Building the Best Feeding Program:
Matching Forages to Feeding Groups

Robert J. Van Saun, DVM, MS, PhD, DACT, DACVN
Department of Veterinary & Biomedical Sciences, Pennsylvania State University, University Park, Pennsylvania 16802-3500
Email address: rjv10@psu.edu

Introduction

The practice of feeding animals is considered part science and part art. Unfortunately, when it comes to basic feeding practices for llamas and alpacas, we are short on science and long on art. Scientific reports documenting specific nutrient requirements for camelids are limited. A large portion of the available data comes from research in South America with very different forages from those available here in North America. In most cases, camelid feeding recommendations have been extrapolated from that of sheep and cattle. Available data relative to camelids does suggest a similarity of the digestive process with other domesticated ruminant animals. With a functional understanding of camelid digestive anatomy and physiology, one could make appropriate recommendations based on well established databases for both cattle and sheep. A recent National Research Council (NRC) publication describing nutrient requirements for small ruminants includes suggested requirements for llamas and alpacas [1]. This review will detail the new nutrient requirement models for llamas and alpacas, summarize current nutrient requirement recommendations, and provide some practical feeding recommendations.

Comparative Anatomy and Physiology

New World camelids are ruminant animals ("chewers of the cud") in that they have an expanded foregut to facilitate microbial fermentation of ingested feedstuffs and they chew their cud. However, camelids are not considered "true ruminants" as a result of some very distinct anatomic and physiologic differences in their digestive tracts compared to the variety of species belonging to the Suborder Ruminantia.

Foregut Anatomy and Function

The most striking difference between camelid and ruminant digestive tracts is anatomic; camelids having only three distinct compartments associated with the foregut and stomach as compared to the four compartment ruminant organ (Figure 1) [2]. Another unique feature of the camelid foregut is the presence of small saccules in both C-1 and C-2. These saccules are lined with a glandular (e.g., secretory function) epithelium as compared to the stratified squamous (e.g., protective function) epithelium of the remaining area [2,3]. A secretory function aiding fermentation buffering capacity has

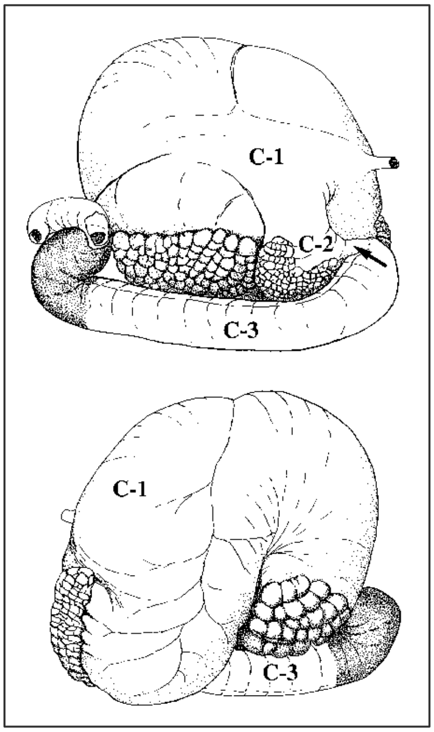


Figure 1. Pregastric fermentation chamber and stomach of camelids (drawing by Dr. Karen Timm).

been suggested [4]. However other investigators have suggested that these saccules aid in rapid absorption of fermentation end products (e.g., volatile fatty acids [VFA]) and solutes [3].

Though anatomically different, studies of fermentation characteristics show the microbial fermentation process and end product VFA production for camelids is similar to true ruminants [2,5]. The microorganisms found in the camelid foregut are the same ones found in other anaerobic fermentation systems (e.g., ruminant foregut and equine hindgut) [6]. This observation is also supported by the clinical ability to transfaunate camelids with rumen contents from cattle, sheep or goats.

Motility of the forestomach is a critical function with regard to continual fermentation activity. Foregut motility ensures constant exposure of the ingested feedstuffs to microbial and subsequent degradation. Similar to the true ruminants, foregut motility in camelids occurs in two distinct phases. Beyond this, foregut motility is dramatically different. In camelids C-2 contracts strongly, followed by contraction of the distal aspect of C-1 (A phase). Phase B initiates when the cranial portion of C-1 contracts followed by contraction of C-2 and the caudal portion of C-1. This B phase may repeat itself 3 to 6 times during a cycle before a brief rest period and beginning of a new cycle [7]. Eructation (e.g., burping of gases) may occur 3-4 times during each motility cycle. In comparison, camelids have greater forestomach activity compared to the single bi- or triphasic contraction per minute of true ruminants. This increased motility pattern found in camelids may also have some bearing on the observation that these animals are fairly resistant to foregut gas accumulation or bloat as opposed to true ruminants.

