Technical Reference Manual Sheepbytes 2013 Version 1.5

Table of Contents

Understanding Nutrition Information and Terms Used in SheepBytes

Nutrient recommendations in this program have been based on the NRC 2007 *Nutrient Requirements of Small Ruminants (sheep)*. Nutritional deficiencies and excesses compromise production aspects such as growth, fertility and lamb survival. However, making best use of low cost grass and forage, and providing the right supplementary feeds at critical periods can maximize efficiency and profit. Using the Sheepbytes ration balancing tool will help you to optimize animal performance and prevent potential profit leaks related to nutrition. However, continuous observation of the flock by the manager is key to understanding production challenges, as the nutritional management of the flock cannot be accomplished from this computer program alone.

SheepBytes is *not* a least cost ration formulation program. Many Western Canadian flocks are managed on locally grown forages, grains and crop by-products. These feed ingredients can vary widely in price and nutrients from year to year due to supply and demand and environmental factors. However, because the program calculates cost per ration, the economics of the rations can be controlled by the user depending on your choice of feeds and the availability of feed ingredients in your area.

Breed Size and Animal Type (small, medium or large)

The nutritional requirements of any animal are based on its' physiological state, body weight, age and environmental conditions including temperature. When balancing rations for groups of animals you must select the average body weight and conditions that reflect the group situation. Otherwise, in non-uniform groups, you may need to create numerous rations to reflect the range of conditions that exist. The more accurate your animal description (weight, average daily gain, breed size, age, gestating, lactating, growing etc.) the more accurate your ration costs and animal requirements will be.

If you don't have weights on your animals you can start by using the 'default' ranges of small, medium or large breed size given below. There are currently approximately 40 breeds of sheep registered in Canada. Most commercial operations in Canada use a combination of breeds in cross-breeding programs to access the strengths of multiple breeds and capture the benefits of hybrid vigour.

The weight ranges suggested here are for **mature ewes** using Canadian Sheep Breeders Association breed information. There is as much variation in size and weight within any one breed as there is between different breeds or breed crosses. This is a guideline only.

1. Small size breed / breed types (40 to 60kg / 88 to 132lb) Border Cheviot, Romanov, Shetland, Icelandic
2. Medium size breed / breed types (61 to 90 kg / 135 to 198 lb) Dorset, Dorper, Texel, Ile de France, Katahdin, Rideau, Canadian, Outaouais, Rambouillet
3. Large size breed / breed type types (+90kg / +198) Suffolk, Hampshire, Charollais, Columbia, Polypay

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Sheepbytes has been formulated to balance rations for many different classes and sub-classes of animals. These include: Mature Rams (if over 12 months of age); Mature Ewes (maintenance, flushing/breeding, gestating early and late and lactating early and late); Replacement ewe lambs (growing; flushing/breeding; gestating early and late; and lactating early and late); Replacement ram lambs (growing and less than 12 months of age); Early weaned lambs (less than 6 months of age); Growing lambs (either under 6 or over 6 months of age); and Finishing lambs (either under 6 or over 6 months of age).

When selecting the appropriate class of animal from the animal tab, consider the following: Sheepbytes uses recommended nutrient requirements for animal classes and sub-classes based on the definitions and assumptions listed in the information below.

- Early weaned lambs have a tendency for a more rapid growth potential compared to the growing lamb category. Early weaned lambs will be considered to be weaned at about 4 to 6 weeks of age and be less than 6 months of age at slaughter.

- Growing and finishing lamb categories are typically greater than 4 months of age and less than 12 months of age at slaughter. Small and medium breed size growing lambs, which are also considered early maturing breeds, are typically less than 50 kg body weight. Large breed growing lambs of late maturing breed types are typically up to 80 kg body weight.

- Finishing lambs of small and medium early maturing breed types are typically in the range of 30 to 60 kg body weight. While, large breed finishing lambs of late maturing breed types will typically be in the range of 30 to 85 kg body weight.

Ration (Main Screen)

The Ration screen is your "working screen" where the feeds are displayed and the rations are balanced. Nutrient content of the feeds can be edited, changed or modified to match your feed test results or other conditions. Animal nutrient requirements and nutrients supplied by the ration are displayed in the bottom third of the screen. The bottom portion of the screen displays ratios of importance when feeding sheep and lambs. Ratios help to explain mineral interactions and other ration proportions. All the other components of SheepBytes can be accessed from this screen. The section below provides an explanation to the different columns and segments of the ration screen.

Dry Matter Intake (DMI)

Dry matter intake is defined as the level of intake that an animal must consume of a ration that contains the energy concentration recommended for them by the NRC nutrient tables. DMI is a critical factor when balancing diets. It is not easily estimated because many factors influence feed intake. SheepBytes will estimate DMI based on animal type, weather conditions, temperature and physical conditions (wet, wind, cold or heat stress, and wool condition) in which the animals are kept. Actual dry matter intake must be monitored at the farm or feedlot to ensure proper nutrition of the animal. If estimates of intake are low and the animal is consuming more feed than expected, total nutrient intake will be higher than expected causing higher rates of gain and increased costs. If intake is over estimated, and the animals are not able to consume the required amount of nutrients; growth or performance will be lower than expected.

Use SheepBytes intake recommendations as a guideline. Generally:

- Ewes have DMI in the range of 2 to 5% of body weight with lactating ewes at the higher end. NRC 2007 estimates maintenance ewe rations to be less than 2% of body weight and typically in the range of 1.6 to 1.8%.
- Lambs typically consume 3 to 6% of their body weight in dry matter intake with intakes decreasing as lambs get heavier and older. However, lambs with very high ADG (over 450 g/d) will have increased intakes over those on lower ADG rations (less than 300 g/d).

Predicted intake is generally calculated based on the mature animal size and intake is expected to increase as the animal reaches 85% of its mature size. Once an animal is approximately 90% of its mature body size, intakes decline after which time they will remain relatively stable. Understanding the factors which influence intake, like environment, physiological state (pregnancy, lactation), diet composition and quality are important when predicting intake. The Sheepbytes program is able to account for most of these factors provided the user enters the appropriate information on the animal screen.

If you have monitored intake and find that the intake is higher or lower than the recommended intake, the ration should be reformulated.

To adjust DMI based on previous experience, modify the Predicted DMI factor contained in the Modification screen before formulating new rations.

DM Fed %

This column calculates the contribution of dry matter from each feed contained in the diet as a percent of the total. This calculation is useful when comparing the total forage content and total concentrate content of the ration. Problems can occur if mature ewes do not receive 1.5 to 2 lbs of digestible forage (25 – 30% forages) each day to keep their rumens functioning well and free from acidosis. A growing lamb ration can contain minimal or no forage only if lambs are early weaned at 6 – 8 weeks of age and have not received pasture/forages, while finishing-lamb rations are typically 80 to 85% concentrate and 15 to 20% forage.

As Fed (AF) kgs/lbs

As Fed basis indicates that the feed being fed includes the moisture present in the feedstuff. A good way to remember this is “by the bale or out of the pail.” On the farm, when hay, silage or concentrates are fed in a ration, it is with moisture present.

Rations can be balanced by entering the pounds of feed required on an “as fed” basis in SheepBytes, but feed intake limits are always calculated using kilograms or pounds of dry matter supplied. When a feed is entered on an “As Fed” basis, SheepBytes automatically calculates the amount of dry matter supplied. This is why it is important that the % dry matter of the feed used for the calculations is accurate.

Comparing feeds on an "as fed" basis is of little value. For example, a crop could be utilized as a cereal silage at 65% moisture and a Crude Protein content of 4.7%. The same cereal cut for greenfeed containing 15% moisture content might have a 10.5% crude protein content.

At first glance, it appears that the greenfeed has a much higher level of crude protein than the silage. If the moisture content is converted to a 100% Dry Matter basis (see next section), the following calculations correct for moisture content resulting in the silage having 13.43% crude protein compared to the greenfeed which has 12.35% crude protein.

The silage is 65% moisture and 35% dry matter. Greenfeed is 15% moisture and 85% dry matter.

Silage 4.7% Crude Protein divided by 0.35 dry matter equals 13.43% Crude Protein (100% Dry Matter basis).

Greenfeed 10.5% Crude Protein divided by 0.85 dry matter equals 12.35% Crude Protein (100% Dry Matter basis).

Nutritionists (and Sheepbytes) always make the nutrient calculations on a 100% Dry Matter basis. The numbers are then converted to an As Fed basis to reflect what the sheep are actually consuming.

Dry Matter (DM)

Dry Matter basis is the actual dry matter content of the feed with all of the moisture removed. As shown in the As Fed section, a feed with 12% moisture content, for example, has 88% Dry Matter. The following example demonstrates the difference between "As Fed" and "Dry Matter" basis and how the calculations are done.

Alfalfa-Grass Hay - 12% Moisture (88% Dry Matter). Each of the As Fed values must be divided by 0.88 (88%) to calculate the 100% Dry Matter values.

	As Fed	100% Dry Matter
TDN (energy)	54.0% / 0.88 =	61.4%
Crude Protein	12.3% / 0.88 =	14.0%
Calcium	1.06% / 0.88 =	1.2%
Phosphorus	0.16% / 0.88 =	0.18%

The only accurate way to compare the nutrient content of one feed to another is to make the comparison on a 100% Dry Matter basis.

Moisture contents of feeds can be extremely variable, depending on how much drying occurred at baling, curing, harvest or storage. A moisture test is the only accurate method to determine the actual moisture content of a feed. Some feeds with high moisture contents like silage may need to periodically be re-tested for moisture content as changes occur over time.

Some examples of the moisture content of commonly used feeds are:

Pelleted Feeds*	10% moisture content (average)
Protein Supplements *	10% moisture content (average)
Minerals	1% moisture content (or less)
Salt (blocks or bags)	1% moisture content (or less)
Vitamin premix	1% moisture content (or less)

It is important to note that feed labels or tags list all nutrients on an “As Fed” basis. If a protein supplement label indicates the product contains 32% Crude Protein, it would actually contain 35.56% Crude Protein on a 100% Dry Matter basis (32 / 0.9 = 35.56).

