NUTRITION OF SMALL RUMINANTS ON RANGELANDS

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Summary

Goats and sheep make an important contribution to the subsistence sub-sector of the economy of many countries in Africa, Asia and in the Middle East and sheep form the basis of the economy in many developed countries like New Zealand, Australia and Argentina. The vast majority of them are raised on rangelands.

Livestock production in the world's rangelands depends on the exploitation of large and extremely complex ecosystems. Grazing animals need an even and continuous supply of food for their maintenance, and additional food for productive processes as reproduction growth of tissues, and wool. Livestock on many rangelands experience successive periods of surfeits and shortages of food. The seasonal distribution of rain means that annual fluctuations in food supply will occur; unreliable rainfall means that forage may be scarce for protracted periods. Thus many problems of flock management arise from the difficulties of ensuring that the fluctuations in food supplies meet the nutritional needs of the grazing flock.

Small ruminant husbandry in semi-arid areas is characterized by phases of under- and over-nutrition ("phased nutrition"). There is an annual cycle of maximum availability. The peak biomass production can be up to 10 times greater than the lowest biomass production. In drought years the availability approaches zero. Nutrient supply and

individual body condition vary widely within a flock and between months of the year, affecting both separately and co-jointly reproductive performance of female small ruminants. The effects of body condition at mating and body gain before mating are often confounded. The availability of forage is as important a consideration as its quality.

Many factors affect the nutritional requirements of small ruminants: maintenance, growth, pregnancy, lactation, fiber production, activity, and environment. As a general rule of thumb, sheep and goats will consume 2 to 4 percent of their body weight on a dry matter basis in feed. The exact percentage varies according to the size (weight) of the animal, with smaller animals needing a higher intake (percentage-wise) to maintain their weight. Maintenance requirements increase as the level of the animals' activity increases

The nutritional needs of the female small ruminant (ewe/doe) are not static; they vary largely with her stage of production. For 16 to 20 weeks of the year, the energy needs are very critical (such as during breeding, immediately before lambing/kidding, and while lactating).

A marvelous symbiotic relationship exists between rumen bacteria and the small ruminant allowing consumption of dietary material, which would be indigestible to the host animal alone, and produce high quality products (e.g., meat, milk and wool) from end products of bacterial fermentation.

Digestion in ruminant animals is accomplished via microbial breakdown of feed parts in the rumen and reticulum, enzymatic activity in the abomasum and small intestine, and microbial breakdown in the cecum and large intestine. The simple compounds derived from the digestion of carbohydrates, proteins, and fats are absorbed mainly from the fore-stomach and small intestine.

Small ruminants require energy, protein, vitamins, minerals, fiber, and water. Energy (calories) is usually the most limiting nutrient. Deficiencies, excesses, and imbalances of minerals can limit animal performance and lead to various health problems. Fiber (bulk) is necessary to maintain a healthy rumen environment and prevent digestive upsets. Water is the cheapest feed ingredient, yet often the most neglected.

Some aspects of nutrient utilization in small ruminants can affect the reproductive efficiency of females, i.e., estrus activity, ovulation and embryo survival. Nutrition affects reproduction through short and long-term effects. Body condition affects the onset of anestrus, and the resumption of post-weaning estrus if photoperiod is favorable, and ovulation rate.

Many minerals are required by small ruminants. Minerals play a major role in the skeletal and nervous systems functions of the body. Mineral deficiencies occur in all continents and cause decreased production of meat, wool, milk and lambs. In many areas, rearing sheep and goats was impossible because a lack of minerals resulted in high mortality or a complete failure to grow and reproduce. These events often occurred even when pasture was plentiful. Mineral deficiencies may cause clinical disorders that have dramatic effects on health and survival of sheep and goats, or marginal deficiencies that result in subtle and often undetected effects on productivity.

Many diseases can affect the digestive system of sheep and goats. Several are nutritionally-related. Nutrient deficiencies, excesses, and imbalances can cause many disease conditions or predispose animals to other problems. They are common but usually produce only sporadic cases of illness or death loss. However, the wrong combination of events can lead to devastating losses.