Feed Intake Differences

Although it would seem that camelids are easily compared to other ruminant animals, there is one glaring difference; dry matter intake capacity. Comparative studies between camelids and true ruminants show a slower rate of passage for particulate material through the camelid foregut [8,9]. This slower rate of passage results in feed materials being retained within the fermentation chamber for a prolonged period of time. As a result of the slowed rate of passage, total feed intake, measured as dry matter intake, will be reduced in camelids compared to other ruminant animals. At maintenance, most ruminant animals will consume between 1.5 and 2.0% of body weight as dry matter feed intake. In contrast camelids have been observed to consume between 1.1 and 1.5% of body weight as dry matter [1,9]. When intake for llamas and alpacas were adjusted for metabolic body weight (i.e., body surface area to mass ratio), there were no differences between llamas and alpacas, but intake was 26% lower for improved and 36% lower for unimproved pastures compared to sheep [9]. This lower intake capacity must be accounted for when extrapolating nutrient requirements from other species. A lower intake capacity in camelids with similar daily nutrient requirements will result in higher dietary nutrient concentration requirements compared to other ruminants.

Camelids are capable of a more extensive fermentation of ingested feed material compared to true ruminants as a result of prolonged feed retention time. This digestive approach would facilitate a diet composed mostly of highly mature, poorer quality forages. In their natural environment, camelids consume this type of diet. From another perspective, high quality forages like alfalfa may result in excessive fat accumulation when fed to camelids. Granted there is much individual variation, social behaviors as well as feed ingredient-based issues that control feed intake.

Metabolic Differences

Although ruminant animals, camelids show unique aspects to glucose and amino acid (protein) metabolism compared to ruminant animals.

Glucose metabolism

Glucose metabolism in camelids is an enigma. Ruminant animals maintain low blood glucose concentration (<70 mg/dl) compared to nonruminant animals (>85 mg/dl). Low blood glucose is the result of microbial fermentation of dietary sugars and starches to the volatile fatty acid propionate, with minimal glucose being presented to the small intestine for absorption. Preweaned milk-fed calves are not functional ruminants and will maintain a higher blood glucose concentration similar to nonruminant animals. As the rumen becomes functional, blood glucose will decline to adult concentrations. In contrast to ruminants, llamas and alpacas maintain higher blood glucose concentrations more similar to that of nonruminant animals. Llamas and alpacas also display an extreme hyperglycemic response (blood glucose concentrations >200 mg/dl) in response to even minimal stress situations. Elevated blood glucose can be somewhat explained by recent studies showing a sluggish insulin response and moderate insulin resistance, somewhat similar to a diabetes condition, in llamas and alpacas [10,11]. This diabetic-like situation in llamas and alpacas may account for their high susceptibility to hepatic lipidosis during periods of stress and reduced feed intake.

Urea metabolism

Another unresolved issue with camelids is the normally higher level of urea nitrogen (UN) in their blood compared to ruminant animals [12,13]. Blood UN concentration reflects protein level of the diet. Low protein diets result in low UN, while high UN is associated with high protein diets or excessive protein breakdown. Higher BUN concentrations in camelids suggest they are being overfed protein relative to requirements, metabolize urea differently from other ruminants, have an inherently high metabolic rate of protein turnover, or some combination [14]. Results from a llama urea metabolism study would suggest llamas have a lower rate of urea turnover, and kidney urea excretion rate compared to other ruminants [15]. These differences allow the llama to recycle more urea to the forestomach for use by bacteria to produce microbial protein. In addition to recycling more urea to bacteria, llamas have been shown to have greater urease activity, the enzyme needed to metabolize urea, than other ruminants [15]. Greater urea recycling and utilization coupled with slower rate of passage in C-1 are critical physiologic adaptations of camelids allowing them to survive in their native environment under harsh conditions consuming low-quality forages for a significant portion of the year.

The observed elevations in blood glucose and UN concentrations may be linked and a unique metabolic adaptation of camelids. A perplexing issue here is the origin of the observed higher blood glucose concentration in camelids. Like other ruminants, camelids do not absorb much dietary glucose as it usually is fermented in the foregut. Predominantly blood glucose is derived from liver synthesis using precursors in the diet, namely propionate. However, typical diets do not contain significant amounts of starch precursors for propionate production. Amino acids are also a good precursor for glucose synthesis. Camelids may metabolize a fair amount of amino acids to support their blood glucose status, thus accounting for the higher BUN concentrations and suggesting a higher than perceived protein requirement.

