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Nutritional Assessment, Nutritional Requirements and Forage Analysis of Llamas and Alpacas

Fiamma Gomez
University of Tennessee - Knoxville

NUTRITIONAL ASSESSMENT, NUTRITIONAL REQUIREMENTS AND FORAGE ANALYSIS OF LLAMAS AND ALPACAS

Dr. Fiamma Gomez, Large Animal Internal Medicine Resident
University of Tennessee Veterinary Medical Center

I. NUTRITIONAL ASSESSMENT

The nutritional status of llamas and alpacas can be particularly difficult to assess because they are stoic animals and their fiber coat can hide changes in body weight.

However, nutritional assessment of camelids can be made simple by three means:

1) Routine monitoring of body condition score (BCS) or body weight **(FIGURE 1)**

You should assess the BCS of your animals once a month, particularly at times of pregnancy, lactation and systemic disease. To body condition score a camelid you need to palpate through the fiber coat to feel the ribs, loin, and pelvis for thickness of fat cover; additionally, you should also visualize the degree of fatness in the brisket and inguinal regions. As animals lose weight, and thus fat, these areas become more pronounced and angular, whereas they are normally smooth and rounded.

The ideal body condition is between 2.5 to 3.5 on a scale of 5. Late pregnant females should have a BCS of 3 to 3.5, in order to have reserves to support impending lactation. Lactating animals will lose weight rapidly as they produce milk, but should not decrease by more than 0.75 overall.

2) Forage and feed testing (see below)

3) Blood metabolite analysis

Blood analysis can be helpful to determine the nutritional status of the animal. Blood analysis is only a supplement to a good BCS determination, animal examination and feed analysis. Have your veterinarian collect blood from a healthy animal to avoid confounding effects of disease.

- NEFA (nonesterified fatty acids) – Measures the fat mobilization due to a deficient energy intake.
- BHB (β-hydroxybutyrate) – Also increases along with NEFA when there is a negative energy balance.
- BUN, total protein and albumin can be used to assess the protein status.

The BCS is a long-term assessment of nutritional status, whereas blood NEFA and BHB concentrations reflect acute changes.

II. FORAGE ANALYSIS

Here are some basic questions that we will try to answer:

1) Why do camelids require forage?

2) What is "forage quality"?

3) How do I determine if I have good quality forages?

4) How much does hay analysis costs?

You do not need to be an expert in order to correctly feed your llama; you just need a basic understanding of camelid digestive function and forage quality.

1) Why do camelids require forage?

Nutritional requirements and disease

To keep our animals alive and healthy, nutrients are needed to keep the basic body functions working properly. This is called the ***maintenance energy requirement***. However, more **energy** is required when we want our camelids to produce crias, provide high quality fiber, and engage in work (e.g. packing llamas).

If there is an imbalance between the forage quality and the nutritional needs then we can have:

- ***Negative energy balance*** (not enough nutrients) we can have problems such as:
  - Malnutrition
  - Slow gain rate in growing animals

- With ***overconsumption*** (the animal ingests more nutrients than required):
  - Obesity
  - Hepatic lipidosis ("fatty liver"), such as in late pregnant and lactating females.
  - Gastro-intestinal upsets and acidosis when too many supplements (such as cereal grain) are available.

Selective feeding behavior

Camelids have a narrow muzzle and prehensile lips, therefore they are extremely discriminatory in selecting the feed consumed. Depending on the forage provided a selective feeding behavior may or may not be allowed:

Forage	*Allows a selective behavior*	*Comments*
Legumes (e.g. alfalfa)	Yes	The animal can select the leaves. This can create a state of obesity if good quality forage is provided, or may allow the animal to obtain a higher quality feed even with low-quality (mature) alfalfa
Grass	No	More health problems are usually encountered with mature grass forages, because they have less leaves, and are more stemmy, therefore not allowing a selective feeding behavior.
Blended forages	Yes	This is why feeding programs with mixed-forages and pasture access may have the greatest application, allowing animals to best express their selective feeding behaviors.

South America vs North America

But…why is forage quality so important for my llama or alpaca? After all, aren't forages grown in North America of far better quality compared to those in South America? Mmmm…..this is only partially true:

1) Yes, it is true that forages near the equator are exposed to higher temperatures and longer day light which induces the production of fibrous forages (high cell wall and lignin content), low in protein and low in nutrient availability. However, llamas and alpacas live at high altitudes were the temperatures are lower, and hence the forages are less fibrous.

2) The camelids of South America are not nearly as productive as the camelids in USA. Consequently, a higher nutrient intake and forage quality is required to achieve this level of production with our New World Camelids.

The critical issue relative to forage quality is the ability of the forage to meet a given animal's nutrient requirements with forage. If the nutrient content of forage is insufficient, then additional supplements will be required, or health and production will be compromised.

Good quality forage is advantageous because it is more conductive in maintaining good animal health by providing the essential nutrients directly to the animal; further, it will reduce your purchased feed costs.

2) What is "forage quality" (FQ)?

The concept of ***forage quality (FQ)*** is used to describe the content and availability of the forage essential nutrients, which includes the energy, proteins, minerals and vitamins.

The FQ is a useful tool to: - Assess if the forage meet the nutritional requirement of a given animal
- Guide a proper ration supplementation

Forage quality is characterized by several processes:

1. Intake - *Will the animal eat the forage?* High palatability = high intake = high FQ.

The intake is the reflection of the palatability of the forage, which is defined by the smell, taste, texture, leafiness, fertilization, and moisture content.

2. Digestibility - *How much of the forage is actually absorbed by the gastro-intestinal tract?*

The digestibility varies greatly among forages, but in general the digestibility decreases with the maturation of the plant.

3. Availability - *Once digested, will the forage provide an adequate level of nutrients?*

The availability is the reflection of the nutrient content of the forage. In order to assess the nutrient content and compare forages, we have to convert the living forage to dry matter (see below).

4. Anti-quality factors – *Does the forage contain toxic harmful compounds?*

5. Animal performance - *Is my animal performing correctly with this type of forage?*

The forage provided should not only be able to maintain a good body condition score, but it should also allow an optimal performance in the desired category (reproduction, high quality fiber, soundness…). Performance of the animal is a way to assess FQ especially when forages are fed alone and free choice.