The animal's diet from day to day is likely to be based on some kind of compromise between the demands of appetite, the availability of forage, the work of collecting it and the competition provide by other animals. The more arid rangelands are comprised of a great variety of forage species. Grasses and forbs (herbage) predominate, although shrubs and small trees may also make a contribution. The digestibility of the forage is the largest single factor affecting the amount of forage energy available for productive purposes. A value of about 50 per cent digestibility is generally sufficient for animal maintenance. Forage digestibility, can be as high as 75 percent but, on average, values are from 55- 65 per cent. Sheep and goats generally select a diet that is several percentage points higher in digestibility compared with a random sample of the forage on offer. Digestibility varies greatly with the phenology of the plants. In the summer rainfall zones, the digestibility follows a saw-tooth pattern of gradual decline during the dry season and rapid increase in the wet season.

1. Introduction

Small ruminant animals, especially sheep and goats, have a well-documented history of aiding mankind. Biblical references to shepherds and their flocks are numerous. Even more notable is the role of small ruminants in improving the quality of life for mankind throughout history.

Goats and sheep make an important contribution to the subsistence sub-sector of the economy of many countries in Africa, Asia and in the Middle East and sheep form the basis of the economy in many developed countries like New Zealand, Australia and Argentina. The vast majority of them are raised on rangelands.

There are about 400 million goats in the world, with Africa accounting for 67%. In East Africa, Kenya has a goat population of 6.4 million, Tanzania 4.3 million and Uganda 3.9 million. China has over 300 million goats and sheep. The countries bordering the Mediterranean Sea also have many goats. Sheep populations are highest in Australia, China, the former Soviet Union and in Central Asia and Africa.

Millions of goats and sheep are slaughtered and consumed annually for meat. It has to be emphasised that meat production from small ruminants is very important in subsistence farming/herding systems (*see Range Livestock Production Systems in the Near East by Zaroug and Mirreh*) This is so because these animals are more suitable for family consumption of 5-10 people, than cattle owing to their comparatively small carcasses (10-15 kg). The absence of networks of rural electrification in many dryland areas virtually prevents exploitation of refrigeration technology and hence limits preservation and storage capacity of the perishable meat surplus.

2. Digestive System of Goats/Sheep

Mature goats/sheep are herbivorous ruminant animals. Their digestive tracts, which are similar to those of cattle, deer, elk, bison, and giraffes, consist of the mouth, esophagus, four stomach compartments, small intestine, cecum, and large intestine (see *Nutrient Metabolism of ruminants in commercial ranching systems* by Caton and Lady)

A brief description of the anatomy and physiology of the mouth and the stomach compartments of goats and sheep follows:

Like other ruminant animals, goats/sheep have no upper incisor or canine teeth. They depend on the rigid dental pad in front of the hard palate; the lower incisor teeth, the lips, and the tongue to take food into their mouths (see 6.1 below for discussion on diet selectivity). The esophagus is a tubelike passage from the mouth to the stomach. The esophagus, which opens into the stomach at the junction of the rumen and reticulum, helps transport both gases and cud.

The *rumen* is the largest of the four stomach compartments of ruminant animals. The capacity of the rumen of ranges from 11 to 22 liters depending on the type of feed. It is lined with small finger-like projections called papillae, which increase the absorptive surface of the rumen. This compartment, also known as the paunch, contains many micro-organisms, such as bacteria and protozoa, that supply enzymes to break down fiber and other feed parts. Microbiological activities in the rumen result in the conversion of the starch and fiber of feeds to the volatile fatty acids acetic, propionic, and butyric acids. These volatile fatty acids are absorbed through the rumen wall and provide as much as 80 percent of the animal's total energy requirements. Microbial digestion in the rumen is the reason that ruminant animals effectively use fibrous feeds and are maintained primarily on roughages.

Rumen micro-organisms also convert components of the feed to useful products such as essential amino acids, B-complex vitamins, and vitamin K. Afterward, the micro-organisms themselves are digested in the small intestine to free up these nutrients for the ruminant animal's use.

Just below the entrance of the esophagus into the stomach is the *reticulum*: This compartment, is also known as the honeycomb or hardware stomach. The reticulum is part of the rumen separated only by an overflow connection, the rumino-reticular fold. Therefore, microbial action also takes place in this compartment. The capacity of the reticulum of goats ranges from 1 to 2 liters. The next compartment is the *omasum*, also known as the manyplies. It consists of many folds or layers of tissue that grind up feed ingesta and squeeze some of the water from the feed. The capacity of the omasum of goats is approximately 1 liter. The true stomach of ruminant animals is the *Abomasum*. It functions similarly to human stomachs. The mucosa of the fundus contains parietal cells, which secrete hydrochloric acid, and chief cells, which secrete the enzyme pepsin. This enzyme is secreted in an inactive form (pepsinogen), which is then activated by hydrochloric acid. Pepsin is responsible for breaking down feed proteins before they enter the small intestine. The pylorus, which is the terminal portion of the abomasum, is characterized by secretions that are largely mucous. The capacity of the abomasum of goats/sheep is approximately 3-4 liters.