Animal Requirements - Understanding Essential Nutrients

Energy Requirements

Various simple and complex carbohydrates, including sugars, starches, hemicellulose, and cellulose, are the primary source of dietary energy for camelids. As with other pregastric fermenting animals, the primary source of energy for the host animal is volatile fatty acids, the end product of carbohydrate and protein fermentation. Metabolizable energy (ME) requirement has been determined to be between 61 and 84.5 kcal/kg $BW^{.75}$ [16,17]. This value is somewhat lower than maintenance ME values determined for either sheep (99 kcal/kg $BW^{.75}$) or cattle (133 kcal/kg $BW^{.75}$). An average of the two determined values (72.85 kcal/kg $BW^{.75}$) was used to estimate llama and alpaca maintenance requirements [1,14]. Energy requirement for maintenance will be influenced by environmental conditions, activity level, and animal insulation factors. Animal insulation factors include hide thickness, length of fleece, and condition of the coat (i.e., dry, wet, muddy, etc.). These factors lead to either increased to decreased conduction and convection heat losses and depending upon the prevailing environmental conditions (i.e., heat or cold stress) will result in increased energy expenditure to maintain normal body temperature. Though little data are available, ME requirements for other physiologic states (i.e., growth, lactation, gestation, activity) were extrapolated from sheep and goat requirement data [1,14].

Based on current NRC recommendations, dietary energy density between 50 and 80% total digestible nutrients (TDN) will adequately meet maintenance, late pregnancy, and lactational requirements (Figure 2). In contrast, dietary energy density recommendations from South America range from 48 to 65% TDN and 41 to 59% TDN for alpacas and llamas, respectively. The discrepancy between these recommendations is primarily a result of lower DMI expectations and slightly higher predicted energy requirements with NRC compared to South American data. An 80% TDN diet seems excessively high considering corn grain has 88% TDN. To achieve such a high dietary energy density, one would need to blend 70% corn grain with 30% high quality forage (60% TDN). The low TDN values for the South American recommendations seem too low for North American conditions. Clearly these differences emphasize the need for further investigation into energy metabolism and intake capacity of llamas and alpacas.

The lower dietary TDN value for maintenance can easily be met with good to average quality forages with minimal additional grain supplements. Additional energy supplements will be needed in the diet to support late pregnancy and lactation, especially if lower quality forages are being fed. The feeding of poor quality forages, especially grasses, to late pregnant or early lactating animals will require more grain supplementation, potentially predisposing the animal to foregut acidosis [18], or result in body weight loss and increased susceptibility to hepatic lipidosis (fatty liver disease) [19]. More moderate feeding recommendation summaries for various feeding groups are presented (Table 1).

Protein Requirements

Protein requirement has been estimated to be 3.5 g crude protein/$kg^{.75}$, which is a lower than that estimated for sheep or cattle [14,20]. No data are available to address issues of degradable and undegradable protein requirements in camelids. Another suggested estimate for crude protein requirement is 31 g crude protein/Mcal digestible energy [21]. However, if one calculates crude protein to digestible energy ratio using original data, the protein to energy ratio is much higher, 47 and 54 g crude protein per 1 Mcal digestible or metabolizable energy,

Figure 2. Comparison of dietary energy density (% total digestible nutrients [TDN]) to support maintenance (square), late pregnant (circles), and lactating (triangles) llamas and alpacas based on National Research Council (A) and South American (B) recommendations. Dry matter intake (% of body weight) for maintenance (Maint Intake) is shown as reference.