Ruminant nutritionists calculate rations based on the amount of dry matter an animal is able to consume. Feed test report nutrient values are entered into SheepBytes on a “Dry Matter” basis. Make sure dry matter % of feed is accurate. The values for price and unit weight are entered on an “As Fed” basis.

Voluntary feed intake of an animal is limited by the amount of space available in the rumen. Stretch receptors in the rumen wall send messages to the brain indicating if the animal is hungry or satisfied. The stretch receptors are triggered by the total amount of weight in the rumen. Silage and fresh grass are two feed types that contain high amounts of moisture. Water that is consumed, or contained in feed adds weight to the rumen. If excessive amounts of water or moisture in feed is consumed, the amount of dry matter an animal is able to consume can be lower than expected. If possible, do not exceed 50% moisture in young lamb, late pregnancy (last 6 wks) and lactating ewe rations. Increasing fetal lamb size in late pregnancy considerably restricts capacity of the rumen of the ewe making silage rations a less desirable feed choice compared to other high quality forages and feeds or concentrates. SheepBytes reports dry matter intake as a percent of body weight and provides an estimate of the maximum dry matter intake (max DMI) that the particular animal can consume, which is particularly useful when formulating late gestation ewe and ewe lamb diets.

Body Condition Score (BCS)

The BCS system is a 5 point scale with 1 being extremely thin and under-weight while a 5 is very fat and being over-weight for the frame size. BCS needs to be selected in the animal tab section, otherwise the program assumes an average BCS of 3. To determine the weight of an animal that you do not have a scale weight for, you need to assume their body weight at the maintenance level. Therefore, if you have a maintenance weight of 175 lbs for a mature ewe and she is thin and weighs only 150 pounds in early gestation, she is likely a BCS of 2. Because the Sheepbytes program uses the BCS system for mature animals, those that need to gain weight should have a BCS of below 3 selected, while those that need to lose weight should have a BCS of 4 or 5 selected so nutrient requirements are correct based on their body condition. The program does not use half scores (ex. 1.5, 2.5, 3.5 or 4.5) so you should select the closest whole number to represent the condition score of the animal in question.

Energy Units
NEm, NEg, DE, TDN

The SheepBytes energy values are predominantly based on NRC (National Research Council) 2007 with a minor emphasis on NRC 1985 where required and use the net energy system developed by Lofgreen and Garrett (1968). Values are inter-convertible with the various forms being used for different purposes. The 2007 values differ from 1985 mainly due to changes in genetic size and productivity of sheep. SheepBytes users have the choice of working on a TDN (total digestible nutrients), DE (digestible energy), or NE (net energy) basis with the conversions handled by the SheepBytes program. Use the Energy Units Tab (a light bulb symbol below the yardage calculator tab) to switch between the different energy bases.

Net energy systems for growing and finishing animals as well as dairy sheep are preferred to the TDN system, whereas, TDN and DE are sufficient for the mature ewe and ram. The net energy system may be more useful as it will show when the estimated maintenance energy requirements have been met. To convert between energy values, enter the known TDN, DE, NEm, or NEg feed energy value and the SheepBytes program will calculate the unknown values.

You may notice that the energy value conversions when switching from the TDN to NE systems and back again do not equal. As an example, there may be a slight excess of supplied TDN in relation to the recommended amount, yet when you switch to the NE system the supplied NEg may be deficient compared to the recommended NEg. This is due to the fact that the NE system is the only energy expression to account for a heat increment of feeding (meaning the energy that is used by the animal for digesting feed). Thus, TDN and DE will slightly overestimate the energetic value of forages relative to concentrate feedstuffs. Because the predicted average daily gain formula uses only the NE system to calculate it, you may observe in this situation when working in the TDN system to have a deficient gain even though requirements have been met. SheepBytes has not accounted for the heat increment of feeding and so differences of 5% in the TDN system may be observed during ration formulation.

Feed energy values are determined through a variety of methods including animal production trials, animal digestibility trials, *in vitro* (test tube) digestibility trials, and chemical analyses. The more detailed methods (animal based trials or complex chemical analyses) can give more accurate and precise feed energy values, but are also more costly. Consequently, many feed energy values are determined from simple ADF (acid detergent fibre) analysis or referenced from established data bases and expressed on a TDN or DE basis.

Although the TDN and DE values are easiest to use for comparing different feed ingredients, the NE values are more accurate as they reflect the variation in efficiency of use of different feeds for different purposes. The TDN and DE systems tend to over value low quality feeds relative to high quality feeds.

NEm

This is the net energy for maintenance in Mcal/kg or Mcal/lb of feed. When formulating a diet the NEm recommendation is met first. NEm in kilocalories of the diet per day is approximated as 56 times the metabolic weight of the animal (or $56*Wt^{0.75}$).

NEg

This is the net energy value of the feed for growth. The NEg supplied does not accumulate until the maintenance recommendation is met and until the protein requirements are at least 80% of recommended values. Energy for tissue gain depends on the energy composition of the gain; whether an animal is gaining muscle or fat. This will be influenced by the genetics, age, sex, body weight, ration type, dry matter intake and average daily gain. Sheepbytes has assumed that young growing animals are gaining predominantly muscle and mature animals are gaining predominantly fat. Thus, there is a range between 2.9 and 6.44 Mcal/kg gain used in the program depending on animal type.

NEmTot

The total net energy for maintenance (NEmTot) is the total energy needed to meet all NE requirements except for growth. This includes the NE required for maintenance, pregnancy, lactation, environmental acclimation, cold stress or heat stress, and activity. The NEmTot will change with:

1. Larger animals have higher NEm requirements.
2. Acclimation to colder weather and wool length.
3. Dairy breeds have higher NEm requirements.
4. Lactating ewes having higher NEm requirements.
5. Rams having increased NEm requirements than ewes and wethers.
6. Better conditioned animals have an increase in NEm requirements as they have more metabolically active tissue to maintain.
7. Later stages of gestation with multiple fetuses resulting in greater NEm requirements.
8. Higher levels of milk production resulting in greater NEm requirements.
9. Cold stress occurs when heat loss is greater than heat production. An animals' lower critical temperature is when energy production equals heat loss. Total animal insulation value is the sum tissue insulation (related to animal age and condition) and external insulation (related to wool thickness and condition as affected by wind and rain). Cold stress can substantially increase animal NEm requirements.
10. NEm requirements for animals experiencing heat stress (panting) increase compared to animals not under heat stress.

Animals that do not receive enough NEm from their diet to meet their NEmTot requirement will mobilize body tissues in an attempt to correct for this deficiency. However, mobilization of body tissue yields only 80% of the energy retained in accumulating body tissues making this process inefficient.

Sheepbytes reports the NEm requirement as the total energy needed for maintenance plus gestation if the animal is a pregnant mature ewe or replacement ewe lamb and reports the NEm requirement as the total energy needed for maintenance plus lactation if the animal is in early or late lactation.

There are two reasons why NEmTot energy is lost:
1. A low heat increment of feeding (HIF) and
2. A low dry matter intake (DMI).

Heat increment of feeding (HIF) is the use of energy to support activities such as chewing, digesting and absorbing feed from the gut. It is energy available to the animal to partially offset other energy costs when cold stressed. When feeds are fed, the NEm representing the Total NEm on the Results page is calculated based on the body weight, gestation, milk yield, body condition score, sex, and various environmental conditions.

A severely under-fed animal will try to maintain itself by mobilizing fat and/or body tissue. However, one energy value of mobilized tissue equals only 80% of the value from the feed. Therefore, underfed sheep will get less HIF from the feed and have a higher critical temperature (i.e. feel cold at warmer temperatures).   For example, a well fed ewe might feel cold at -30 but the same ewe underfed begins to feel cold at -20°C. The amount of energy needed to keep the animal's internal temperature constant goes up and is automatically added to the NEmTot so it increases. Secondly, the low DMI results in the predicting formulas being less accurate.

An inadequate intake of energy during late pregnancy when the majority of fetal growth is occurring can result in pregnancy toxemia in thin, fat, older and ewes carrying multiple lambs. Pregnancy toxemia can be prevented by providing adequate energy, usually ½ to 1 lb of grain/hd/day during late gestation.

It is suggested that sheep be fed close to the recommended DMI of the SheepBytes program.

DE

Digestible energy (DE) content of the diet is the gross energy less the fecal energy (energy which is lost in the feces). One Mcal of DE = 0.227 kg or 0.5 lb. of TDN. SheepBytes does not report ME (metabolizable energy is DE less the gaseous and urinary energy loss) but calculates ME = 0.82 times DE. DE recommended is estimated from NEmtot and NEg recommendations. For DE we first calculate the Mcal DE to meet maintenance based on NEmTot and then add on the Mcal for the desired average daily gain. However, during the calculation and conversion from the NEm to the DE and TDN system, some accuracy may be lost. Although the DE and TDN systems are easy to use, the Net energy system is more accurate since it gives the net value of each feed after taking into consideration all the necessary energy losses. The DE system tends to overvalue low quality feeds relative to high quality feeds.

TDN

Total Digestible Nutrients (TDN) of the diet is similar to DE but includes a correction for digestible protein. One kg TDN = 4.4 Mcal DE. TDN in SheepBytes is calculated from DE values (see DE).

TDN is increased in response to cold stress and TDN requirements change in response to wool length as newly shorn sheep with <1 cm fleece will experience cold stress at a higher temperature than animals with full fleece (>1 cm fleece length).

Conversion Between Energy Systems

On the Ration screen, energy values are displayed as digestible energy (DE) and Total Digestible Nutrients (TDN) or as Net Energy of maintenance (NEm) and Net Energy of gain (NEg). Either system can be used.   Use the system that is most appropriate or that you are most comfortable with. Use the Energy Units Tab (a light bulb symbol below the yardage calculator tab near the top of the screen) to switch between the different energy systems.