Assessing the FQ:

1) The FQ is most importantly affected by the **Stage of maturity** at harvest **(FIGURE 2)**.

The difference between a mature and an immature plant is summarized in the following table:

Plant	*Definition*	*Components*	*Nutrients*	*Digestibility*	*Dry matter yield*
Immature	Rapidly growing	High leaf/stem ratio (many leaves)		↑	
Mature	Reproductive components (flowers, seeds)	- ↑ cell wall fiber and lignin - Low leaf/stem ratio (more stems)	↓	↓	↑

As you can see, with the advance in plant maturity the FQ declines due to a higher fiber content, lower leaf/stem ratio and an overall decline in nutrients and their digestibility. Further, as plants mature and become more fibrous, the forage intake drops dramatically. This is because the older fibrous plants are more difficult to digest.

2) Plant species

The forages can be in the form of hay or pasture, and can originate from **legumes** (such as alfalfa or clover), **grass** (timothy, orchard grass, fescue, ryegrass, etc) or **mixed forage.**

Legumes vs grasses - To understand the difference between legumes and grass forage, we first need to describe the difference between the leaves and stems:

Leaves	***Stems***
High in digestible nutrients (higher FQ)	High in cell wall components = poorly digested, decreases the availability of other nutrients (lower FQ)

Having this in mind, it is easier now to visualize the difference between the legumes and grasses:

	Legumes: Alfalfa	***Grasses: Timothy***
Leaves and stems	They are distinct	They are intertwined
Leaf/stem ratio	High (many leaves)	Low (more stems)
Digestible nutrients	More (leaves)	Less (stems)
Energy	More	Less
Decreased energy with maturity	Less	More
Fiber	Less	More
Favor intake	More	Less
FQ	Higher	Lower

Legume: Alfalfa 

Grass: Timothy 

Cool season vs warm season forages

	Cool season (temperate regions)	***Warm season*** (tropical and subtropical)
Types	**- ORCHARD GRASS** **- FESCUE GRASS** **- TIMOTHY** - Kentucky blue-grass - Perennial and annual ryegrass	**- BERMUDA GRASS** - Bahia grass - Dallis grass - Corn
Digestibility	Higher (9 % more)	Lower (their leaves are more lignified)
Crude protein	Higher	Lower
Yield	Less	More
FQ	Higher, varies with the season	Lower, but less linked to the season

The cool season grasses usually have cold winter and hot summers, and they tolerate periods of draughts by going dormant. The FQ of cool season grasses is very linked to season. They are adapted to have cold winters (required for flowering) and hot summers, and they tolerate draught by going dormant. Only in the spring they produce the reproductive stems (mature plant with lower FQ), followed by re-growths of higher and more stable FQ.

Legumes and some grasses such as bermuda grass can flower several times each season, so their FQ patterns are less closely linked to the season.

This explains the benefits of feeding a blend of legumes with grasses to improve the FQ of the forage (higher crude protein and lower fiber concentration than grass alone).

3) Environmental factors

Temperature and daylight are the 2 most important environmental factors affecting the FQ, and they explain most of the within and between year variation of FQ from a given location.

Temperature - In general plants grown at high temperatures produce lower quality forages, because a larger amount of fiber (cell wall and lignin) is produced, decreasing the digestibility.

Daylight - When the daylight increases the plant is more active to produce highly digestible sugars and the yield is increased, improving the FQ.

Fertilization - Applying substantial amounts of nitrogen fertilizer to grasses can make their crude protein levels comparable to legume forage, and can also increase the yield. However, excessive levels of some elements (e.g. potassium) may decrease the availability of other elements (e.g. magnesium).

Daily fluctuations in FQ – Plants accumulated simple sugars during the day and use them overnight. Thus, soluble sugars are lowest in the morning and highest after a day of bright sunshine.

Rainfall – When there is drought stress, there is a decline in the cell wall production, which actually delays the plant maturity, improving the FQ.

4) Harvesting and storage

Harvesting – It mainly affects the dry matter. Improper harvesting techniques induce the loss of leaves, which implies the loss of proteins and a decrease in digestible dry matter. Rainfall on cut forage induces leaching of highly digestible nutrients, particularly the leaves of legumes. Damage from rain increases as forage becomes dryer, and is especially severe when rain occurs after it is ready to bale.

Storage –It mainly affects the wet material. The exposure of bales to air and sunlight (forage stored uncovered) for 45 to 60 days induces a 30 to 40 % decrease in digestible nutrients (dry matter), as opposed to 10 % if the bales are covered. Refusal during feeding of cows ranged from 1 % for inside-stored bales to 22 % for bales stored outside on the ground. A moisture level above 15 % increases the risk of yeast and mold grow; this is more frequently encountered with large round bales, were it can be problematic to decrease the moisture to the desired level.

3) How do I determine if I have good quality forage?

1. Sensory evaluation of hay

1)	Visual	
	Stage of maturity	Look for the presence of seed heads (grass forages) or flowers or seed pods (legumes), indicating more mature forages
	Leaf-to-stem ratio	Look at forage and determine whether the stems or leaves are more obvious; good-quality legume forages will have a high proportion of leaves, and stems will be fine and less obvious
	Color	Color is not a good indicator of nutrient content, but bright green color suggests minimal oxidation; yellow hay indicates oxidation and bleaching from sun, and hay will have lower vitamins A and E content
	Foreign objects	Look for presence and amount of inanimate objects (twine, wire, cans, etc.), weeds, mold, or poisonous plants
2)	Touch	Feel stiffness or coarseness of leaves and stems; see if alfalfa stems wrap around your finger without breaking; good-quality hay will feel soft and have fine, pliable stems
3)	Smell	Good quality hay will have a fresh mowed grass odor; no musty or moldy odors

2. Chemical testing – Forage analysis

The forage test is highly recommended particularly when hay is the primary forage in a feeding program. The goal of any feeding is to make sure that the available feed ingredients meet the daily nutritional requirements. To accomplish this goal we need to know the nutritional composition of the feed ingredients, which varies tremendously between different feeds. This is especially true for forages: forages harvested from the same field, same year can vary greatly due to the influence of environmental conditions and cutting time.