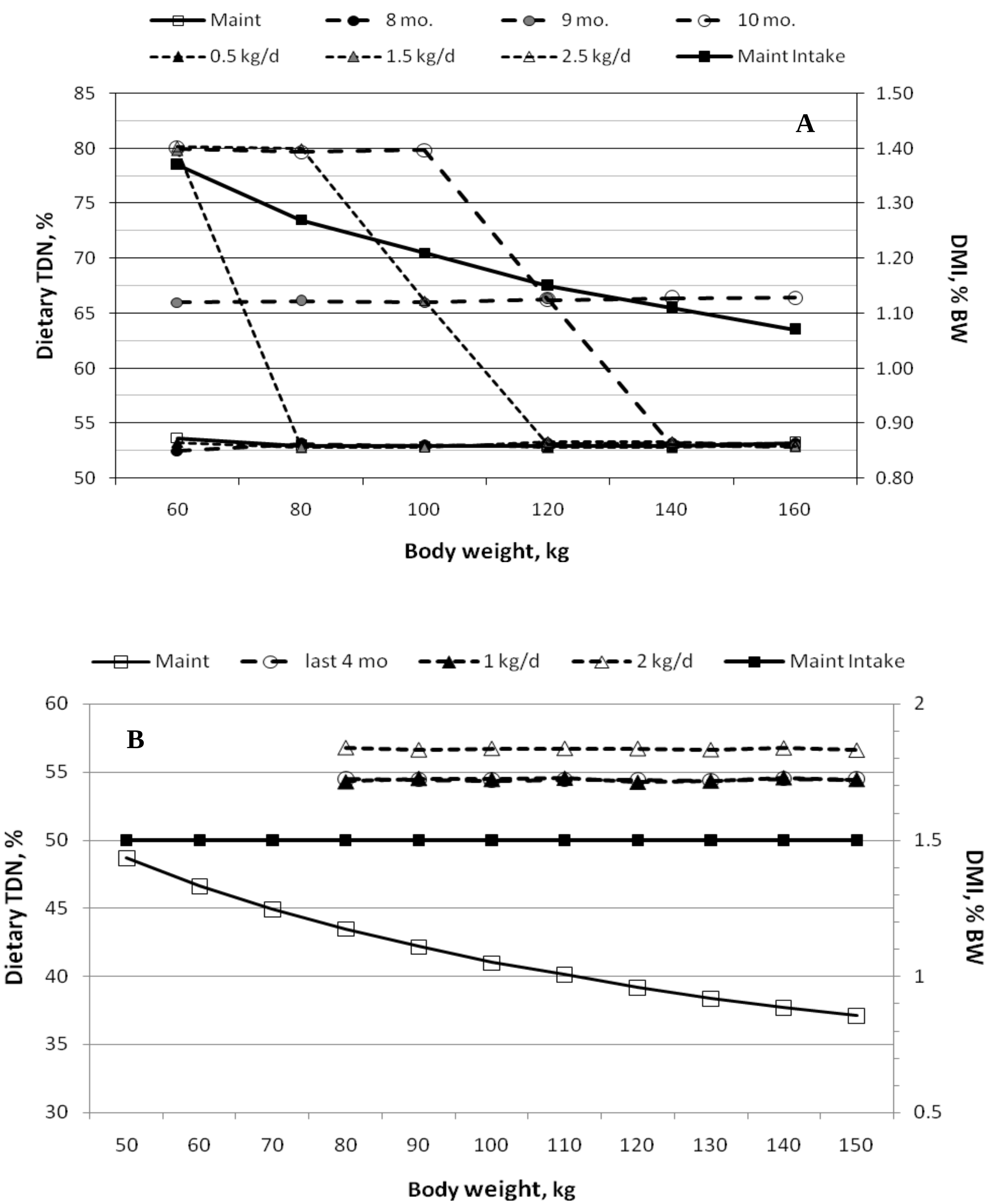


Table 1. Suggested feeding groups based on physiologic state and nutrient requirements. More precise dietary needs will be determined by level of production (milk, rate of growth), environmental conditions and desired changes in body condition.

Group	Physiologic State	Feeding Plan	Dietary Guidelines*
Nursing Dams with crias	Lactation	Highest nutrient requirements, feed best-quality forages, with energy/protein supplements	60 to 70% TDN, 12-14% Crude protein, 0.45-0.62% Ca, 0.32-0.45% P,**
Weanlings up to 1.5 years	Growth	Highest nutrient requirements, feed best-quality forages, with energy/protein supplements	55 to 65% TDN, 14-16% Crude protein, 0.53-0.73% Ca, 0.27-0.38% P, **
Males >1 year	Maintenance	Low requirements unless working, then adjust accordingly, low-to-moderate quality forage	55 to 60% TDN, 8-10% Crude protein, 0.3-0.48% Ca, 0.21-0.28% P,**
Pregnant females 1-8 months	Maintenance	Low requirements, but ensure no loss of body condition, adequate protein, minerals, and vitamins	50 to 55% TDN, 8-10% Crude protein, 0.2-0.24% Ca, 0.12-0.2% P
Pregnant females 9-11 months	Pregnancy	Moderate to high forage quality with supplement for additional mineral and vitamin needs	55 to 70% TDN, 10-14% Crude protein, 0.45-0.56% Ca, 0.28-0.33% P, **,†
Breeding females	Maintenance	Low to moderate; ensure do not become fat or lose condition	50 to 55% TDN, 8-10% Crude protein, 0.2-0.24% Ca, 0.12-0.2% P
Obese females	Sub-Maintenance	Low; low-quality forages with mineral/vitamin supplement unless pregnant	45 to 53% TDN, 8-9% Crude protein, 0.2-0.24% Ca, 0.12-0.2% P

*Ensure adequate available water and free choice salt. White salt should be used when trace minerals are included in a supplement. Otherwise trace mineral salt should be available.

**These feeding groups require higher amounts of trace minerals and vitamins preferably delivered by a supplement (refer to text for details).

†Dietary energy and crude protein content may need to be increased further in late pregnancy if dry matter intake drops below 1.5 percent of body weight.

respectively. This observation is consistent with the idea of a higher protein requirement in camelids. Using a ratio of 48 g crude protein per Mcal ME as an average, protein requirements for other physiologic states were estimated from the defined energy models [1,14].

