the "true stomach."

After birth, the rumen is very small and the abomasum is four times the size of the reticulorumen. Milk fed to kids curdles in the abomasum by rennin found in the gastric juices and is digested by enzymes. The kids depend only on the mother's milk, not roughage as a food source; hence the milk goes directly to the abomasum through what is called the esophageal groove.

The esophageal groove is a flap of skin/membrane at the entrance of the rumen that reflexively folds over to form a groove so the milk passes the rumen delivering the milk directly to the abomasum to be digested by stomach acids. This is a reflexive response from suckling, upon weaning the reflex wanes. As the kids begin to eat roughage, the rumen becomes active, microorganisms increase and the rumen enlarges. The reticulum and omasum respond to the new diet and become larger as well. Technically, full rumen capacity is not reached until about 12 weeks of age. Weaning should not begin before 10 weeks of age using good quality hay, and grain very sparingly. At about 2 week, start giving a teaspoon of grain a day building up to one-quarter cup a day by 12 weeks old.

Intestines

From the abomasum, the remaining food particles are passed into the small intestine. The small intestine of smaller breeds of goats comprises 77% of the intestinal tract and is located on the right side of the abdomen because the reticlorumen is on the left. As food enters the small intestine, it mixes with secretions from the pancreas and liver to elevate the pH from 2.5 to 7-8 necessary for the enzymes. Any remaining proteins are reduced to amino acids, starch to glucose and complex fats to fatty acids. Absorption occurs in the lower half of the small intestines through more finger-like protrusion called villi while muscular contractions mix and move digesta into the cecum.

The cecum, large intestine (colon) and rectum are collectively considered the large intestines. The cecum is a tubular shaped quarter gallon sac connecting the small and large intestines where microbes also digest food material. Fatty acids are the end products of microbial fermentation in the cecum. Fatty acids: acetate, propionate and butyrate are absorbed in the large intestine as sources of energy. Not only large populations of bacteria, protozoa and anaerobic fungi colonize the rumen, they also populate the large intestines.

The large intestine functions under anaerobic conditions (without oxygen), as does the rumen, and is composed of the large intestines and rectum; it can hold over a gallon of material. The large intestine is located to the right of the reticulorumen. Extensive water removal occurs in this last processing; this is considered an adaptation for water conservation. Any remaining foods that escaped digestion (less than 15%) are processed in this last step. Retention time in the large

intestines is approximately 18 hours compared to 3 hours in the small intestines which is surprising since the small intestines are three times longer than the large intestines. Fecal pellets are formed at the end of the large intestines and are excreted out of the rectum.

Acidosis

Cellulite bacteria are sensitive to acidic conditions and lose their ability to digest plant fiber. Unfortunately, there is no mucus lining in the rumen, as is the case for the first three of the four goat stomachs. Only the abomasum, the fourth stomach has a mucus lining. Therefore acidic conditions in these stomachs can cause inflammation, ulceration and scarring of the stomach lining. Permanent damage to the rumen lining and intestines will inhibit nutrient absorption for the rest of the animal's life.

Low fiber diets generate little cud and less salvia causing acidosis when the pH is under 5.5 or lower. Appetite loss leads to even less saliva to exasperate the condition further. Animals eating no roughage and high amounts of easily digestible starches such as grains can die from acute rumen acidosis. This is more commonly associated with industrial farming practices. Other obvious symptoms are cessation of rumen movements, bloat, increase of pulse and breathing, staggering and coma. Consequently, the whole microbial network fails killing the animal.

Other bacteria species such as *Streptococcus bovis* digest starches or sugars found in the seeds of plants but are found in lower numbers since goats are not naturally starch eaters. If fed an overabundance of grain, the grain-digesting bacteria will outgrow the fiber bacteria and produce lactic acid instead of volatile fatty acids that cannot be absorbed across the rumen membrane. However, other bacteria present convert the lactic acid into usable fatty acids but this can result in severe to mild acidosis. Furthermore, lactic acid generating bacteria secrete sugars that produce gassy foam; the bloat can compress the lungs to suffocate the goat. Also excess undigested grain generates the intestinal bacteria *Clostridium perfringens* to produces toxins that can cause enterotoxaemia.

Fusobacterium necropori utilizes the lactic acid but can also infect ulcers that have formed on the rumen membrane. More seriously, if the infection from the ulcers moves into the blood stream, it can also cause liver abscesses and produces toxins called endotoxins released when microbes die. If the acidic condition continues the rumen lining will produce enzymes that destroy stomach tissue. The endotoxins and enzymes that have moved into the bloodstream can cause hoof tissue to become inflamed or even cause the hoof wall to fall off.