Hay sampling - In order to assure a representative sample of hay, follow this recommendations:

1. Identify a single lot of hay - Ideally the lot of hay selected should be from a single cut, field and variety. Different lots should be sampled separately.

2. *** When to sample?* -*** You should sample the hay as close as possible to sale or to feeding. Particularly DM can vary after harvest and during storage. During the days or weeks after harvest the hay may heat up due to the activity of microorganisms, losing some of its moisture. If the hay has been baled at excess moisture, further biological activity may result in molding. However, after hay has equilibrated to the range of 90% DM (10% moisture), it is typically quite stable.

3. Hay probe and technique

– It is not ideal to send flakes or grab samples, because they will not represent a hay lot. Hand-grab samples have been shown to be significantly lower in quality than correctly sampled forage.

– Chose a sharp coring device, 12-14 inches long, with a 3/8–3/4 diameter, a tip 90' to shaft and produce ½ lb (200 g) samples . Sample butt ends of hay bale, between string or wires, not near the edge. Probe should be inserted at 90° angle, 12 – 18 inches deep.

– To sample pasture or browse is more difficult: you need to mimic the selective behavior of the animals in order to obtain a representative sample. Collect the samples randomly, but based on your observation of the areas grazed by the animals. Ideally you want to collect samples before the animals are allowed to graze; however, this may limit your ability to collect the samples that the animals may graze.

4. *** Sample at random *** - Walk around the stack, and sample bales at random, trying to represend all areas of the stack. Do not avoid or select bales because they look especially bad or good.

5. *** How many cores should I take? *** If you have a large hay inventory, collect 2-3 core samples from 10-20 % of the bales. If you have a limited inventory, sample all bales. You need a minimum of 20 cores to represent a hay lot. This is because core-core (and bale-bale) variation in FQ is tremendous.

6. *** Send out of samples *** - Collected core samples should be mixed thoroughly and placed in a clean well-sealed plastic bag (double bagging is even better) and protect from heat. Deliver to lab as soon as possible. Do not allow samples to be exposed to sun (e.g. in you car); refrigeration of hay samples is helpful; however, dry samples (90 % DM) are considered fairly stables.
The pasture or browse samples should be frozen (due to their high moisture content).

7. *** Choose a NFTA-Certified lab *** (National Forage Testing Association) – This is a volunteer group set up by growers, sends blind samples to labs, and they must match the true mean within an acceptable range of variation. Make sure that the lab you chose grounds the entire sample that you sent. If you want to test two labs, either grind and split the sample (never split un-ground samples), or better yet, ask for your ground sample back to send to another lab. Never work with labs that are unwilling to do this, labs should be willing to tests their performance. www.foragetesting.org

Understanding feed analysis (FIGURE 3 and 6) - A typical forage analysis includes the measurement of the several components listed below. However, it is the dry matter and crude protein that are the main determinants of FQ.

***** 1) Dry matter (DM) ***** - This is the portion (weight) of feed that is not water, this is, the non-moisture portion. There is 3 reasons why wee convert the nutrient content of feeds to a DM basis:

1. To eliminate the dilution effect of moisture - It is in the DM that the essential nutrients are located. We convert to a DM basis because feeds vary tremendously in their moisture content:

- Pastures contain 75 to 90 % moisture (or 10 to 25 % DM)
- Dried feeds contain < 15 % moisture (or > 85 % DM)

2. Allow to compare nutrient content of different feeds on an equal basis - The nutrient content on a DM basis is always superior than in an "as fed" basis (moisture included) , in which the nutrients are "diluted" by the water. The use of DM facilitate the formulations of diets, and monitoring of animal DM intake.

3. To compare prices and nutritive value among lots of forage - The DM is used to evaluate if the feed moisture content is within the expected ranges. For example, hay with excessively low moisture (< 10%) could indicate brittleness (low palatability) or excessive leaf loss; hay with excessively high moisture (> 15 %) will promote mold growth. The DM percentages should be used to adjust as-received tonnages to determine true yields of forage and to determine the actual amount of forage (without the water) being bought or sold.

***** 2) Fiber *** -** As fiber increases, the FQ declines. Two measures are used to assess the fiber content of forage:

1. Neutral detergent fiber (NDF) - Measures the total components of the plant cell wall, which include the **hemicellulose, cellulose, and lignin**. As the plant matures, the cell wall production (and the NDF) increases, decreasing the animal DM intake, and increasing the chewing. Consequently, the NDF is used to predict feed intake: when NDF ↑, the voluntary feed intake ↓.
However, if the NDF of the ration is too low, other health problems may occurs (e.g. acidosis).

2. Acid detergent fiber (ADF) – ADF is a subset of NDF, and contains the poorly digestible cell wall components (**cellulose and lignin**) and **ash.** The ADF is used to predict the energy content and digestibility of feeds.

***** 3) Crude protein (CP) *** -** In ruminants the protein content is often measured as CP in order to take in consideration the non-protein nitrogen that is converted into microbial protein by the rumen microbes. The CP is 6.25 times the nitrogen content of forage: CP = Nitrogen content of forage (N %) x 6.25

The CP vary greatly among forages, and is a good reflection of the FQ because as forages mature, the fiber content increases, and the CP decreases. However, the CP cannot be used when there is a high level of nitrate (fertilizers) in the forage, and explains why both the CP and fiber should be used to evaluate the FQ.

In the results of your hay analysis you may find the term Relative feed value (RFV). This is a score of hay crop forages that is derived from the ADF and NDF. It is considered that the RFV of alfalfa should be between 100 to 150, and the RFV of grasses should be between 80 and 100.

4) Energy

The energy level of a given feed is not directly measured. It is derived from calculations of CP, NDF, lignine, fat, ash and non-fiber carbohydrates. Based on these calculations, six measures of energy exist:

1. Total digestibility nutrients (TDN) - TDN is the best energy estimate for camelids, given the similar digestive functions between cattle and camelids. Consult table of Figure 4.