Calculations of suggested dietary crude protein content range from 9 to 10%, 11 to 16%, and 10 to 16% for maintenance, pregnancy, and lactation, respectively [1]. Variation in dietary protein content is a function of differing expected intakes within a physiologic state and levels of production (gestation month or milk yield). Of concern in the NRC [1] recommendations is the expected increase in dry matter intake with progressing pregnancy. Most data would suggest a decline in intake, thus resulting in a higher dietary protein content to meet daily requirements. This observation underscores the critical need to have reliable information on intake capacity. Lack of good data characterizing milk compositional changes over lactation constrains our ability to more accurately define dietary requirements; resulting in mostly conservative estimates of dietary protein requirements. If grass forages are predominately fed, additional protein supplementation may be necessary to achieve these dietary recommendations.

Mineral Requirements

Feeding trials to establish mineral requirements for camelids have not been completed, thus no specific recommendations have been made in the new NRC publication. However, there are no data suggesting that camelids are distinctly different with regard to any specific mineral to any of the other domesticated ruminant animals [1]. Nutrient recommendations for camelids were extrapolated from beef cattle, sheep, and goat data taking into account this difference in dry matter intake capacity. These extrapolated nutrient recommendations can be used as a starting point for minimum suggested nutrient concentrations in formulating diets. Clinical reports have substantiated llamas and alpacas are susceptible to deficiency and toxicity disease similar to what is observed in other ruminant animals [22]. Further research is necessary to determine if camelids have micromineral requirements higher or lower relative to other ruminants. Camelids seem to be intermediate in their sensitivity to copper toxicity compared to sheep (most sensitive) and other ruminants (more tolerant) [22].

Of the recommended dietary mineral content ranges provided in Table 2, the lower values would be appropriate for maintenance animals and the higher values for growing or lactating animals. The challenge to mineral nutrition in camelids is not only defining the requirement, but facilitating delivery and adequate consumption of mineral supplements. Forages are notoriously variable in their macro- and micromineral content; being predominately low with respect to requirements for most minerals. A predominately forage feeding program for llamas and alpacas will require some form of mineral supplement, balanced to forage mineral content, to be supplied and consumed at an appropriate rate. This becomes the challenge to the animal feeder as there is tremendous variability in commercially available mineral products.

Vitamin Requirements

As with other ruminants, it is hypothesized that all necessary B-vitamins are synthesized by bacteria in the fermentation vat and therefore are not required in the diet. However, under certain stress conditions or fermentation disorders, B-vitamin supplementation may be beneficial. Fat soluble vitamins, namely vitamins A, D, and E, are of greatest concern and should be supplemented in the diet. Vitamins A and E will be adequately ingested if the camelids are grazing on fresh pasture. Dietary vitamins A and E may be insufficient when feeding stored sun-cured forages, thus additional supplementation is required [23,24]. Current NRC

Table 2. Suggested dietary macro- and micromineral concentrations (dry matter basis) for camelids based on sheep and cattle data and adjusted for reduced dry matter intake.

Macromineral	Requirement % DM	Micromineral	Requirement ppm
Calcium	0.17 - 0.75	Copper	8 – 12
Phosphorus	0.14 - 0.43	Cobalt	0.12 - 0.15
Magnesium	0.13 - 0.22	Iron	35 – 40
Potassium	0.6 - 0.96	Iodine	0.55 - 0.75
Sodium	0.07 - 0.14	Manganese	22 – 30
Chloride	0.15 - 0.25	Selenium	0.42 - 0.5
Sulfur	0.19 - 0.23	Zinc	45 - 60

recommendations consider vitamins A and E requirements for llamas and alpacas to be consistent with other small ruminant species [1], suggesting 31.4, 45.5, 53.5, and 100 retinol equivalents (RE)/kg body weight daily for maintenance, pregnant, lactating, and growing camelids, respectively. Vitamin E recommendations are 5.3, 5.6, and 10 IU/kg body weight daily for maintenance, reproduction, and growing animals, respectively. Many mineral supplements may also contain vitamins A and E to meet this need. Fat-soluble vitamins do not significantly cross the placenta, thus the newborn animal is in a fairly deficient state. Most fat-soluble vitamins are important mediators of the immune response, and if deficient, can increase infectious disease susceptibility. Colostrum is a good source of fat-soluble vitamins is the late pregnant dam is adequately supplemented.

A greater documented problem in llamas and alpacas is a vitamin D-responsive rickets syndrome in neonatal (3-6 months) camelids, which is characterized by hypophosphatemia [25]. Further investigation has shown a seasonal incidence with this syndrome with highest incidence occurring during the winter months of December to March, coincident with lowest serum vitamin D and phosphorus concentrations occurring during these same months [26]. These data might suggest a decreased ability of camelids to either absorb dietary vitamin D or synthesize endogenous vitamin D. Further research has shown an appropriate dose response curve to parenteral vitamin D supplementation in treating or preventing the disease [27]. Additional research on oral vitamin D supplementation has suggested a higher level of supplementation (30-40 IU/kg body weight) compared to other species is necessary to maintain preventive serum vitamin D concentrations [1,14].