All energy systems have different formulas and calculations to establish the energy content of a forage, straw, or grain. Each system is correlated to the others by mathematical equations. Within SheepBytes, three energy systems DE, TDN and the Net energy system are available. If the energy value from one system is entered into the program, the energy values for the other two systems are automatically calculated. For example, if the TDN value is entered or changed, the DE, NEm and NEg values will be replaced within the program. To change the energy content of a feed, zero out the existing value and enter the new value. Because these conversions are based on mathematical formula and calibrated within laboratories performing feed analyses, they may not be exactly the same in each laboratory. The values, however, are within reason close enough for practical purposes. This is why you may see values determined from the Sheepbytes program that do not match exactly the values you may have been provided on your feed report for the DE, NEm and NEg.
Appendix 1 shows an Energy Comparison Chart taken from Cowbytes Version 5.

Crude Protein (CP)

The crude protein content of each feed is reported as a per cent. The CP requirements are not constant and are dependent on:

● type and weight of the animal being fed, stage of production (young lambs, ewes in early, late pregnancy or during lactating, mature or growing rams or growing and finishing animals).

● wool growth; crude protein requirements for wool growth are estimated at 6.8g/day for ewes and rams and 3.4 g/day for growing lambs.

●amount of degradable intake protein (DIP) and undegradable intake protein (UIP) content of the feed.

There are different efficiencies of use for DIP and UIP; thus the CP and the efficiencies change with the amount (pounds or kg) and type of feedstuff (straw vs. alfalfa hay) provided. The CP system assumes that the CP value of different feedstuffs is the same; that all feedstuffs have an equal extent of protein degradation in the rumen and that CP is converted to MP with equal efficiency in all diets. However, these assumptions may not be true. CP requirements are not adjusted for efficiency of protein use. For a more accurate assessment of protein recommendations, see the DIP, UIP, and MP columns.

Calcium (Ca)

Enter the calcium (Ca) content of a particular feed as a percent. Calcium requirements differ depending on animal type and stage of production, varying between 0.20 to 0.82% of DMI. Calcium functions in building and maintaining the structures of bone and teeth, milk production, initiation of the clotting of blood, maximizing activity of digestive enzymes and is involved as part of the messenger system in the body. The body uses both active and passive transport systems to absorb Ca from the intestine in response to parathyroid secretion. Absorption is increased by arginine chelation and lysine but decreased by oxalates, phytates and phosphates. Deficiencies include rickets in the young, osteomalacia in mature animals, and slow growth. Low dietary Ca levels, vitamin D deficiency, hypoparathyroidism, renal insufficiency or excessive P dietary levels are some of the causes of Ca deficiency. In extreme cases, which may develop in lambs on high grain diets, low intakes of Ca may result in tetany or precipitate an outbreak of urinary calculi in intact or castrated male sheep. Hypercalcemia does not normally occur because excessive Ca is not absorbed.

Calcium is abundant in grasses, legumes and some oil seeds. In these feeds, Ca generally occurs in the oxalate and phytate form. Even though a feed analysis indicates a specific value, a portion of that Ca is unavailable to the animal. For example, in alfalfa hay, 30% or more of the Ca may not be in a digestible form. Cereal grains contain limited amount of Ca. Supplementation is common with grains. Feed Grade Limestone is an inexpensive form of Ca which contains about 38% Ca. To see the calcium to phosphorous ratio, click the Ratios tab at the bottom of the Rations screen. Acceptable ratios are from 1.5:1 to a maximum of 5:1 (Calcium : Phosphorus). Recommended calcium intake values from NRC Sheep (1985 and 2007) have taken into consideration the reduced availability from forages. Calcium requirements provided in SheepBytes program are based on the NRC recommendations. Calcium levels are affected by K and Mg and Vitamin D. In addition, level of production (high milk yielding dairy sheep as well as high performance feedlot lambs) can have increased Ca and P requirements compared to lower performing animals. Refer also to the DCAB (dietary cation/anion balance), Ca:P and K/Mg + Ca (tetany) ratios.

Phosphorus (P)

The phosphorus (P) content of a particular feed is entered as a percent. Recommended P content is 0.16 – 0.38% DMI as it varies with higher requirements needed for younger grazing lambs. P functions in bone and cell membrane structures, milk production, genetic, energy, enzyme and blood buffering systems. P absorption involves both active and inactive systems but is independent of Ca absorption. Over 90% of P can be absorbed from P deficient diets. However, the availability of P is rather low (about 15 to 20 percent). Presence of fatty acids, aluminum and iron can form complexes with P in the gut and decrease P absorption. Sheep efficiently utilize P, partly by recycling considerable amounts in parotid and other salivary secretions.

Deficiency symptoms include slow growth, pica (the persistent craving and compulsive eating of nonfood substances), low appetite, low conception rates, reduced feed efficiency and low milk production. The maximum tolerable level P is 0.6% of DMI. Toxicity can occur when Ca and Mg phosphates precipitate in the urine (the cause of urinary calculi). Feeding a diet high in P and low in Ca can cause urinary calculi in wethers and intact males. Although sheep may receive sufficient P when fed high grain diets, supplementation is normally required for most classes of sheep and lambs. Drought and over mature forages may result in low P concentrations in forage plants. To see the calcium to phosphorous ratio, click the Ratios tab. Acceptable ratios are from 1.5:1 to a maximum of 5:1 (Calcium : Phosphorus). Ensure that adequate levels of P are available, then balance the diet for Ca. Several factors may influence the Ca and P nutrition of sheep, for example: chronic internal parasitic infections can have a serious negative impact on Ca and P status. Whereas, level of production (high milk- yielding dairy sheep as well as high performance feedlot lambs) can have increased Ca and P requirements compared to lower performing animals.

Cost/Unit

To obtain the accurate feeding cost for an animal or a group of animals; the fair market value of the feeds used should be entered into the Cost / Unit column on the Ration screen. The value should be based on what it cost to purchase the feed or what you could sell the feed for if it was home produced. Sheepbytes determines the cost of the ration on an as fed basis. Enter the cost by the pound, bushel, bale, or per ton / tonne, and enter the corresponding weight per unit of the feed in kilograms or pounds in the Unit column beside the Cost column. For example, if hay you purchased was 4 cents per pound, then you could enter as $0.04 in the cost column and 1 in the units column. Alternatively, if the hay bales were 1400 lbs and you purchased them for $56, then cost is 56.00 and units are 1400 lbs. Total feed cost per head per day is shown in the bottom section of the ration screen. The cost of feed waste is not included in the cost of feed per head per day. Feed waste varies considerably between different production and management systems and it is critical that you monitor the feed waste and adjust rations accordingly to ensure animals are maintaining suitable dry matter intakes on the rations you have balanced for them.

Kgs or Lbs/Unit

This column along with the Cost / unit column on the ration screen are used to establish the cost of feeding an animal or group of animals per day or for a period of time. Enter unit weight that corresponds to the price that is entered. The information provided in this column is also used to establish total feeding costs on the Ration Summary report.

Magnesium (Mg)

Growing and finishing lambs need 0.12% of DMI as magnesium. Gestating ewes need 0.15% and lactating ewes need 0.18% magnesium, as a % of DMI.

Maximum tolerable level is 0.60% of DMI. Mostly present in bone and muscle, magnesium functions in nerve transmission, genetic (DNA) formation and many enzyme reactions and also amino acid metabolism. Absorption is dependent on Mg status of the animal varying from 25 to 75% of dietary intake. Absorption of Mg is influenced by the amount of Ca, P and K in the diet. Deficiency symptoms include grass tetany (nervousness, staring eyes, muscle problems, etc). Mg levels may need to be increased when feeds contain nitrogen in the form of non-protein nitrogen (NPN) or urea since it affects efficiency of Mg absorption or utilization. In situations where ewes in early lactation are grazing forage with high N and K contents, minimum level of Mg in the diet should be 0.2% of DMI. The dietary K/(Mg+Ca) “tetany” ratio should not exceed 2.2:1. High dietary K or Na sulphate or phosphorus reduces absorption of magnesium. To view this ratio press the Ratio tab.

Potassium (K)

Growing and finishing lambs and gestating ewes need 0.5% of DMI as potassium. Lactating ewes need 0.7% potassium. Maximum tolerable level is 3% of DMI. Potassium functions in the acid-base balance of the body, enzyme systems, glucose and amino acid uptake, and blood pressure regulation. Absorption is mostly by passive means. Several hormones including antidiuretic hormone, aldosterone (decrease), glucocorticoids (decrease), insulin and glucagon (increase), influence K levels in the body. Deficiency symptoms include abnormal electrical activity of the heart, slow growth, stiffness, convulsions and even death. Deficiency can occur in animals fed high grain diets and during stressful situations. A small increase in blood K can be toxic. The dietary K/(Mg+Ca) ratio should not exceed 2.2:1. High dietary K reduces absorption of magnesium but increases calcium absorption from the intestine. High levels of K can

negatively affect Mg utilization and result in tetany in sheep on diets marginal in magnesium. To view the ratios, click the Ratios tab.
Potassium is also important in the dietary cation anion balance (DCAB).

Sulphur (S)

Sulphur is needed at 0.16% of the diet for mature ewes and 0.22% for young lambs. Maximum tolerable level is 0.30% on a high concentrate diet and 0.4% on a high forage diet. Sulphur is a constituent of the amino acids methionine and cysteine. Sulphydryl compounds are involved in the activation of various enzymes, formation of adrenaline and creatine, bone calcification and prevention of enzymes from damaging epithelial cells. Most absorption of S occurs in the small intestine as part of amino acid sulphur. In the rumen, dietary S is usually degraded to sulphide and then re-used in the formation of microbial protein. Deficiency symptoms are extremely varied due to the numerous functions performed by S. Because wool is high in S, this element is closely related to wool production. Toxicity can lead to polioencephalomalacia (feed or diet induced polio). Excess sulphur (greater than 0.4% DM basis) from either the diet and/or water combined interferes with copper availability. Blind staggers which was thought to be caused by Se, is now thought to be due to sulfate toxicity due to consumption of high sulfate alkali water. Where forages are low in S, or where diets contain large amounts of urea, weight gains and growth of wool can be increased by feeding a sulfur supplement. Sulfur forms insoluble complexes with Cu and Mo and decreases their utilization. It also decreases Se retention. It is recommended that the dietary Nitrogen to Sulfur ratio of 10:1 be maintained in sheep rations since S has functions in the body related to protein structure. Refer to the N:S ratio in the ratios section at the bottom for specific values.