2. Metabolizable energy (ME) – Calculated based on the following formula: 60 to 85 kcal/kg x BW $^{0.75}$

3. Digestible energy (DE) – Derived from the formula: DE = (TDN x 2)/100 Mcal

4. Non-fiber carbohydrates (NFC) – This is a calculated value, and so all laboratory analytical errors will be compiled into this NFC value. Since the NFC includes the non-structural carbohydrates, which are the most digestible portion of the plant, the higher the NFC value the higher the FQ.

5. Net energy maintenance (NEm)

6. Net energy lactation (NEl)

7. Net energy growth (NEg)

These are the primary energy values used in cattle. They measure how efficiently the animal uses the energy for maintenance (NEm), to produce milk (NEl) or to grow (NEg). However, due to different fiber degradability between cattle and camelids, the feed energy availability of lower-quality forage predicted for cattle is too low compared to camelids; in other words, camelids can get a higher feed availability from poor-quality forage compared to cattle.

5) Other

1. Fat (Ether extract) - Little value in evaluating feed quality (except when comparing high fat feeds).

2. Minerals – *Macro-minerals:* Calcium, phosphorus, magnesium, potassium, sodium and sulfur
- *Micro-minerals:* Iron, copper, zinc, manganese, molybdenum

4) How much does a hay analysis costs?

The most common reasons that people cite why they do not perform a hay analysis includes:

1. Costs - The price can be between $12 to 40 for the basic tests depending on methodology used and number of tests performed.

2. Lack of laboratory availability – Today the labs are easily available. Make sure you use certified feed analysis laboratories: www.foragestesting.org

3. Constant forage turn-over - This can be an issue in farms that purchase small lots of hay often. However, if you are having health problems with your camelids running a hay tests is definitively worth the price and effort. This is particularly true if you are having cases of protein energy malnutrition despite your impression of feeding an adequate amount of forage and/or supplements.

III. NUTRITIONAL REQUIREMENTS

There is little research studies and lots of empiric knowledge concerning llamas and alpacas basic feeding practices. However, several extrapolations can be done from other ruminants due to similar digestive process and susceptibility to nutritional diseases.

Here are some basic questions that we will try to answer:

1) What is it so different between camelids and other ruminants?

2) What are the nutritional requirements of llamas and alpacas?

3) Grain? Concentrate? Or supplement?

4) Let's be practical: How much forage and/or supplement should I feed?

1) What is it so different between camelids and other ruminants?

Understanding the digestive anatomy and metabolism of camelids

Camelids are ***"true ruminants"*** in that they share some characteristics of other ruminants:

- Expanded foregut for microbial fermentation of ingested feed
- They chew their cud
- Presence of microorganisms in the foregut for anaerobic fermentation; this allows the transfaunation of camelids with rumen juice from cattle, sheep, or goats.
- Foregut motility also occurs in 2 phases

However, camelids are ***"non-ruminants"*** in that they have some unique features:

- Three 3 digestive compartments (and not four)
- The first (C1) and second (C2) compartment have small saccules with secretory function (glandular epithelium), as opposed to the adjacent area that has a protective function (stratified squamous epithelium). This saccules may increase the fermentation-buffering, or they may increase the absorption of volatile fatty acids (VFA) fermentation end products.
- Foregut motility is much more active, with 3 – 4 contractions/cycle (vs 2-3 in true ruminants). This may explain why camelids are fairly resistant to foregut gas accumulation or bloat.
- Longer retention time in the fermentating foregut, allowing a greater feed degradation; in contrast, water passes more rapidly through C1, providing greate C1 buffering capacity and increasing microbial yield.

Overall these factors are advantageous to camelids consuming poor-quality, low-protein forages; however, these advantages are lost when feeding high quality forage.

Furthermore, camelids are characterized by certain metabolic differences compared to other ruminants: * ***Glucose -*** True ruminants maintain a lower blood glucose (40 – 60 mg/dL). This is because the microbial fermentation of dietary sugars/starches results in minimal glucose presentation to the small intestine for absorption. Thus, ruminants primarily rely on gluconeogenesis (from propionate) for glucose availability. Camelids maintain higher blood glucose (85 - 160 mg/dL), and have an extreme hyperglycemic response (> 200 mg/dL) to stress. The high blood glucose of camelids is believed to be due to a moderate insulin resistance and a continuous hepatic gluconeogenesis (from amino-acids, since the camelid diet do not have much starches as propionate precursors). This may account for the high susceptibility of camelids to hepatic lipidosis during stress and reduced feed intake.

*** Blood urea nitrogen (BUN)** – Camelids have higher BUN levels. While in true ruminants a high BUN reflects the level of protein in the diet, in camelids it is due to a lower rate of urea turn-over and kidney excretion. Thus, camelids recycle more urea to the forestomach for use by microorganisms to produce bacterial protein, allowing them to survive under harsh conditions consuming low-quality forages.

2) What are the nutritional requirements of llamas and alpacas? **(FIGURE 4)**

In camelids the slower rate of particle passage fills the gastro-intestinal tract, limiting the feed intake. In average, camelids have 25 % less dry matter intake than other ruminants. Although camelids require less energy for maintenance than other ruminants, their lower feed intake capacity and higher CP requirements results in the necessity of higher dietary nutrient concentration for camelids compared to other ruminants.

An animal performance is determined by several factors:

1. Feed availability
2. Feed intake
2. Feed nutrient content – The digestible energy (digestibility) is the most common limiting factor, however protein and minerals can also be the limiting factor especially when animals are only grazed.

Maintenance - For the maintenance of older animals or animal with a low level of activity, even low quality forage can be enough, if proteins and minerals are adequate.

Breeding and gestation - During the breeding season animals should receive forages that are 10 to 20 % higher in digestible energy, and lower in NDF. During early pregnancy (first two-thirds of gestation) the nutritional requirements of females are low. During the last third of pregnancy, nutrient requirements increase because fetal weight increases rapidly. Also, females often need to store fat that will be used during the high-energy demand of early lactation. During the latter stages of pregnancy not only do nutrient requirements increase, the internal body space for the digestive tract is reduced. Thus, in the last 10 % of pregnancy it is important to increase dietary nutrition substantially.