Feeding Management - Role of Feeding Behavior

Feeding management is that part of the science of nutrition that enters the realm of art. In many instances one could feed the exact same ration to animals on two different farms and observe completely divergent responses. Feeding management is the integration process of providing an adequately formulated diet to the proper animals in a manner which results in sufficient consumption to meet daily nutrient needs. Factors to be considered in feeding management concerns include feed availability, environment, housing facilities, and animal grouping strategies.

Feeding system facilities means size, number, and placement of hay feeders or amount of pasture and expected stocking density. All of these factors need to be considered in properly providing adequate nutrients to all animals. The environment in which the animals are housed should also be considered. How good is the ventilation when the animals are inside? Do the animals have to wade through knee-high mud to get to pasture or hay racks? What kind of feed storage facilities are needed to support the number of animals? What kind of animal segregation can be accomplished with the facilities?

Animal grouping is an important aspect of feeding management. After all we have just discussed how animals in different physiologic states have different nutrient needs. A proper feeding program should have the capability to segregate different animal groups in order to feed to meet their specific nutrient needs.

Most operations would not have the capability to separate out this many groups; however, a number of these groups could be combined as a result of similar requirements. When groups are combined, one needs to be aware of the possibility of overfeeding one or more individuals and make appropriate adjustments. Many llama and alpaca feeding systems are based on individual feeding, which allows one the greatest flexibility in more precisely meeting the daily animal needs.

One other consideration is the proper feeding of the newborn and growing animal. Of first concern is the ingestion of an adequate amount of good quality colostrum or a sufficient substitute (cow or goat colostrum). Neonatal camelids will begin to nibble at dry forage within the first week of life. It is extremely important to remember that the fermentation process in the foregut is not present at birth and needs to be developed over time. Weaning usually occurs between 4 and 6 months of age. Even though fermentation end product concentrations are similar to adult values at 12 weeks of age, this does not mean that the weanling can be placed on adult diets. The higher nutrient requirements to support growth and the less efficient fiber fermentation system of the young animal all support the need for a little special care diet wise to ensure continued good growth and performance. Nothing can set a recently weaned animal back more than a poor quality diet. One can monitor body weight of growing animals to assess adequacy of their postnatal feeding system.

Role of Feeding Behavior

One final piece to the feeding management puzzle is feeding behavior. If one is to have a successful feeding program, irrespective of facility planning, an understanding of the animal’s feeding behavior and how it may be impacted by social behaviors is needed. Llamas and alpacas, like other domestic species, establish and reestablish a strong social hierarchy, which can derail a well-planned diet. Feeding behavior defines what forages are preferred by llamas and alpacas and how selective they may be in consuming other available forages in an environment. The more selective the feeding behavior, the more adaptable the animal is too harsh conditions. An animal’s ability to select feeds is dependent upon two factors: anatomy and feed availability. Both the llama and alpaca have a narrow muzzle and prehensile lips that allows them to be extremely discriminatory in selecting feed to be consumed.

Llamas are considered more of an intermediate browser, preferring to consume some forbs (weeds) and browse (leafy plants) along with grasses. In contrast the alpaca is considered more of a grazer, not preferring to consume forbs and browse. However, forbs and browse have been observed to account for a significant proportion of the alpaca diet in Peru. What this says is that given the opportunity, llamas and alpacas will make good use of non-grass forage as part of their diets. Therefore, feeding management programs that minimize the llama’s nature ability to forage are more critically dependent upon forage quality concerns. These comments are not inferring that overrun weedy pastures are the preferred feeding management system for camelids.

Often the question of forage type is asked relative to feeding llamas. Is alfalfa better than grass or visa versa? There really is no simple answer. Alfalfa hay has received much negative press relative to feeding camelids in that it is often associated with causing obesity. Situations of malnutrition or deficient energy intake where alfalfa was fed have not been documented. In contrast, most cases of malnutrition, hepatic lipidosis, or other energy deficiency problem have been associated with grass hay feeding programs.

One needs only to understand the difference between alfalfa and grasses relative to the relationship of stems and leaves in each plant. Alfalfa has a very distinct leaf and stem. As the plant matures, the stem thickens but this does not significantly impact nutrient availability in the leaf. With the selective feeding ability of the llama, the alfalfa leaf could be preferentially consumed, thus potentially leading to obesity problems. In situations where mature alfalfa is being fed, the animal can compensate for the low forage quality by primarily consuming the leaves. The llama does not have this luxury with the grass plant. In grasses the leaf and stem are one in the same. As the grass matures and becomes more lignified, nutrient availability is greatly reduced and the animal cannot compensate for low forage quality with selective feeding behaviors if no other forage source is available. Thus the association of more animal health problems with mature grass forages.