Sodium (Na)

Sodium is needed at 0.06 to 0.08% of the diet for growing and finishing lambs or gestating ewes and at 0.09% for lactating ewes. Sodium functions to regulate the movement of water into cells and osmotic pressure, transport of glutamine and glucose and to maintain muscle tone, acid-base balance, nerve transmission, and intracellular K concentration. Most of Na in the diet is absorbed. Deficiency symptoms include craving for salt, muscle cramps, tetanus, and reduced feed intake, growth, and milk yield. Toxicity can occur when high sodium is fed with limited water. Symptoms include nervousness, muscle twitching, diarrhea and death. Water is extremely variable in Na content. High Na content in water warrants special consideration in ration formulation. Sodium is 40% of salt (NaCl) so Na content divided by 0.4 or (multiplied by 2.5) gives an approximation of salt available. Salt may be safely used to limit free-choice supplement intake if adequate water is available. The maximum tolerable level of dietary salt for sheep is set at 4% (NRC 2005) which is considerably lower than the previous level of 9%. However, decreases in weight gain of growing lambs have been observed as salt increases from 2-8% of the diet.

Chloride (Cl)

There is no chloride requirement. Generally, it is assumed that if the salt requirements are met, the Cl requirements should be adequate. However, in Sheepbytes, the dietary cation anion balance (DCAB) in the ratios section is affected by the minerals Na, K, Cl and S. In order to get an accurate ratio, you must ensure that there are some values of Cl entered in the feeds you have selected, otherwise the ratio cannot calculate accurately.

Chlorine functions to determine the acid level in the stomach (abomasal juice), acid-base balance and the so-called chloride shift (the oxygen and carbon-dioxide exchange in the red blood cells in the presence of carbonic anhydrase which involves movement of the chloride ion). Absorption involves both active and passive systems and is lost through urine, sweat, etc. Deficiency symptoms include slow growth, but this is very rare.

Salt

Salt needed is based on the sodium recommendation. Sodium is 40% of salt so Na content divided by 0.4 (or multiplied by 2.5) gives an approximation of available salt. Recommended salt values are 0.15%, 0.15% and 0.22% for growing/finishing lambs, gestating and lactating ewes, respectively, and have a maximum tolerable level of 4% salt in the ration DM for all classes of sheep and lambs (NRC 2005).

Sodium and chloride are the elements in salt.

Using Salt to Restrict Feed Intake

Inclusion of coarse white salt to limit free choice feed intake to prevent over consumption is a management tool available to producers. Unfortunately, individual animals have different salt tolerances so it is not a precise method to limit feed intake.

Supplying cereal grains free choice in a creep feeder to lambs prior to weaning can result in digestive upsets and possibly death. This can also happen if sheep over consume barley and other grains. Feeding ewes free choice oat hulls can also result in digestive upsets and even impaction so limiting their intake may be necessary.

If salt is used to restrict feed intake, clean water must be available at all times to ensure water intake is acceptable. Total Dissolved Solids (TDS) concentration in the water must not exceed 5000 parts per million otherwise feed intake may decrease, or the animals may be in a salt toxicity situation. When limiting feed intake with salt, water consumption can increase by 50 to 75% of normal. Such mixtures to restrict feed intake are usually 10-50% salt depending on the desired amount of ration to be consumed. Trace mineralized or iodized salt should not be used for this purpose because of the possibility of excessive intake of various trace minerals, particularly toxic levels of copper. It is usually necessary to increase salt concentration in the mix over time because the sheep become accustomed to higher salt levels.

To prevent separation of the salt and grain, a coarse salt similar in size to the grain should be used.

Vitamin A

Vitamin A content of a feed is expressed in International Units (IU) per kg or Ib. Recommended and supplied levels of vitamin A within SheepBytes are expressed as IU's. Recommended values are 2300, 4200 and 5000 IU / Kg DMI for growing/finishing lambs, gestating and lactating ewes, respectively. Values are entered as KIU or 1000 international units per Kg. Vitamin A may also be reported in retinol equivalents (RE) as it is widely accepted throughout the world and has been used to describe vitamin A activity. RE multiplied by 3.3=IU.

Vitamin A is a generic term and refers to all compounds other than carotenoids (pro-vit A), with vitamin A activity. Vitamin A is fat soluble and is absorbed in the gut mainly as free retinol and carotenols but is esterified with long-chain fatty acids and released into the lymph as chylomicrons. Over 90% of vitamin A is stored in the liver. Since Vitamin A is found in high levels in actively growing forages and grasses, animals that graze on green forage during the normal growing season will perform adequately on low carotene diets for periods of 4 to 6 months after the grazing season ends. Vitamin A deficiency may occur after that time period. Light and oxygen oxidize vitamin A and usually over 90% of activity in feeds is retained for periods up to 6 months. Stability is reduced by pelleting and heat and humidity when stored as a formulated product. Stability is also reduced in the presence of trace minerals. Excretion is in the bile and urine.

Stability of carotenoids found in hay or silage is limited. Oxidation starts a few days after forage is cut and after 90 days, availability is reduced. If the forage is rained on and weathered, 80% of the carotenoids are destroyed. Hay or silage rations should be supplemented with vitamin A.

Vitamin A is required for vision, growth, glycoprotein formation, reproduction, maintenance of mucus membranes and immunity. Deficiency symptoms reflect the many functions of vitamin A. Toxicity results in bone abnormalities, loss of hair, poor growth and congenital abnormalities.

Vitamin D

Animals are able to manufacture their own vitamin D from exposure to ultraviolet light on their skin. Absorption is reduced by increasing subcutaneous fat, heavy coats of wool or hair and barriers like glass or indoor confinement.

Vitamin D is a fat soluble vitamin required for calcium and phosphorus absorption and mobilization of calcium from bone. It also serves a role in the immune function of the body. In the liver and kidney vitamin D is transformed into potent forms known as 25-hydroxy-vitamin D3 (4 times more active/potent than vitamin D) and 1-25-dihydroxy-vitamin D3 (20 times more active/potent than vitamin D), respectively.

Requirement of all sheep except early weaned lambs is 555 IU /100 kg of live weight per day where one IU is defined as 0.025 µg (microgram) of cholecalciferol D3. For early weaned lambs the requirement is 666 IU/100 kg live weight. More recent research has shown that requirements are higher than previously established.

Deficiency symptoms include loss of appetite, digestive disturbances, rickets, swollen and stiff joints, irritability, tetany, convulsions, bones that are weak and easily broken and a decrease in blood calcium. Vitamin D has been shown to reduce the occurrence of lambs being born weak, deformed or dead. Toxicity symptoms include very high blood calcium levels as a result of increased mobilization from bone leading to very soft bones. Sheep on pasture with sunny climates seldom need additional vitamin D.

Vitamin E

Vitamin E content of each feed is expressed in international units (IU) per kg. Recommended level is 15 IU/kg DMI with levels of up to 60 IU/kg DMI for immune function, reproduction or stress. Lambs under 20 Kg should receive 20 IU/kg DMI. These recommendations assume dietary selenium levels of >0.05 ppm because Vit E and Se are closely linked in metabolic function. Vitamin requirements should be increased if the goal is to enhance immunity response of the animal or extend the storage case life of lamb meat. NRC (2007) recommends 10 IU vitamin E/kg body weight as an aid to protect sheep from infectious disease and to extend the storage life of lamb meat, however these levels are very costly to supplement.

In conjunction with Selenium (via Glutathione peroxidase) Vitamin E functions as part of a multi-component antioxidant defense system. High levels of Vitamin E can spare but not replace Se; as Vitamin E is fat soluble and protects at the lipid layer, and Se acts within the aqueous level in the cell. Vitamin E is generally considered one of the least toxic of the vitamins. Deficiency of vitamin E can present as white muscle disease, or nutritional muscular dystrophy and has been associated with high neonatal losses.

Vitamin E supplementation of sheep diets is more costly compared to Vitamin A and D supplementation. However, deficiencies of Vitamin E can have a serious impact on health and productivity of the sheep flock. While good quality pastures and harvested forages can provide a significant portion of the Vitamin E requirements of the flock, particular attention to dietary supplementation should be made in the following circumstances:

1. Whenever mature or weather damaged forages are fed;
2. When feeding ewes in late gestation or early lactation;
3. When feeding early weaned lambs;
4. When white muscle disease, muscular dystrophy, weak lamb syndrome, or immune system incompetence are observed or diagnosed in the flock.

Gestating sheep grazing dormant range or fed harvested feeds preceding late winter or early spring lambing may need supplemental vitamin E to positively affect lamb production. Although supplemental vitamin E given to the newborn lamb will increase serum levels, this practice is not as effective in reducing mortality or increasing lamb performance as providing the ewe with vitamin E supplementation prior to lambing (in the last 3 to 4 weeks of pregnancy). Placental and mammary transfer of vitamin E from the ewe to the lamb is most effective and results in greater body weight gain and weaning weights in the lambs.

Copper (Cu)

Sheep have a narrow range between required levels and levels where toxicity can occur with regards to copper. Copper requirements of sheep are so dependent on dietary and genetic factors that it is difficult to state requirements without specifying the conditions for which they apply.

The presence or absence in the diet of sheep of other minerals and some ionophores affects the copper metabolism of sheep; especially the level of molybdenum and sulfur in the diet. Mo and S act as antagonists to copper and prevent gut absorption and increase excretion of absorbed copper in the liver and body tissues. Thus, Mo reduces Cu availability and high S levels amplify this effect. Sheepbytes uses the rule that if Mo is less than 1.0 mg/kg and S is less than 0.25%, the maximum tolerable level of Cu in the ration will be 15 mg/kg. However, when the Mo is above 1.0 mg/kg and S is above 0.25, then the maximum tolerable level will be 25 mg/kg.