Growth – Muscle is primarily protein, and bone is mostly minerals (calcium and phosphorus), so growing animals have much higher requirements for CP, minerals and also energy. However, younger animals have less internal body capacity to accommodate consumption of bulky forage than older animals. Thisexplains the need of greater energy density in the diet of young, growing animals (especially until they reach 50 % of their body weight). Milk from the mother is an excellent supplement for youn g animals, that allows them to perform well when consuming forages. After weaning, supplementing the forage diets with protein and minerals often improves the growth rate.

Lactation – Lactation places the greatest nutrient demand on animals. Thus, a high quality forage and/or feeds need to be provided. A balance of fiber is important: too much fiber lowers energy density and limits intake, resulting in low milk production; too little fiber increases fattening f the female, and increases incidence of digestive and metabolic disorders.

The current feeding recommendation of the National Research Council (NRC) for llamas and alpacas are summarized in the following table:

	Daily requirements	***Example: For a 150 lb animal (68 kg)***
Dry matter intake	**1 to 1.3 % of BW** (or 38 g/kg x BW $^{0.75}$)	68 kg x 0.01 = 680 g = **1.5 lb** 68 kg x 0.013 = 884 g = **2 lb**
Metabolizable energy (ME)	70 kcal/kg x BW $^{0.75}$ (range 60 – 85 kcal/kg BW $^{0.75}$)	70 x (68kg) $^{0.75}$ = **± 1,650 kcal**
Protein	For maintenance: 3.5 g CP x kg BW $^{0.75}$ (or 48 g of CP/1 Mcal)	3.5 x (68 kg) $^{0.75}$ = **± 80 g**

Note: 1 Mcal (megacalorie) = 1000 kcal (kilocalorie)

3) Grain? Concentrate? Or supplement? (FIGURE 5)

Many terminologies have been used to describe the non-forage portion of a diet, such as grain, concentrate, supplement, pellet, mineral, cereal, commercial feed, etc. Lets clarify this terms:

Grain – Cereal grains are the seeds obtained from various plants (such as corn, barley, wheat, oats, and rye). They are low in fiber, high in starch and are readily digestible. Thus, they provide a digestible form of concentrated energy. When fermented, the grains can provide glucose, but when rapidly fermented they can also generate lactic acid leading to forestomach lactic acidosis. Processing methods (grinding, flaking, extruding, and pelleting) can make the starch more readily available, increasing their propensity to induce acidosis.
Cereal grains do not supplement well for minerals (such as calcium), and hence when additional mienal supplementation is required when the animals are being fed forages and cereal grains.

Concentrate – Concentrates are feeds used with another to improve the nutritive balance, and intended to be further diluted and mixed to produce a supplement of complete feed. Some examples include:

- *Energy concentrate:* cereal grain..
- *Protein concentrate:* soybean, canola, or cottonseed meals.
- *Mineral and vitamin*
- *Fiber concentrates:* this *fiber byproducts* are derived from the cereal milling or brewing industries. They have moderate to high NDF, and variable energy (TDN), CP, and mineral content. They do not have high starch, but instead they have high fermentable fiber which provides energy without inducing lactic acid production and lowering the forestomach pH.

****** Supplements *** –*** Feed used with another to improve the nutritive balance. Can be feed undiluted, offered free choice separately available, or further diluted/mixed to produce a complete feed. It is usually fed in addition to forage as part of the total ration. It corresponds to what most people feed to alpacas and llamas, typically in the form of a commercial product. Given the lack of feeding standards for camelids, supplement nutrient content varies tremendously: feeds intended for other species, or different physical forms. Pellets are the most suitable form for alpacas and llamas, because it allos them to express their selective feeding behavior. When grains are used, molasses (e.g. sweet feed) can be used to help keep the different particle sizes together and promote intake. However, pellets also have their disadvantages:

- Some pellets end-up being finely grounded, increasing the ingredient availability and decreasing the fiber potential. This increases the potential of forestomach acidosis.
- When rapidly consumed, it can lead to "choke" (esophageal obstruction)

4) Let's be practical: How much forage and/or supplement should I feed?

1. Forage only? or also a supplement?

The type and amount of feed provided to our animals depend upon two main factors:

1. The ***nutrient requirements*** of your animal **–** The nutrient requirement of your animal is determined:

- The physiologic state of your animal (maintenance, pregnancy, growth, lactation)
- The degree of activity or work of your animal

2. The ***quality of forage*** that you provide to your animal – It is important to match your forage and supplements to meet the requirements of your animal. Since we want our animals to be not only healthy but also productive, some additional nutrients will have to be provided by the supplement.

- Legume forage (alfalfa, clover) - Have high protein content; does not require additional protein in the form of cereal grain.
- Grass hays - Their CP can vary tremendously, and mature hays may require protein supplementation.

Ideally, you want to maximize the intake of good quality forage in order to minimize the amount of supplements to add to your forage. Mineral and vitamin supplementation will depend upon forage and geographic area.

2. Matching forage and supplements

By law feed companies only have to provide the values of crude protein, fiber and fat contained in feed, such as supplements. Sometimes the TDN value is also provided, but very rarely the caloric content is available. This is why we typically use the CP and, if available, the TDN to assess the quality of the feed. This particularly true for camelids, in which we currently only have reference values for CP and TDN. This is why submitting a sample of your forage, and even your supplement, to a certified laboratory to be analyzed is advantageous: it will provide you all the information you need to know to assess the nutrient content of the foodstuff that your animals are eating. This is particularly important if you are having animals affected with protein energy malnutrition (weight loss, emaciation, etc).

It is very important that you use the body condition score (BCS) to adjust the amount of energy supplement to be fed besides the forage. And remember that if you have to increase the amount of feed or change the type of food always do so progressively over at least one week .