Body Condition Scoring

There are a number of ways one can determine nutrient adequacy. By far, the single best method is body condition scoring. Body condition scoring is a method which subjectively grades animals by amount of subcutaneous fat stores over the loin, pelvis, and tailhead into five categories covering physical states of emaciated (1), thin (2), average (3), fat (4) and obese (5) (Figure 3). Alternative scales are also used grading animals from a 1 to 9 scale [28,29]. As with sheep, to body condition score a camelid one needs to palpate through the fiber coat to feel the ribs, loin, and pelvis for thickness of fat cover. Important times to assess body condition score would be during early to mid pregnancy; early to mid lactation and periodically to other animals of the herd to assess energy status [28]. As a diagnostic tool, body condition scoring is the least expensive and yields excellent information relative to animal energy balance. However, body condition scoring is often overlooked as a herd management tool because it is viewed as being too time consuming.

Summary

Nutrition of llamas and alpacas is not necessarily complicated, though some unique differences provide some challenges. The intent of this review was to provide readers with a strong foundation on which to make sound decisions, based on functional knowledge, relative to their feeding management approaches. The current state of knowledge on llama and alpaca nutrition is limited, but growing with many essential components being available. Given the majority of financial resources needed to maintain a camelid herd goes to nutrition, owners also need to be informed in various aspects of agronomy. Understanding the fundamentals of forage growth and its impact on composition is absolutely essential to making a nutrition program work. Distributing available forages to match quality with animal requirements will provide the greatest return on investment through improved animal health and performance. The final phase is knowledge application-- integrating issues of animal numbers, forage resources, and handling and feeding facilities into an economically sound nutrition program designed to maintain good animal health and meet desired level of productivity.

Figure 3. Body condition scoring chart for llamas and alpacas. Degree of fatness is assessed by hands-on palpation of four defined areas as shown. Transverse processes of the spine and the paralumbar fossa are located in the region behind the ribs and in front of the pelvis (on last page of notes).

References

[1] National Research Council. Nutrient Requirements of Small Ruminants, National Academy Press: Washington, DC, 2007.

[2] Vallenas A, Cummings JF, Munnell JF. A gross study of the compartmentalized stomach of two New World camelids, the llama and guanaco. J Morphology 1971;134:399-424.

[3] Rübsamen K, von Engelhardt W. Morphological and functional peculiarities of the llama forestomach. Ann Rech Vet 1979;10:473-475.

[4] Eckerlin RH, Stevens CE. Bicarbonate secretion by the glandular saccules of the llama stomach. Cornell Vet 1973;63:436-445.

[5] Vallenas A, Stevens CE. Volatile fatty acid concentrations and pH of llama and quanaco forestomach digesta. Cornell Vet 1971;61:238-252.

[6] Navarre CB, Pugh DG, Heath AM, Simpkins A. Analysis of first gastric compartment fluid collected via percutaneous paracentesis from healthy llamas. J Am Vet Med Assoc 1999;214:812-815.

[7] Heller R, Gregory PC, von Engelhardt W. Pattern of motility and flow of digesta in the forestomach of the llama. J Comp Physiol B 1984;154:529-533.

[8] Clemens ET, Stevens CE. A comparison of gastrointestinal transit time in ten species of mammal. J Agric Sci, Camb 1980;94:735-737.

[9] San Martin FA. Comparative forage selectivity and nutrition of South American camelids and sheep. Texas Tech Univ, Lubbock, TX (PhD Dissertation), 146 pp, 1987.

[10] Cebra CK, Tornquist SJ, Van Saun RJ, Smith BB. Glucose tolerance testing in llamas and alpacas. Am. J. Vet. Res. 2001;62(5):682-686.

[11] Cebra CK, McKane SA, Tornquist SJ. Effects of exogenous insulin on glucose tolerance in alpacas. Am. J. Vet. Res. 2001;62(10):1544-1547.

[12] Lassen ED, Pearson EG, Long P, Schmotzer WB, Kaneps AJ, Riebold TW. Clinical biochemical values of llamas: Reference values. Am J Vet Res 1986;47:2278-2280.

[13] Simons JA, Waldron DL, Hennessy DP. Clinical biochemical reference ranges for female alpacas (Lama pacos). Comp Biochem Physiol 1993;105B:603-608.

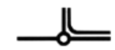
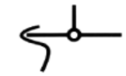
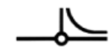
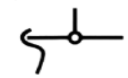
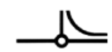
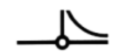
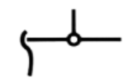
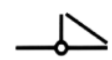
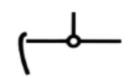
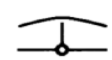
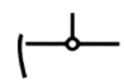
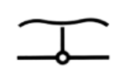
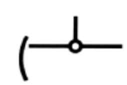
[14] Van Saun RJ. Nutrient requirements of South American camelids: A factorial approach. Small Rum Res 2006;61:165-186.