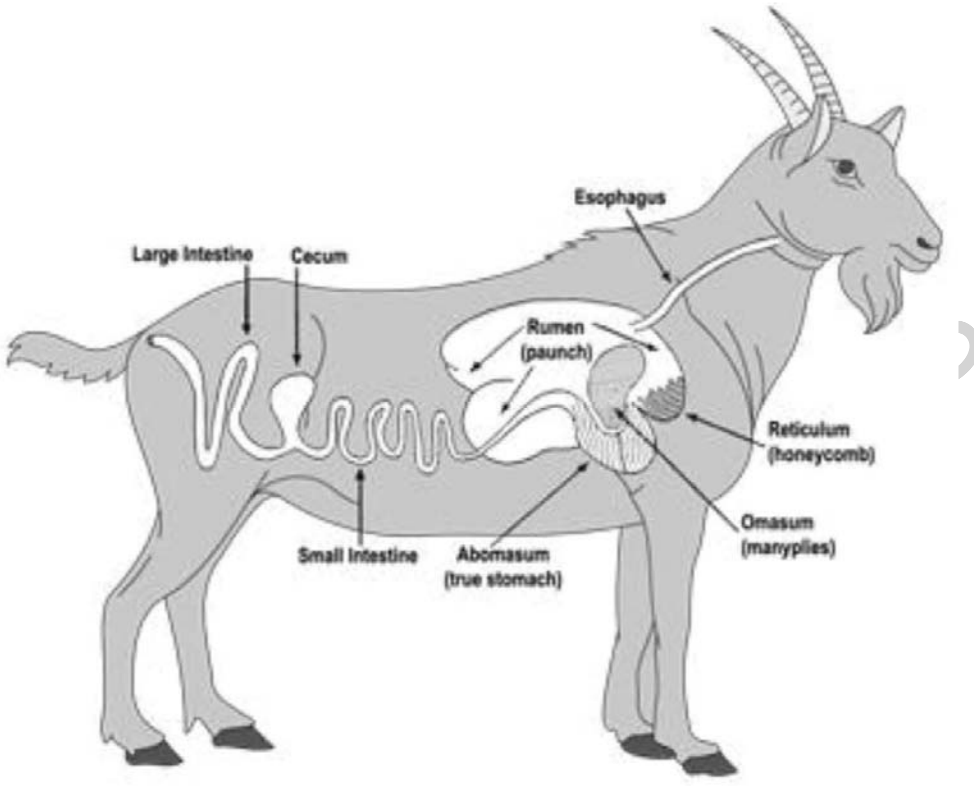

Figure 1. The digestive tract of the goat.

As partially digested feed enters the duodenum, the first part of the small intestine, the enzymes produced and secreted by the pancreas and the Brunner's glands of the duodenum further break down feed nutrients into simple compounds. These compounds are absorbed into the bloodstream or lymph by an active process carried on largely in the jejunum and ileum (second and third part of the small intestine, respectively). The small intestinal wall is lined with many small finger-like projections called villi, which increase the absorption area of the small intestine. The capacity of the *small intestine* of goats/sheep is approximately 9 liters. A simple tubular structure (the cecum) also known as the blind gut, is located at the junction of the small and large intestines. Feed materials entering this compartment are digested by inhabiting micro-organisms. The capacity of the cecum of goats is approximately 1 liter (see chapter *Nutrient metabolism of non ruminants* (*equines*) *in rangeland systems* for a comparison with horses and other equids).

Undigested feed and unabsorbed nutrients leaving the small intestine pass into the *large intestine* The functions of the large intestine include water absorption and further digestion of feed materials by micro organisms. The large intestine is comprised of the colon and rectum. Fecal pellets are formed in the end portion of the spiral colon. The capacity of the large intestine of goats/sheep ranges from 1-1 to 5 liters.

The salivary glands, liver, and pancreas contribute to digestion. Saliva secreted by the salivary glands is important in the chewing of the cud. Bile produced by the liver, and stored and secreted by the gall bladder, helps emulsify fat in preparation for digestion. Enzymes secreted by the pancreas are important in the small intestinal digestion of carbohydrates, proteins, and fats.