Here are some general recommendation to match the nutrient requirement at different physiologic status of camelids with different qualities of forage and different supplements:

	Grass FQ	Add supplement to match forage?
Maintenance	Moderate	No →forage provides 8 – 10 % CP
Walk long distance to graze, or "hard keeper"	Moderate	Fiber byproducts →to obtain CP 10-12 %
Packing (high energy)	Moderate	Mixture of cereal grains (corn-oats-barley) or Oats * →to obtain CP 10-12 %
Show feeding (stress)	Higher	Fiber byproducts **; May add a little vegetable oil, soybean or canola *** →to obtain CP 14 – 16 %
Reproduction, growth, pregnant, lactating	Higher; add legume hay.	Mixture of cereal grains and fiber byproducts →to obtain CP 10 - 18 %

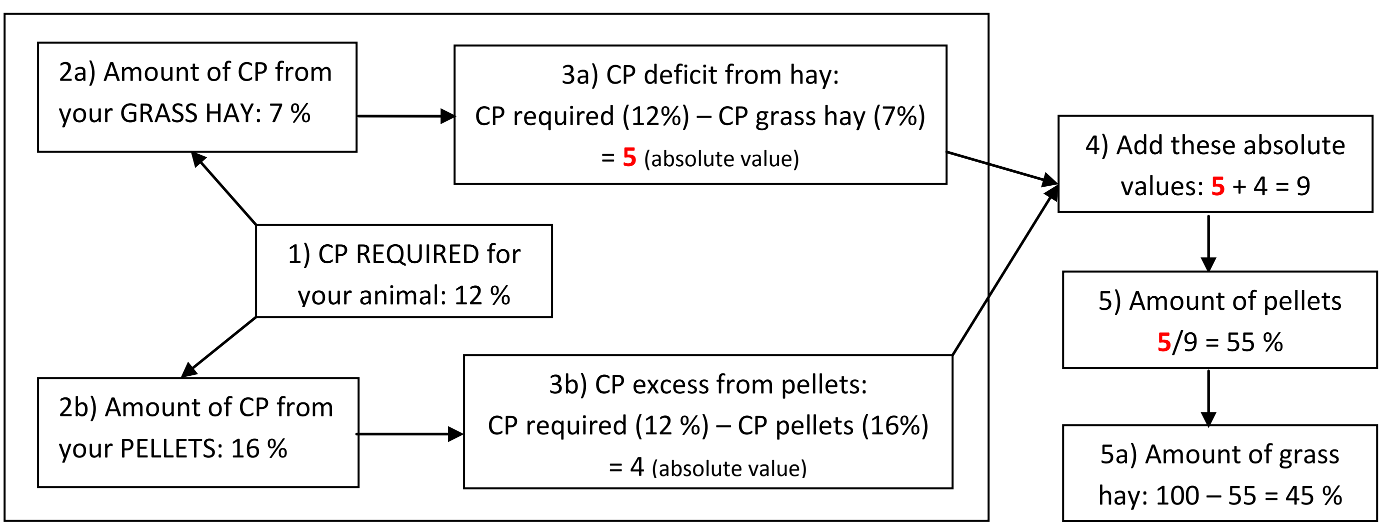
* Cereal grains can easily lead t overconsumption and obesity. However, if cereal grains are selected, prefer mixture of them. Oats is a cereal grain with a good balance between starch and fiber, but oats can be expensive and difficult to find.

**In other ruminants fiber-based products have shown to help expand the gut and give the animal a "flush and fit" appearance.

*** This oils can be supplemented to provide essential fatty acids. However, fat supplementation should be carefully controlled, as fat can adversely disrupt the microbial populations involved in the fermentation processes.

The **Pearson Square** is a method that helps us to reach a desired CP and/or TDN based on the CP and/or TDN of the forage and supplement available.

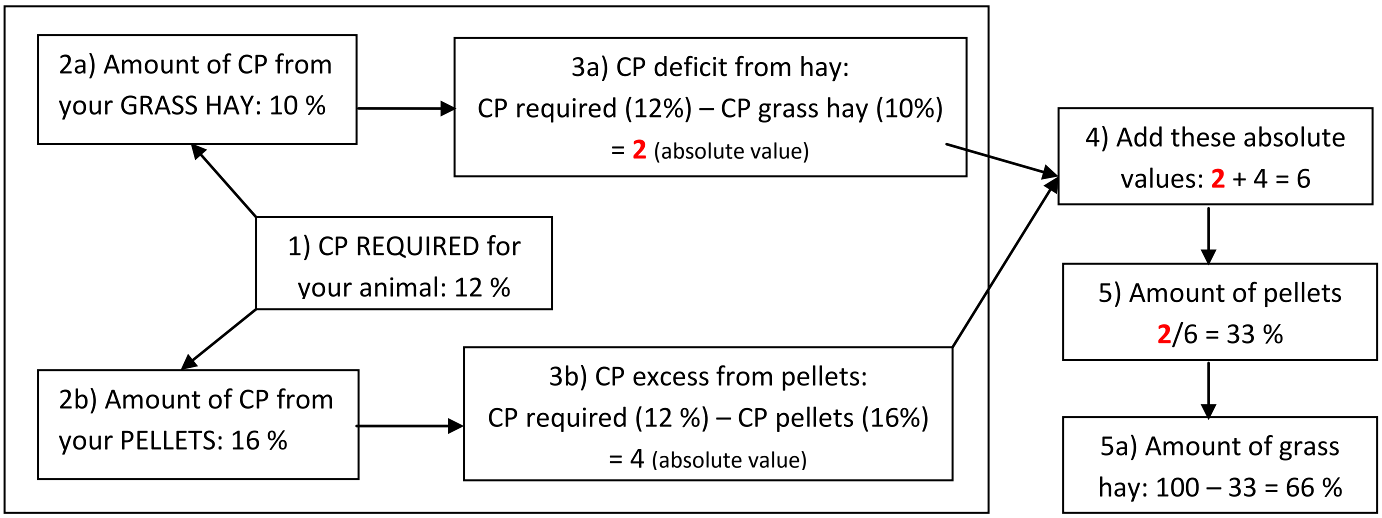
Example 1: Let's say that your grass hay has 7 % CP, and you have a feed supplement with 16 % CP.