Feeding ionophores (ex. monensin; active ingredient in Rumensin® or lasalocid active ingredient in Bovatec®) to sheep can result in increased efficiency of copper absorption by sheep. Refer to the section on ionophores for more information. Generally accepted levels of copper in the diet of sheep are 7-11 mg/kg with a maximum tolerable level of 25mg/kg. Do not feed specifically formulated swine, poultry or cattle feeds to sheep as they may contain high levels of copper by design.

Copper deficiency can result in a condition known as neonatal ataxia or “swayback” in very young lambs. Sheep suffering from copper deficiency have “steely” or “stringy” wool, lacking in crimp, tensile strength, affinity for dyes and elasticity. Lack of pigmentation of the wool of black sheep occurs with Cu deficiency with a similar condition occurring with high levels of molybdenum.

Copper metabolism in sheep is influenced by the breed or breed crosses. Generally, the down type, medium wool sheep of British or European origin and sheep from Texel breeding are the most susceptible to copper toxicity. Fine wool type sheep are intermediate in susceptibility to toxicity while sheep with Finnish Landrace breeding are least susceptible to copper toxicity.

Reference

Adapted from article written by Mike Neary, 2002, Purdue University

Recommended Copper Allowance from NRC 1985

	Recommended Cu Allowance (mg/kg diet DM)		
Mo Content of Diet (mg/kg)	Growth	Pregnancy	Lactation
< 1.0	8-10	9-11	7-8
> 3.0	17-21	19-23	14-17

Manganese (Mn)

Manganese has a minimum recommended level of 20 mg/kg of diet for sheep. Maximum tolerable level is 2000 mg/kg of diet. Absorption is through the gut but the efficiency of absorption is low (up to 25%) with absorption rates highest for iron and higher for cobalt than Mn. Excretion of excess Mn is through the bile. Functions in activating many enzymes, as an antioxidant, in brain function, and in carbohydrate, lipid and protein metabolism. Deficiency symptoms include enlarged joints, malformation of bones, ataxia of the newborn lamb, reproduction problems, slow growth, poor reflexes, more fat in liver and kidney, and reddening of hair colour. Toxicity may cause anemia due to blockage of iron absorption and loss of appetite. Blood levels are not acceptable. Levels in the liver are more accurate. High levels of calcium and phosphorus may increase the occurrence of manganese deficiency.

Zinc (Zn)

Zinc has a minimum recommended level of 20 mg/kg of DM for growing sheep and 33 mg/kg DM for breeding males, pregnant and lactating females.
Maximum tolerable level is 750 mg/kg of diet. Absorption occurs throughout the gut with efficiency up to 30%. Chelation with amino acids such as histidine, cysteine, lysine and glycine increases absorption while calcium, cadmium, copper, lead, iron, phytate and phosphates as well as indigestible fibre decrease absorption. Excretion is mainly through the feces, with smaller amounts in urine, wool, sweat and semen. Zinc functions as a component of over 200 enzymes, stabilizes cell membranes, binds proteins to membranes, and controls gene transcription, and immune function. Zinc deficiency can cause weak brittle hoof, horn and a higher incidence of foot rot. Deficiency symptoms include loss of appetite, scaly skin, loss of wool, reduced immune function, vision impairment, excessive salivation and impaired reproduction. In addition, all phases of reproduction in females from estrus to parturition and lactation may be adversely affected by deficient zinc levels. Toxicity of Zn can result in Cu deficiency in pregnant ewes, but it is normally not a problem. Interpret blood levels with caution. Liver levels are more reliable.

Selenium (Se)

The NRC requirement for selenium is 0.1 mg/kg but a more practical level is 0.2 mg/kg especially if legume forages are being grazed or fed and if sulfur levels are high and vitamin E levels in the feed are low.

Maximum tolerable level is 4.0 mg/kg. Absorption in association to methionine and cysteine is almost 100% with inorganic sources being about 60-70% efficient. Excretion occurs through the urine, bile and pancreatic juice. Deficiency symptoms include white muscle disease, loss of condition, retained placenta, lameness and diarrhea. Toxicity can cause loss of wool, sloughing of hoofs, reduced reproductive performance and death from respiratory failure. Selenium and vitamin E perform related functions in the muscle, one can replace the other to an extent but not completely. Generally Se is low in B.C., Northern Alberta, Northern SK, Northern MB and all of eastern Canada.

Iodine (I)

The minimum recommended level for Iodine for growing lambs is 0.25 mg/kg, and for ewes pregnant and/or lactating is 0.80 mg/kg of diet. The maximum tolerable level is 50 mg/kg. Lactating animals require more iodine due to excretion in the milk. Absorption is throughout the gut with the rumen being the major absorption site. Excretion is mainly through urine with small amounts in feces and sweat. Functions in control of energy metabolism (oxygen consumption, body temperature) mental vigor, fat metabolism and weight loss and conversion of carotene to vitamin A. Deficiency symptoms include goiter formation, reduced performance, lowered metabolic rate and water retention. Toxicity can result in reduced feed consumption, damage to the lining of the gut, increased number of premature births, still births and weak and abnormal lambs at birth. Interpret blood levels with caution; liver levels are not acceptable.
Iodized salt should not be used in a mixture with a concentrate supplement to limit feed intake, since the animals may consume an excessive amount of iodine at the high rates that salt needs to be added to limit intake.

Cobalt (Co)

Minimum recommended level for Cobalt is 0.2 mg/kg of diet. Maximum tolerable level is 20 mg/kg. Cobalt is necessary for the synthesis of cyanocobalamin (vitamin B12) in the rumen. Thus, signs of cobalt deficiency are actually signs of vitamin B12 deficiency including loss of appetite, rough hair coat and lost body condition. Absorption is over 50% and is dependent on an intrinsic factor which protects Co from intestinal proteases, heat and bacteria. Excretion is mainly through the bile. Functions in the formation of methionine from homocysteine and in utilization of propionate. Deficiency symptoms are similar to energy-protein malnutrition or heavy parasitism. Toxicity is very rare.

Iron (Fe)

Iron is the most abundant trace mineral in the body, and about 60% of it is in hemoglobin that is necessary for transporting oxygen and carbon dioxide to and from the tissues and lungs. Iron is required for fetal growth in the gestating ewe, wool and weight gain in the growing lamb and milk in the lactating ewe. It is assumed that the requirements for iron in older animals are lower than younger animals because considerable recycling of iron occurs when red blood cells turn over and in older sheep the blood volumes are not increasing as they are in young animals. The dietary iron requirement of sheep was set at 30 mg Fe/kg dry matter intake in the previous edition of NRC (1985). Soils can be high in iron and therefore provide the forages, crops and grasses that grow on them with adequate concentrations of iron. However, animals kept indoors and fed concentrate grain mixtures and milk based diets containing limited iron may develop deficiencies. Deficiency symptoms may include poor growth, loss of appetite, blanching of mucous membranes and increased respiration.

Vitamin E deficiency increases an animal's susceptibility to iron toxicity. High levels of iron in forages, particularly in spring grazing conditions, can cause copper deficiency in lambs and goats. The maximum tolerable level of dietary iron is 500 mg/kg dry matter.

Molybdenum (Mo)

The minimum Molybdenum requirement is not exactly known, but appears to be low. A requirement of 0.5 mg Mo/kg diet dry matter was set for sheep in NRC 1985 and has been accepted in NRC 2007. Maximum tolerable level is 10 mg/kg of molybdenum with copper supplementation. Absorption is mainly in the abomasum and small intestine with an efficiency up to 85%. Excretion is mainly in urine and bile. Molybdenum functions as enzyme co-factors such as sulphide oxidase (reduction of sulphates to sulphides) and metabolism of drugs and foreign compounds. Absorption is reduced when intake of sulphate is high (over 0.1%). High levels of Mo and S influence the availability of copper. If normal levels of Mo and S are present in the feeds, the dietary Cu:Mo should ideally be greater than 6:1. However, if the Mo levels of the diet are low, <1 mg/kg, then forages with a normal copper content of 8 to 11 mg/kg can produce toxicity. Mo toxicity is controlled by increasing the copper level in the diet by 5 mg/kg. Toxicity results in same symptoms as copper deficiency. Click the Ratios tab to view the Cu:Mo ratios.

Chronic toxicosis can occur when pastures contain 20 to 100 mg/kg of Molybdenum dry matter, inducing anorexia, weight loss, scours, and secondary copper deficiency.

Trace Mineral Availability

Mineral supplements for ruminants contain trace minerals essential to meeting the requirements of the animal for maintenance and production. However, not all trace minerals are the same in that there are different levels of bioavailability depending on the form of the mineral: organic or inorganic. For common minerals such as copper, zinc, manganese and selenium, trace mineral forms include oxides, carbonates, chlorides and organic (complexed chelate, proteinate, etc.).

Generally there is a scientific consensus that the oxide and carbonate forms of copper, zinc and manganese are 30-60% less available than the sulphate form. For organic forms of copper, manganese and zinc, absorption levels are improved by up to 30%, 75% and 59-100% respectively over the sulphate forms. In summary, organic forms of trace minerals have higher bioavailability than sulphate forms which are more available than oxide forms.

The decision to use organic forms of trace minerals should only be precluded by symptoms of trace mineral deficiency or to counteract the interactions with other substances. Situations where there is a high sulphate level in the feed and/or water and an imbalance with other dietary minerals (such as excessive dietary molybdenum and iron) may require the use of organic trace minerals. Organic minerals may be beneficial when the animal is undergoing production stress (e.g. weaning, lactation). However, under most feeding conditions, the sulphate form of copper, zinc and manganese will be adequate in meeting the mineral requirements.

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NDF %

Neutral detergent fibre (NDF) is expressed as a percentage of dry matter. NDF is a fibre estimate of the feed and is the sum of ADF (acid detergent fibre) plus hemi-cellulose. NDF affects rumen fill. The maximum NDF intake is close to 1.5% of body weight. However, the feeding environment is highly variable and sheep are able to select parts of the plant or components of their ration in such a way that what the nutrient analysis of a feed may report and what the nutrition of that feed consumed is to an individual animal, may be different. Sheep, if given the option, will select higher quality components out of a ration and often leave the less digestible coarse components behind. Thus, the maximum NDF as a % of body weight is based on the nutrient analysis of the feed and may be overestimated when sheep eating behaviours are not considered. Sheepbytes color codes NDF as a % of body weight to be red when over 1.5% to account for their selective eating behaviours. Each feed must have an NDF and eNDF (effective NDF) value to ensure a proper rumen microbial protein synthesis calculation.