In the process of digesting feeds, rumen micro-organisms also produce large amounts of gases, primarily methane and carbon dioxide. The animal normally eliminates these gases by eructation (belching). When the gases are produced faster than the animal can eliminate them, a potentially lethal condition known as bloat can result. This condition is often associated with the rapid consumption of large amounts of leguminous vegetation and is more common in cattle than sheep or goats.

2.1. Development of the Four Stomach Compartments

In the neonate, the rumen is small and the abomasum is the largest of the four stomach compartments. The rumen of a goat kid, for example, is about 30 percent of the total stomach area, while the abomasum is about 70 percent. Hence, digestion in the goat kid is like that of a monogastric animal. In the suckling goat kid, closure of the esophageal groove ensures that milk is channeled directly to the abomasum instead of going through the rumen, reticulum, and omasum. Peptic cells in the abomasum of young milk-fed ruminants secrete, in addition to pepsin, the enzyme rennin. This enzyme is responsible for forming milk curdles and digesting milk protein.

When the suckling goat kid starts to eat vegetation during the first or second week after birth, the rumen, reticulum, and omasum gradually develop in size and function. After approximately two months, the four stomach compartments reach their relative adult proportions.

2.1.1. Rumination

Rumination is defined as the regurgitation, re-chewing, and re-swallowing of rumen ingesta. During resting, animals with four stomach compartments regurgitate ball-like masses of fibrous and coarse feeds called bolus or the cud. The regurgitated cud is chewed thoroughly for about one minute then swallowed again. Ruminant animals may spend up to 8 hours per day in rumination, depending on the type of feed. This phenomenon affects the amount of feed the goat can eat. Reducing the particle size of the feed through re-chewing allows the material to be easily accessible to the micro-organisms and to pass out of the rumen.

2.1.2. Rumen Microbiology

More than 150 different species of micro-organisms have been identified in the rumen. These organisms range from bacteria, the most abundant, to protozoa, fungi, and viruses. Although there are a wide variety of bacteria found in the rumen, they can be loosely grouped into four major categories. A basic understanding of nutrient and environmental requirements of these different microbial groups is necessary to fully appreciate how feeding programs may impact on rumen health. Substrates, nutrient requirements, fermentation end products, and pH tolerance are different for these different microbial groups. One important concept to remember is that fiber fermentation (i.e. the bacterial breakdown of plant cell wall) occurs only at higher pH levels. In abnormal rumen environments, usually one group of bacteria has overwhelmed all other groups and dominates fermentation activity. Reduced dietary amount of either effective or total fiber reduces rumination activity and salivary buffering resulting in acidic conditions impeding fiber fermentation. In addition, with loss of the rumen mat, fiber fermenting bacteria will be washed out of the rumen.

Microbial protein production is a function of dietary ingredients that can be broken down (i.e., degraded or fermented) in the rumen by the microbes. If any of the required building blocks are in limited supply, microbial protein production will be determined by the availability of the most limiting substrate. In many ewe rations based on low quality forages, energy (ATP) and protein are in limited supply. A marvelous symbiotic relationship exists between rumen bacteria and ewe allowing consumption of dietary material, which would be indigestible to the ewe alone, and produce high quality products (e.g., meat, milk and wool) from end products of bacterial fermentation (Table 1).

Nutrient	**Ewe**	**Bacteria**
Energy	VFA's Glucose	Complex Carbohydrates Sugars, Starches, Amino Acids
Protein	Amino Acids Microbial Protein	Ammonia, Amino Acids, Peptides
Minerals	Dietary	Dietary
Vitamins	Dietary Bacterial	Dietary Synthesized

Table 1. Relative contribution by the host (ewe) and the rumen microflora in the digestion process

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Biographical Sketch

Dr Victor Squires is an Australian who as young man studied animal husbandry and later Botany/Ecology. He has a PhD in Rangeland Science from Utah State University. He is a former Dean of the Faculty of Natural Resources at the University of Adelaide and was the Foundation Director of the National Key Center for Dryland Agriculture and Land Use Systems. Since retirement from the University, Dr Squires was a Visiting Fellow at the East West Center in Hawaii and is currently an Adjunct Professor in the University of Arizona, Tucson. He has been a consultant to World Bank, various UN agencies and the Asian Development Bank. He was GEF Advisor on a World Bank pastoral development project in NW China in 2006-2007. He is author of over 100 papers in refereed journals and numerous invited chapters and author/editor of 6 books. He was awarded the 2008 International Award and Gold Medal for International Science and Technology Cooperation by the Government of China.