Remember that camelids require a minimum of 1 to 1.3 % of dry matter intake. So you first need to calculate the dry matter requirement of your animal; for example, for a 150 lb animal(68 kg) you need to do the following calculation: 68 kg x 1.3 % = 68 kg x 0.013 = 884 g = ~ 2 lb. When the grass hay contains only 7 % of crude protein (CP), the diet must contain 45 % hay and 55 % supplement; for a 150 lb (68 kg) animal this

would be a minimum of 0.9 lb of hay (=0.45 x 2 lb) and 1.1 lb of supplements (=0.55 x 2 lb). To feed less pellets with lower quality hay, the pellet CP content would need to be increased.

Example 2: Let's say that your grass hay has 10 % CP, and you have a feed supplement with 16 % CP.



If CP content of hay is 10 %, then to meet the same 12 % CP requirement, one blends 66 % hay with 33 % pellets. For a 150 lb (68 kg) animal this would be a minimum of 1.3 lb of hay (=0.66 x 2 lb) and ~ 0.7 lb of supplements (=0.33 x 2 lb). In this example the higher quality of hay allowed to feed less pellets to reach the same 12 % CP requirement.

With this two examples we can see that with low forage quality less nutrients are available, and hence more supplements will need to be added to the diet.

Here below is a table that summarizes the daily supplement intake required to achieve a total dietary CP of 12 or 14 %. Calculations are based on feeding 10 % CP grass with different supplements containing 10 %, 16 % or 18 % CP.

Supplement Crude Protein Content	**Desired Dietary Crude Protein Content**			
	12 %		**14%**	
	Lbs/day	**% of Total Diet**	**Lbs/day**	**% of Total Diet**
14%	1.5	50	3.3	100
16%	1.0	33.3	2.2	66.7
18%	0.75	25	1.65	50

FIGURE 2: Typical nutrient content of alfalfa and grass hay harvested at various stages of plant maturity (all values on dry matter basis)

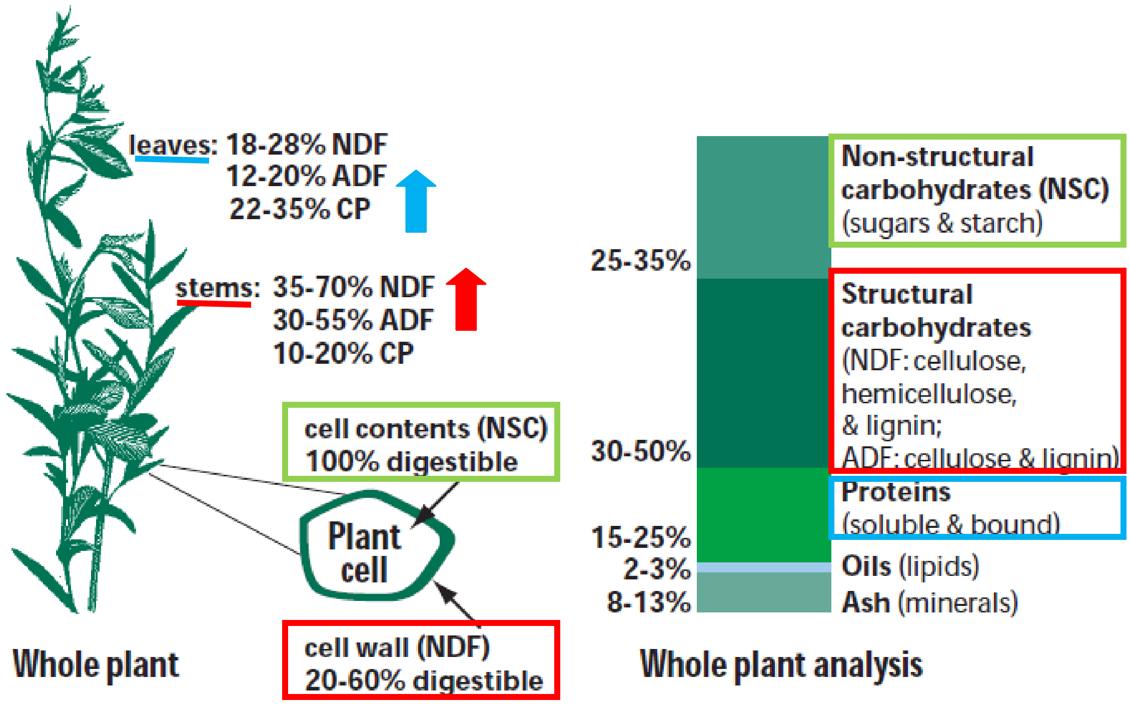
Type of Hay and Stage	Plant Description	CP (%)	ADF (%)	NDF (%)	TDN (%)
Alfalfa					
Prebloom	Bud to first flower; vegetative growth	>19	< 30	< 35	>62
Early bloom	25% flowers present	17–19	30–35	35–39	57–62
Mid bloom	Approx. 50% bloom	13–16	36–41	41–47	51–56
Late bloom	>75% bloom	<13	>41	>48	<51
Grass					
Prehead	Late vegetative growth to early boot stage	17	< 29	< 55	>54
Early head	Boot to early head stage; up to ½ inflorescence (seed head development)	12–17	30–35	56–61	47–54
Head	Head to milk stage; >½ inflorescence in anthesis to stage of well-formed seeds	8–12	36–44	60–65	44–46
Posthead	Dough to seed; full inflorescence in anthesis with release of mature seeds	<8	>45	>65	<44

FEEDSTUFF	*MEm (Mcal/lb)	lb DM			% BW		
HAYS		**110**	**220**	**330**	**110**	**220**	**330**
Orchard Grass	0.96	1.63	**2.69**	3.78	1.48	1.22	1.15
Brome Grass	0.97	1.61	2.66	3.74	1.46	1.21	1.13
First Alfalfa	1.04	1.50	2.48	3.50	1.36	1.13	1.05
Third Alfalfa	1.07	1.46	2.41	3.39	1.33	1.10	1.03
Oat Hay	0.92	1.70	2.80	3.89	1.54	1.27	1.18
Oat Straw	0.86	1.81	3.00	4.22	1.65	1.36	1.28
SPRING PASTURES							
High Fert Rye Grass	1.36	1.15	1.90	2.66	1.04	0.86	0.81
N.J. Mixed Grasses	1.32	1.18	1.95	2.75	1.07	0.89	0.83
Oregon Mixed Grasses	1.06	1.47	2.43	3.28	1.34	1.11	1.00
Colorado Mixed Grasses	1.10	1.42	2.35	3.28	1.29	1.07	1.00