For feed samples where the NDF and eNDF have not been determined, use the equivalent NDF and eNDF figures given in the Default Feed Table in SheepBytes. Some guidelines for the percent of NDF as eNDF are:

30% if grains (except corn, use 60%)
100% if straw
95-98% if long hay
80% if chopped hay greater than 20% over 1 inch length
65% if ground hay at 1/4 inch length
60% if silage

You also need to know the DIP and UIP percentages in your feedstuffs as they are dependent on the eNDF and TDN fed. Again, the default figures listed in the Default Feed Table can be used as guidelines if those values are not available.

eNDF%

Effective NDF (eNDF) is expressed as a percentage of NDF. eNDF is the portion of the NDF that stimulates chewing activity, rumination and rumen motility which all help to maintain a healthy rumen. Long forages have high eNDF values exceeding 85%. Grains will have eNDF values up to 35%.

A minimum of 20% eNDF in the ration is required to maintain rumen pH at an optimum level for fibre digestion. As eNDF drops below 20% microbial protein production is reduced. There is a reduction in microbial protein production efficiency of 0.025% for each one percent that eNDF falls below 20%. Feeder lambs on grain based rations require a minimum of 8% eNDF. Each feed must have an NDF and eNDF value to ensure a proper microbial protein calculation.

Effective fibre has the ability to stimulate rumination, cud chewing and saliva production which buffers the rumen. A rumen pH less than 6.2 results in a progressive reduction of microbial protein production and fibre digestion. Rumen pH is extremely variable from animal to animal and changes dramatically with time after feeding so there is no one pH level for a given diet. Rumen pH is not only affected by the amount of grain fed, but also by the type of grain and its processing method both which influence the amount of acid produced in the rumen. For example, the rumen pH of sheep on a forage-based diet will be about 6.8 while a ration with grain may result in a rumen pH below 6.5.

DIP % of CP

Degradable intake protein (DIP) is expressed as a percentage of CP. DIP is rumen soluble nitrogen (NPN plus soluble true protein). Sufficient DIP must be available in the rumen for the micro-organisms to digest fibre. The requirement for DIP is dependent on eNDF and TDN fed. A calculation of TDN for DIP should not include TDN from fat since microbes cannot utilize the TDN from fat. It is important to meet DIP or at least be within 5% of the recommendation. If a feed's DIP is unknown, use the DIP value for an equivalent feed from the Feed Table. DIP conversion to MP is assumed to have an efficiency of 64%.

Dealing with Excess Protein

Feeding excess CP (specifically feeding excess DIP) above amounts needed for microbial synthesis results in ammonia production and accumulation in the rumen. Ammonia in the rumen also comes from hydrolysis of urea recycled to the rumen and from degradation of microbial crude protein. Ammonia disappears from the rumen through absorption by the rumen, uptake by the microbes and flushing to the omasum. Usually, ammonia absorption increases with increases in concentration and is also pH dependent (higher diffusion at higher pH). Apart from overt toxicity there are subclinical effects such as low fertility associated with high blood urea nitrogen levels.

Since higher ammonia levels can be toxic, sheep must rid themselves of ammonia. It takes a net of one energy-rich phosphate bond to synthesize one molecule of urea from ammonia which is then excreted in the urine. Thus, high DIP feeds can take away from the growth potential of sheep since energy needed for growth will be diverted to the detoxification of ammonia.

On the other hand, excess by-pass protein (excess Undegraded Intake Protein – UIP) may be metabolized after deamination in the Krebs cycle for energy. However, it is a very inefficient system for the generation of energy for sheep.

See also CP, UIP, MP, and ratio DIP/TDN %

UIP % of CP

Undegradable intake protein (UIP) is expressed as a percentage of Crude Protein (CP). UIP is true protein digested in the small intestine. It is also called by-pass protein since it is the amount of feed protein that escapes the rumen to the small intestine. Microbial protein from feed is UIP intake times 80%. It can be calculated as (MP-DIP)/0.80. SheepBytes calculates the UIP recommended intake based on the % forages and % concentrates fed in the ration. For all classes of sheep and lambs the recommended UIP is estimated to be approximately 33% of CP. Sheepbytes calculates the crude protein requirements for the classes and sub-classes of sheep based on crude protein having 20% UIP except the class of finishing lambs where the assumption is that high concentrate feeds will be fed therefore using crude protein requirements based on 60% UIP.
The body is able to recycle nitrogen in the saliva. An excess of UIP can partially compensate for a small shortage of DIP via the saliva.

MP

Metabolizable protein (MP) is protein (amino acids) that is actually absorbed from the gut. MP supplied is bacterial MP plus feed MP which is equivalent to UIP intake times 80% plus DIP intake times 64%. Recommended MP is based on the animal's body weight and stage of production (including pregnancy, growth, milk production, etc.). Sheepbytes calculates the crude protein requirements for the classes and sub-classes of sheep based on crude protein having 20% UIP except the class of finishing lambs where the assumption is that high concentrate feeds will be fed therefore using crude protein requirements based on 60% UIP.

To estimate DIP and UIP without an analysis, open the Feed Table and select a feed which most closely resembles your feed and scroll over to the DIP and UIP columns to see the average values for the DIP and UIP of that feed. Feed Analysis reports sometime report soluble protein, digestible protein, acid detergent insoluble crude protein (ADIP or ADICP), etc. Note: These values are not DIP or UIP.

Ionophore

Ionophores improve feed utilization and gain in ruminants by altering rumen fermentation. They are also coccidiostats; killing coccidia primarily during the sporozoite stage. Common brand names for ionophores are Rumensin® and Bovatec® containing active ingredients of monensin and lasalocid respectively. Lasalocid (Bovatec®) and Monensin (Rumensin®) are ionophores that can be added to mineral mixes or complete rations. Lasalocid (Bovatec®) is labeled as a coccidiostat for confined sheep. Ionophores can be toxic to horses and to dogs.

Enter the ionophore concentration in the feedstuff into the Ionophore column. Feed tag concentration is listed on an "As fed" basis. If entering the concentration into the Ration screen, divide the ionophore concentration by the % dry matter in the feedstuff to obtain DM concentration. In a high forage ration, feed efficiency is improved due a 6% reduction in dry matter intake. In a high grain ration such as a finishing ration, dry matter intake is not impacted, but nutrient utilization by the animal is increased by approximately 6%.

If ionophores are included in the ration, dry matter intake may decrease and absorption of copper may increase and Sheepbytes has accounted for these changes.

Output

This section explains the main output values generated by Sheepbytes.

Color coding on output values

Sheepbytes uses the colors Red, Yellow and Green to denote ranges or values of nutrients it determines in the animals' nutrients requirements. A nutrient value within an acceptable range will appear on screen as a value with a Green background color. No further action needs to be taken when a nutrient is coded Green.

If the nutrient is not within the recommended range (it may be either higher or lower than recommended values), but will not be harmful to the animal, the background color is Yellow. Yellow is a color code that alerts the user to take a closer look at the ration and while it may be considered acceptable in most instances, practical attempts to correct or eliminate yellow should be undertaken. Yellow should also prompt the user to check if any known symptoms have occurred in the flock while feeding the ration.

A nutrient value with a Red background is either below recommended levels, is excessive to the point of being harmful to the animal, and/or is of financial concern. Cells with the Red color code should be attempted to be corrected by the user or to seek professional opinions on possible solutions whether by a nutritionist or veterinarian. Colors are guides only and do not account for all interactions between nutrients.

The user needs to be aware that there are mineral interactions that can take place when nutrients are not within certain ranges of one another. All practical attempts to make the user aware of the most important mineral and vitamin interactions have been put in place with the aid of the ratios section.

MAX DMI

There is a theoretical estimate for the maximum dry matter intake (Max DMI) for an animal. This value is calculated based on the NDF of the diet. It gives an indication of the intake potential of the animal when you have not yet indicated how much you want to feed. Maximum DMI takes into account animal type, ionophore, temperature, environment and body condition score. Maximum NDF intake is approximated as 1.5% of body weight. MAX DMI values can be modified on the Modifications Page.

Recommended DMI

This is predicted DMI. DMI kg or lb takes into account animal type and body weight, its' expected average daily gain, whether an ionophore is fed or not, temperature, environment in the pen and body condition score. DMI values can be modified on the Modifications page. Recommended DMI does not consider the feed energy or feed protein content in the calculation.

Animal body weight is used to help predict dry matter intake. However, stressed animals can take up to 10 days to get onto full feed when placed into a backgrounding or finishing feedlot. This impacts ration formulation requirements.

Ewe and wether lambs should be marketed at 65 to 75% of their potential mature weight in order to produce a market lamb with desirable feed efficiency and fat cover. It takes more feed to produce a pound of fat than it does to produce a pound of lean. Timely marketing of finished lambs will help to reduce lamb feeding costs. Canadian lamb with 5 to 12 mm of fat (approximately equivalent to USDA YG2 and 3) is most desirable. The table below presents market weights at which ewe and wether lambs are expected to produce USDA Yield Grade 2 carcasses (0.16 to 0.25 inches of fat over the loin at the 12^{th}-13^{th} rib). These target weights can be used to help predict DMI. Target weights in this table should be increased by 10 to 20 pounds if the goal is Yield Grade 3 carcasses (0.26 to 0.35 inches of fat over the loin at the 12^{th}-13^{th} rib).

Target slaughter weights* to produce YG2 carcasses from ewe and wether lambs produced from sire and dam breeds of varying mature weights.