[15] Hinderer S, von Engelhardt W. Urea metabolism in the llama. Comp Biochem Physiol 1975;52A:619-622.

[16] von Engelhardt W, Schneider W. Energy and nitrogen metabolism in the llama. Anim. Res. and Develop. 1977;5:68-72.

[17] Carmean BR, Johnson KA, Johnson DE, Johnson LW. Maintenance energy requirement of llamas. Am. J. Vet. Res. 1992;53:1696-1698.
[18] Cebra CK, Cebra ML, Garry FB, Belknap EB. Forestomach acidosis in six New World camelids. J Am Vet Med Assoc 1996;208:901-904.
[19] Tornquist SJ, Cebra CK, Van Saun RJ, Smith BB. Metabolic changes and induction of hepatic lipidosis during feed restriction in llamas. Am J Vet Res 2001;62:1081-1087.
[20] San Martin FA, Bryant FC. Nutrition of domesticated South American llamas and alpacas. Small Rum Res 1989;2:191-216.
[21] Fowler ME. Feeding and Nutrition. Medicine and Surgery of South American Camelids: Llama, Alpaca, Vicuna, Guanaco, 2nd ed., Ames: Iowa State University Press, pp. 12-48, 1998.
[22] Van Saun RJ. Nutritional diseases of South American camelids. Small Rum Res 2006;61:153-164.
[23] Dart AJ, Kinde H, Hodgson DR, Peauroi JR, Selby AW, Maas J, Fowler ME. Serum α-tocopherol, vitamin A, and blood selenium concentrations, and glutathione peroxidase activity in llamas fed alfalfa hay. Am J Vet Res 1996;57:689-692.
[24] Smith BB, Van Saun RJ, Reed PJ, Craig AM, Youngberg A. Blood mineral and vitamin E concentrations in llamas. Am J Vet Res 1998;59:1063-1070.
[25] Van Saun RJ, Smith BB, Watrous BJ. Evaluation of vitamin D status of llamas and alpacas with hypophosphatemic rickets. J Am Vet Med Assoc 1996;209:1128-1133.
[26] Smith BB, Van Saun RJ. Seasonal changes in serum calcium, phosphorus and vitamin D concentrations in llamas and alpacas. Am J Vet Res 2001;62:1187-1193.
[27] Judson GJ, Feakes A. Vitamin D doses for alpacas (Lama pacos). Aust Vet J 1999;77:310-315.
[28] Hilton CD, Pugh DG, Wright JC, Waldridge BM, Simpkins SA, Heath AM. How to determine and when to use body weight estimates and condition scores in llamas. Vet Med 1998;93:1015-1018.
[29] Johnson LW. Llama Nutrition. Vet Clinics of NA: Food Anim Pract 1994;10:187-201.

Body Condition Scoring Sheet for Camelids

	Score	Animal Description	1 Frontal Profile	2 Rear Profile	3 Spinous to Transverse Process	4 Paralumbar Fossa
Emaciated	1.0	No visible or palpable fat or muscle between skin and bones. Ribs, dorsal spinous and transverse processes, and pelvic bones are individually prominent. Extreme loss of muscle mass.	Prominent "V" Keel	Acutely Inverted "V"	 Deep depression	Gaunt, tucked-in fossa 
Poor	1.5					
Thin	2.0	Slight cover over bony structure. Ribs, spinous processes still visible and easily palpated as sharp. Less muscle mass loss.	Gradual Flattening of Sternum	Gradual Filling of "V"	Obvious depression	 Prominent shelf
Borderline	2.5					
Moderate	3.0	Overall smooth appearance. Slight fat cover over ribs and other bony processes. Ribs and spinous processes can be palpated with slight pressure. No muscle mass loss present.			 Smooth concave curve	 Slight shelf
High Moderate	3.5		Moderate fat	Moderate fat	 Smooth slope	
Excess	4.0	Fleshy appearance with visible coverage of fat. Moderate to firm pressure necessary to palpate bony structures under skin.			 Nearly flat	No shelf
Fat	4.5					 Edge barely discernable
Grossly Obese	5.0	Excessive fat cover over entire body with smooth, rounded appearance. Bony prominences cannot be palpated, even with firm pressure. Bulging fat pads visible around tailhead.	Sternum Bulging in fat	Inguinal Area Bulging in fat	 Rounded	 Buried in fat

Adapted from Edmonson et al., JDS 1989;72:68 and Russel, A. Body condition scoring sheep, Sheep and Goat Practice 1991.