*MEm - metabolizable energy for maintenance

From: http://www.scla.us/feeding_camelids.html

FIGURE 3: Structural components of alfalfa



Essential components of feed analysis:

Essential nutrients			*Analytical procedures*		
DRY MATTER (or moisture)			**Measures the amount of moisture in forage; determine how well the forage will store without molding**		★
Proteins, Amino acids		Nitrogen Protein Non-protein nitrogen	**Crude protein (CP)** **Reflects forage maturity (and fertilization)** **Alfalfa > 15 %, Grass > 9 %**		★
Carbo-hydrates	**GLUCOSE**	Sugars Starches	**Non-structural carbohydrates (NSC)**	**Non-fiber carbohydrates (NFC)**	★
	FIBER	Soluble fiber			
		Hemicellulose		**Neutral detergent fiber (NDF)** **=total cell wall content; reflects forage maturity**	★
		Cellulose	**Acid detergent fiber (ADF)** **=most indigestible portion of cell wall; reflects degree of lignification**		
		Lignin			

Nutritional content goals for the different type of forages:

	DM	TDN	NDF	ADF	NFC	CP
ALFALFA (legume)	**> 85 % DM (< 15 % moisture)**	**50 – 60 %**	**< 40 %**	**< 35 %**	**> 30 %**	> 15 %
GRASS			**< 55 %**		**> 20 %**	> 9 %
SUPPLEMENT		**> 76 %**	**< 20 %**		**75 % (corn) 48 % (oats)**	**9 – 14 %**

FIGURE 4: Suggested feeding groups based on physiologic state and nutrient requirements

Group	Physiologic State	Feeding Plan	Dietary Guidelines[a]
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,[b]
Weanlings up to 1½ 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,[b]
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,[b]
Pregnant females 1–8 months	Maintenance	Low requirements; 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%–12% crude protein, 0.45%–0.56% Ca, 0.28%–0.33% P,[b,c]
Breeding females	Maintenance	Low-to-moderate requirements; ensure no overweight or loss of body condition	50% to 55% TDN, 8%–10% crude protein, 0.2%–0.24% Ca, 0.12%–0.2% P
Obese females	Submaintenance	Low requirements; low-quality forages with mineral/vitamin supplement unless pregnant	40% to 50% TDN, 8%–9% crude protein, 0.2%–0.24% Ca, 0.12%–0.2% P

More precise dietary needs will be determined by level of production (milk, rate of growth), environmental conditions and desired changes in body condition.

[a] 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.

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

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

From Van Saun RJ. Feeding the alpaca. In: Hoffman E, editor. The complete alpaca book, 2nd edition. Santa Cruz (CA): Bonny Doon Press; 2003. p. 179–232; with permission.

FIGURE 5:

Table 1. Comparative nutrient content of common cereal grains and dried byproduct feeds.[1]

	DM	NDF	TDN	CP	NFC	Fat	Ash	Ca	P
	%	- - - - - - - - - - - - % of Dry Matter - - - - - - - - - - - -							
Cereal Grains									
Barley grain	88	18.1	84	13.2	64.1	2.2	2.4	0.05	0.35
Corn grain, shelled	88	9	88	9.8	75.3	4.3	1.6	0.03	0.31
Oats grain	89	29.3	77	13.6	48.6	5.2	3.3	0.009	0.41
Rye grain	88	19	84	13.8	63.5	1.7	2	0.07	0.36
Sorghum grain	89	13.3	76	11.6	70.0	3.1	2	0.05	0.34
Wheat grain	89	11.8	88	14.2	69.7	2.34	2.01	0.05	0.44
Fiber By-Products									
Barley malt sprouts	93	46	71	28.1	17.5	1.4	7	0.19	0.68
Beet pulp	91	44.6	74	9.8	39.7	0.6	5.3	0.68	0.1
Brewers grains	92	48.7	66	29.2	7.3	10.8	4	0.29	0.7
Citrus pulp	91	23	82	6.7	60.0	3.7	6.6	1.88	0.13
Distillers grains	91	23	88	29.7	30.1	9.2	8	0.32	1.4
Rice bran	90.5	33	70	14.4	26.1	15	11.5	0.1	1.73
Soybean hulls	91	66.3	80	12.2	14.5	2.1	4.9	0.53	0.18
Wheat bran	89	42.5	71.5	17.3	29.6	4.3	6.3	0.13	1.18
Wheat middlings	89	36	83	18.5	40.0	3.2	2.4	0.15	1.0

[1]Abbreviations: DM=dry matter; NDF=neutral detergent fiber; TDN=total digestible nutrients; CP=crude protein; NFC=nonfiber carbohydrates (includes starch); Ca=calcium; and P=phosphorus.

References

1. Ball,D.M., M.Collins, G.D. Lacefield, N.P. Martin,D.A. Mertens, K.E.Olson,D.H. Putnam, D.J. Undersander, and M.W.Wolf. 2001. Understanding Forage Quality. American Farm Bureau Federation Publication 1-01, Park Ridge, IL

2. Hay Testing and Understanding Forage Quality. Mississippi State Agricultural Extension

3. Stokes, S.R. Prostko, E.P. Understanding forage analysis. Texas Agricultural Extension Service.

4. Van Saun, R.J. Nutrient requirements of South American camelids: A factorial approach. Small Ruminant Research 61 (2006) 165–186

5. Van Saun, R.J. What is forage quality and how does it affect a feeding program? Lamalink.com June, 2006;3(6):31-36.

6. Van Saun, R.J. Determining forage quality: Understanding feed analysis. Lamalink.com August, 2006;3(8):18-19,22,24, 25-26.

7. Van Saun, R.J.. Grain feeding: It's all about energy. Lamalink.com October, 2006;3(2):28-31.

8. Van Saun, R.J. Problems following grain consumption. Lamalink.com, June 2007;3(10):32-33.

9. Van Saun, R.J. Alternative Forage Feeding in Drought Conditions. *Department of Veterinary and Biomedical Sciences Penn State University*