Ewe breed mature wt., lb.	Sire breed mature wt., lb. (wt. of ewes of the breed)													
	250	240	230	220	210	200	190	180	170	160	150	140	130	120
250	163	159	156	153	150	146	143	140	137	133	130	127	124	120
240	159	156	153	150	146	143	140	137	133	130	127	124	120	117
230	156	153	150	146	143	140	137	133	130	127	124	120	117	114
220	153	150	146	143	140	137	133	130	127	124	120	117	114	111
210	150	146	143	140	137	133	130	127	124	120	117	114	111	107
200	146	143	140	137	133	130	127	124	120	117	114	111	107	104
190	143	140	137	133	130	127	124	120	117	114	111	107	104	101
180	140	137	133	130	127	124	120	117	114	111	107	104	101	98
170	137	133	130	127	124	120	117	114	111	107	104	101	98	94
160	133	130	127	124	120	117	114	111	107	104	101	98	94	91
150	130	127	124	120	117	114	111	107	104	101	98	94	91	88
140	127	124	120	117	114	111	107	104	101	98	94	91	88	85
130	124	120	117	114	111	107	104	101	98	94	91	88	85	81
120	120	117	114	111	107	104	101	98	94	91	88	85	81	78

*Target slaughter weight = ((sire breed mature wt. + ewe breed mature wt.)/2) x 65.
Shaded areas indicate desired live weights for markets.

Estimates of average mature ewe weights for some U.S. breeds:
230 - Suffolk; **210** – Hampshire; **200** – Columbia; **180** - Dorset, Lincoln, Oxford, Shropshire;
170 – Border Leicester, Corriedale, Dorper, East Friesian, Montadale, Romney, Targhee;
160 – North Country Cheviot, Polypay, rambouillet, Texel; **150** – Coopworth, Romanov, Southdown, Tunis;
140 – Cheviot, Clun Forest, Finnsheep, Katahdin, Merino, Perendale, St. Croix;
130 – Cheviot, Scottish Blackface; **120** – Barbados, Karakul; **110** – Jacob; **90** – Shetland.

Table taken from ***Lamb Nutrition and Feeding***, Dan Morrical, Sheep Extension Specialist, Iowa State University with modifications and additions by David L. Thomas, Sheep Extension Specialist, University of Wisconsin-Madison. **The Shepherd, August 2011.**

Predicted ADG

The predicted average daily gain (ADG) is based on the excess energy intake above maintenance. The predicted ADG formula only accounts for energy, provided the protein fractions are within 80% of recommended values. Predicted ADG in SheepBytes is calculated when 80 to 85% of the protein recommendations are met and when the energy requirements for

maintenance have been fully met. If the energy or protein being provided in the ration is below these amounts, there will be low gain, no gain or a negative ADG. On the farm, the predicted ADG can only be met if, energy, and protein requirements (DIP, UIP and MP) are also met. Net energy of gain NEg is dependent on the animal type and breed size and expected ADG in addition to environmental factors.
Predicted ADG can also be considered the growth rate of the animal. Typical lambs generally need to be growing in excess of 300 g/day (0.67 lbs/day) to be profitable (Meat and Livestock Australia, producer's Guide 2007) and this is also true in North American situations. Feed costs account for anywhere between 50 and 70% of the production costs of raising sheep and are critical to optimize the performance of the lambs. Predicted ADG is computed for growing and finishing animal types, whereas, mature ewe and ram categories will use "days to gain or lose ½ BCS" to evaluate whether the nutrients from their rations are meeting their maintenance and production requirements.

Days to Gain or Lose 1/2 BCS

Sheepbytes uses the value of body condition score (BCS) for the mature animal classes, whereas, average daily gain (ADG) is used for the growing and finishing animal classes. This is the number of days required to gain or lose 7.5% of bodyweight which is approximately half a body condition score. 1 BCS is equivalent to approximately 15% of the animal's weight. For example, a 175 lb ewe at a BCS of 3 will weigh about 150 lbs if at a BCS of 2. The Canadian BCS system is on a scale of 1 to 5. The program does not use half scores when defining the animal type (ex. 1.5, 2.5, 3.5 or 4.5) so you should select the closest whole number to represent the condition score of the animal in question.

One Mcal of mobilized tissue is valued at 80% of diet NEm due to metabolic inefficiencies, and one Mcal of diet NEm provides one Mcal of tissue NE. The net energy of gain for mature ewes will be approximated at 5.7 Mcal/kg of body weight gain for muscle tissue and 9.4 Mcal/kg of body weight gain for fat tissue. It is assumed that mature ewes will gain 80% fat and 20% lean when they put on gain or lose weight. Mature rams are assumed to have a net energy of gain at 82% of mature ewes because the ram's weight gain is largely muscle and less fat compared to females (fat requires more Mcal per kg gain). Early weaned and young, light weight lambs are assumed to require 2.9 Mcal/kg gain while growing and finishing lambs require a range from 3.4-5.7 Mcal/kg gain depending on age, breed type and weight.

Ratios

This section explains the ratios that Sheepbytes calculates. Ratios are presented as additional information to help the user become aware of possible nutrient interactions that are common when feeding sheep and lambs.

Ca:P

Calcium and phosphorus must be supplied in adequate amounts (grams per head per day) to meet nutritional requirements. They also must be supplied in the proper ratio. The minimum acceptable Ca:P ratios are a minimum of 1.5 part calcium to 1 part phosphorus with minimum calcium requirements met; to a maximum of 5 parts calcium to 1 part phosphorus with the minimum phosphorus requirements met. Animal performance will be reduced at the ratio extremes. Calcium availability is affected by high levels of K and Mg. To view Ratios press the Ratios Tab.

See also Ca, P, K and Mg.

Tetany Ratio K/(Mg + Ca)

High dietary potassium (K), lowered calcium (Ca) and lowered magnesium (Mg) can all cause the tetany ratio to increase and predispose animals to tetany. The tetany ratio is expressed as K/(Ca + Mg) in milliequivalents (mEq) per kilogram of dry matter. Milliequivalents take into account both molecular weight and valence (ion charge) because acid-base balance is affected by electrical charge rather than mass. To determine the tetany ratio from dietary percentages, the formula used is:
(% K supplied in the ration times 255.74) divided by [(% Ca supplied in the ration times 499) + (% Mg supplied in the ration times 822.64)].
A suitable tetany ratio is considered to be less than 2.2:1.

Grass or winter tetany is a complex disorder characterized by a deficiency in blood Mg also known as hypomagnesemia. A high K intake can decrease the absorption of Mg from the gut inducing hypomagnesemia. Animals initially exhibit a depressed appetite and a dull lethargic appearance. As the disease progresses, stiffness, a staggering gait, nervousness, excitability, muscular tremors, collapse, thrashing about and finally death may follow. Mortality among untreated clinical cases can be greater than 30%. Older ewes (5 years +) are more susceptible to tetany because of their decreased ability to mobilize skeletal Mg. Ewes are more susceptible to tetany immediately prior to lambing and when they are nursing multiple lambs. Outbreaks of tetany occur most frequently in nursing ewes shortly after they are turned out to pasture in the spring (grass tetany). Incidence is highest during the first 4 to 5 weeks after lambing, when magnesium requirements for lactation are maximal.

Keep in mind all the following points when working with high K feeds:

- Be particularly concerned when forage K exceeds 2.5%. High levels can occur in barley and oat cereal greenfeeds.
- Consider alternative forages (low K%) during the critical period of 4 to 6 weeks prior to lambing
- Ensure Calcium to Phosphorus (Ca:P) ratios are between 2:1 and 5:1; this may require feeding 0.5 to 1 ounce of limestone per head per day.
- The dietary cation:ion balance (DCAB) may be more important in preventing metabolic problems around lambing than the tetany ratio, but there are no specific recommendations for a suitable DCAB for ewe diets so the Sheepbytes program has followed recommendations for dairy cattle as suggested by the NRC. Keep the DCAB as low as possible especially the last 4 to 6 weeks of gestation.

To view ratios click the ratios tab.
See also K (potassium percent), Mg (Magnesium percent) and Ca (Calcium percent).

Cu:Mo

Copper, molybdenum, sulfur and iron should be considered together in determining proper feeding management. Acid soils increase copper and lower molybdenum in forages; however,

molybdenum is higher in alkaline or high organic matter containing soil (and also high in sulfur). In particular, high levels of molybdenum reduce the availability of copper. The dietary Cu : Mo should ideally be greater than 4:1 but not higher than 10:1, borderline at 2-3:1 and toxic if less than 2:1. Use the Ratios tab to view the Cu : Mo ratio. Blood Cu levels are not acceptable as a method of monitoring the copper status of sheep. Blood levels will only provide an accurate reading when levels are extremely low. Copper status is more accurate when a liver biopsy is completed.
Copper availability in the ration is impaired by Molybdenum. For every 1 ppm Molybdenum in the diet, 7 ppm copper in the ration is rendered unavailable to the animal.

Copper / Molybdenum / Sulphur : Thiomolybdates

When copper, molybdenum and sulphur are combined in the diet and the rumen; there is a three way interaction that results in the creation of an insoluble complex called thyiomolybdates. Thiomolybdate formation results in reduced absorption and availability of each mineral, particularly molybdenum and copper. In the presence of high levels of dietary molybdenum and moderately high levels of sulphur, copper absorption and availability from the diet, liver and plasma is greatly reduced and may result in a secondary copper deficiency. Sheep are 10 times more susceptible to copper toxicity than cattle. Copper toxicity can occur in relation to molybdenum when the dietary ratio of copper to molybdenum increases above 6 – 10 : 1. Affected animals go off feed and become weak and urine will be red-brown in color.

Cautionary levels
Diets should be evaluated when dietary levels of molybdenum are:

1. Greater than 3 mg/kg when animals are fed copper sufficient diets.
2. If the Molybdenum levels are normal and dietary copper levels are low (< 5 mg/kg in the diet). NRC recommends a minimum of 5 – 7 mg/kg copper in the diet to meet nutritional requirements of different classes of sheep.
3. If the copper : molybdenum ratio is less than 4 : 1.
4. An increase in dietary sulphur from 0.20 to 0.40 percent can reduce copper availability by 50 percent.
5. For every 1 mg/kg of molybdenum in the final ration, 7 mg/kg of copper in the ration is tied up or not available.