Bloat

If gas expulsion diminishes, the rumen expands, compresses the lungs causing difficulty in breathing or circulatory failure from pressure on the diaphragm. Other obvious symptoms are a sudden appearance of a bulge on the left side of the goat, pain, grinding teeth, depressions and kicking their legs to their sides. As the bloat progresses, the skin over the left flank becomes more taunt. Never give water to a goat that has ingested large quantities of grain or wet protein-rich food or young fodder, wait 12 -24 hours before watering to stimulate the rumen.

A more mild form of bloat is indigestion or colic showing symptoms to include tamping of hind feet, grunting, diarrhea and nosing its side. One-quarter cup of Pepto Bismol usually helps. Kids can bloat if milk curd gets into the rumen, the curd ferments and the stomach fills with gas. Treatment for this is 1-3 teaspoons of Pepto Bismol.

Goats suffering from extreme bloat (called ruminal tympany) due to gas retention can easily die of asphyxia from this condition. Further complication can arise when carbon dioxide is absorbed by the rumen into the bloodstream.

Although the mucous of the saliva has antifoaming agents, saliva production is reduced when eating rich forage containing high protein content, which is rapidly digested releasing a large amounts of gases. Small bubbles form into a forth that render the animal unable to expel gas; this is called frothy bloat. Plant proteins are the major source of the foaming agents in the rumen. If the bloat is severe, it can kill the animal within a day.

Typical fodder or livestock feed that can initiate bloat are: alfalfa (Lucerne), barley, kale, rapeseed (Canola), red/white clover, ryegrass, corn, millet, oats, sorghum, soybeans and wheat. In particular, immature plants that are growing rapidly can put animals at higher risk of bloat.

Treatment for bloat is typically sodium bicarbonate, Milk of Magnesia, DiGel or a small amount of laundry detergent in water or oil as a drench. Massaging the stomach or walking the goat helps mix the medicine with the rumen contents. Consult your veterinarian immediately if the bloat is considered serious or especially when the goat is suffering from free-gas bloat, which can be caused by an obstruction in the esophagus.

Probitoics

Probiotics are living microorganisms such as bacteria, protozoa, viruses, and yeasts that are beneficial to the animal's health. Active bacteria assist proper digestion in the rumen where the majority of the fermentation takes place. Friendly bacteria are necessary for proper immune system development, to combat harmful disease causing microorganisms as well as to aid digestion and absorption of nutrients. Drugs such as antibiotics can kill friendly bacteria along with unfriendly bacteria in the stomach. Probiotics inoculants can be purchased over the counter to assist with repopulation of microbes for goats and humans.

Over the counter or Internet probiotics usually contain Lactobacillus species for lactic acid producing bacteria and other intestinal microbes. Unfortunately, they do not contain all the neccessary rumen microbes that adhere to strict conditions of pH, temperature and anaerobic environment that are indispensable to the rumen. Many of the microbes die when outside of the bodies.

Do not confuse probiotics with prebiotics. Prebiotics just bolster the microbes that are already in the stomachs and intestines to stimulate growth/activity of these beneficial microorganisms to assist with nondigestible foods. Probiotics and prebiotics can be mixed together to form a symbiotic drug.

A more popular method to inoculate the goat with the necessary microbes is to pass a partially degraded bolus from the mouth of a health animal into the mouth of a sick animal to bolster microbe repopulation; this is called cud transfer. This is the reason does clean the face and mouth of her newborn, inoculating the newborn with bacteria that will establish large colonies by the time the kid is ready to eat forage.

Natural cud transfer is the most desirable way to reintroduce microbes to augment digestion. Normally, saliva is transferred when goats feed in the same feeding pan sharing microbes at the same time. Rather than buying probiotic drugs products from the store, it is advisable just to transfer fresh cud from a healthy goat into a sick goat's mouth. However, administering store or Internet bought probiotics can help to offset gas, cramping, or diarrhea. Nevertheless, the

interaction between the huge networks of microbes is not very well understood. However, it is obvious that probiotics drugs do not supply all the necessary microorganisms necessary for a well-honed ruminant digestive system.

Summary

Ruminants have a complex digestive system fueled by the appropriate type and amount of feed. The digestion is accomplished by microbes in the reticulum, rumen and omasum with enzyme/acid activity in the abomasum. Essentially, there are three forestomachs and one true stomach. The small intestine conducts enzyme and microbe activity. The cecum and large intestine conduct microbe activity to process the remainder of the undigested material.

Digestion of carbohydrates, proteins, and fatty acids absorbed through the stomachs and intestines supply the majority of the energy needs of the goat. Fiber should be the bulk of the goat's diet with grains and sugars only fed in small amounts. Any diet changes should be done gradually so as not upset the sensitive balance of microbes necessary for proper digestion. The majority of the goat's diet should be forage from browsing, hay, smaller amounts of grains, and vitamins and minerals in trace amounts.