Mineral supplementation strategies in the presence of low levels of copper or high levels of molybdenum and/or sulphur should be resolved by increasing the amount of copper in the mineral supplement or utilizing a chelated or proteinated copper to increase availability. See the section on Trace Mineral Availability.

Nitrogen : Sulfur (N:S)

Sulfur deficiency signs are similar to protein deficiency (loss of appetite, reduced weight gain or weight loss and reduced wool growth). When the diet contains low levels of protein and/or much of the dietary nitrogen is from nonprotein nitrogen, sulfur supplementation is required. Non protein nitrogen (NPN) which may also be known as urea or equivalent crude protein (ECP) refers to protein that is not naturally occurring from a plant or animal source.

For efficient utilization of dietary nonprotein nitrogen, the dietary ratio of nitrogen:sulfur should be between 10 and 12:1. When supplementing with significant amounts of ruminally undegradable protein sources (UIP), this nitrogen:sulfur ratio may need to be checked on the ruminally degradable fraction (DIP) to be sure that the rumen microbes' sulfur requirements are met. Excessive sulfur intake can interfere with the absorption of other elements, especially copper and selenium.

Sulfur in distillers products has become a recent concern (2008). Adapted from D. Schingoethe, A. Garcia, K. Kalscheur, and A. Hippen, Department of Dairy Science, South Dakota State University K. Rosentrater, Agricultural Research Service.

When starch in corn is fermented to ethanol, other nutrients in the kernels are concentrated approximately three fold in the distillers grains with solubles (DGS). Therefore, the 0.1% sulfur in corn should translate to approximately 0.3% sulfur in DGS, Such a level moves DGS into the low- to medium-end of sulfur levels found in some other common feeds Thus, the industry norm for sulfur in today's DGS is greater than the 0.4% maximum tolerable level for sheep listed in the small ruminant NRC 2007.

The extra sulfur in DGS is not from the corn. Most of it is likely from chemicals added during the processing to control pH and for cleanup. Such chemical sources of sulfur will usually be higher in the distillers solubles (often referred to as condensed distillers solubles or CDS) than in the distillers grains because the solubles fraction is where such compounds are originally collected. A recent survey indicated a range of 0.22 to 1.80% of dry matter as sulfur in the solubles, with the average being typically higher than the average for DGS. Modified DGS also often contains more sulfur (e.g., 0.89 to 1.38%) than DGS because modified DGS often contains more than the proportionate amounts of solubles accounted for by the starting corn.

One can usually formulate diets within the recommended range of 0.2 to 0.4% sulfur, even when dealing with high sulfur-containing distillers products because the distillers product should not typically make up more than 20% of the ration. It is recommended that producers obtain sulfur content information when using DGS in diets of livestock.

Dietary Cation Anion Balance (DCAB)
(Na + K) – (Cl + S)

Milk fever is a metabolic disease most commonly observed in high producing, mature dairy cows at, or near calving. The disease is associated with low serum calcium concentration causing neuromuscular symptoms such as involuntary muscle contractions, downed animals and in severe situations coma and death. This disease can also be a concern for lactating ewes and ewe lambs.

A ewe on the day of lambing produces colostrum requiring a significant amount of calcium. In addition the ewe also requires calcium for maintenance. The total daily requirement of dietary calcium for a newly freshened ewe is approximately 8 to 10 times the blood concentration of calcium. If prior to lambing, the ewe is able to increase calcium absorption from the ration, mobilize bone calcium stores, and reduce urinary excretion, she will be fine. If her body cannot effectively manage the mobilization and excretion processes, milk fever (hypocalcaemia) may occur. (Adapted from the Alberta Dairy Management Factsheet) It is generally assumed that low blood calcium may precipitate milk fever especially when most of the blood calcium is drawn into milk when the ewe nears lambing.

A strategy widely used in the dairy industry to minimize the incidence of milk fever is to use the concept of dietary cation-anion balance (DCAB). DCAB is the sum of the major positive ions minus the sum of the major negative ions in the feed. While there are several formulas for calculating the DCAB, it is most commonly calculated as $[(Na^{+}+K^{+}) - (Cl^{-}+S_2)]$ measured in milliequivalents (mEq/kg of the diet dry matter) (Oetzel, 1993). *Equivalent weight* is the molecular weight of the element divided by the valance of the ion. When the sum of the positive ions Na and K is higher than that of the negative ions Cl and S, a mild metabolic alkalosis (blood pH increases) occurs and the blood environment becomes slightly alkaline. On the other hand when the sum of the positive ions Na and K is lower than the sum of the negative ions Cl and S, a mild metabolic acidosis (blood pH decreases) occurs and the blood environment becomes slightly acidic (Oetzel, 1993). The release of calcium from bone is enhanced under mild acidic conditions. In contrast when forages with high potassium levels are fed (i.e. the average potassium content of alfalfa is 1.8% on DM basis), DCAB may become highly positive and the process of calcium mobilization from bone becomes inefficient. For Dairy cows, the ideal DCAB is in the range of -75 to -200 mEq/kg of feed dry matter (Alberta Dairy Management Factsheet 1M1). Since many types of forage contain high levels of potassium, it is becoming common to feed dairy cows anionic salts (negative DCAB) in order to achieve such low negative DCAB values. Anionic salts are fed to slightly depress blood pH (i.e. mild acidosis). Some feed companies have close-up supplements containing ammonium sulphate (-15, 169 mEq/kg) and magnesium sulphate (-8, 131 mEq/kg) which are usually fed 3 weeks prior to calving to dairy cows to decrease DCAB levels, These salts are quite unpalatable and also quite potent in lowering blood pH; it is therefore essential to maintain control over intake.

Because limited data exists in sheep, on this issue, NRC suggests following the dairy cattle requirements. It is recommended that when formulating diets for ewes in the last 6 to 8 weeks prior to lambing that you keep the DCAB ratio as low as possible, less than 200 mEq/kg of feed DM.

The formula to calculate DCAB in Sheepbytes is to sum all the Na, K, Cl and S using:
mEq/kg feed DM = charge x (% in feed dry matter / mEq weight) x 10

The charge for both Na and K is +1 while the charge for Cl is -1 and for S is -2. The mEq weight of Na is 0.023; K is 0.039; Cl is 0.036; and S is 0.016.

During late pregnancy DCAB should be < 200
During lactation DCAB should be <-100

In order to achieve this, it is important to know the level of potassium in the feed. Under certain conditions, cereal crops grown for greenfeed or silage may accumulate very high levels of potassium (2.5% or higher). Extended periods of dry growing conditions, high levels of fertilization and excessive use of manure applied to fields may contribute to potassium accumulation in plants. Golden German Millet is another plant known to accumulate potassium. A number of feed analyses have shown potassium levels greater than 5% (dry matter basis). As previously discussed, feeds with high potassium content can contribute to high positive DCAB ratios and predispose ewes to milk fever. See also Na, K, and S.

References:

Mason, S., Alberta Dairy Management Factsheet 1M1. Dietary Cation-Anion Balance.

Oetzel, G.R. 1993. Use of anionic salts for prevention of milk fever in dairy cattle. Compendium on Continuing Education for the Practicing Veterinarian. 15:1138-1146

Feed : Gain

This is the amount of feed on a dry matter basis required per unit of gain. For example, if grower lambs were consuming 4 lbs. of dry matter for a gain of 0.7 lbs., the Feed:Gain value would be 5.7, meaning it takes 5.7 pounds of feed to put on a pound of gain. Keeping the feed to gain ratio low, provided the ration ingredients are not too expensive, helps to improve feed efficiency and reduce production costs for feeding the flock.

DIP as a % TDN

One use for protein in a ration is to maintain rumen microbial populations. Microbe generation intervals can be as short as 20 minutes for bacteria, 8 hours for protozoa and 24 hours for fungi. Degradable Intake Protein (DIP); protein that is digested in the rumen is used by the microbes for growth and reproduction. When feeding low quality forages such as timothy aftermath, slough hay or straw, the amount of protein provided by the forages may not be sufficient to maintain microbial populations needed to digest fibre in the forage. The lack of protein causes microbial populations to decline, causing reduced fibre digestion rates. Reduced fibre digestion limits feed passage rates, which limits feed intake due to less room for additional feed in the rumen. If no additional protein is added to the diet, rumen function can be disrupted and impaction can occur.

The amount of protein required in a ration is dependent on animal type, size and stage of production. The DIP as a % Total Digestible Nutrients (TDN) ratio is important when feeding low quality forages to sheep. A minimum DIP as a % TDN ratio of 12 to 13% is recommended. This ratio may need to be higher if forage protein content and quality is especially low. Preferred supplements to supply DIP and thereby increase digestibility of fibre are; grains, and grain protein supplements that contain urea. For extensive grazing systems, molasses and urea protein supplements in liquid and block form are suitable.

See also DIP and TDN

DMI as % BW

Dry matter intake as a % of body weight generally varies from 2 to 6%, but can reach over 7%. NRC 2007 recommendations are considerably lower in some cases of animals, especially the mature ewes and replacement ewe and ram lambs during maintenance periods which are less than 2% of body weight. Heavily pregnant ewes and ewe lambs have reduced rumen space and therefore DMI is limited but nutrient quality will need to be high. Younger animals will have intake greater than 3% of body weight. Mature sheep will consume up to 5% when thin, but might average closer to 2% under normal feeding conditions without stress. For newly arrived, stressed or diseased lambs, DMI may be well below normal as a % of body weight over a range of 7 or more days. Weaned lambs, or newly placed feeder lambs can take approximately 10 days to get on full feed.

Vitamins, minerals and protein and energy concentrations of the feed may need to be increased to make up for the decreased DMI in stressful situations.

NDF as a % of BW

Intake is limited by the total amount of neutral detergent fibre (NDF) and NDF is a fibre estimate of the feed that affects rumen fill. The maximum NDF intake is close to 1.4% of body weight for mature sheep. However, the feeding environment is highly variable and sheep are able to select parts of the plant or components of their ration in such a way that what the nutrient analysis of a feed may report and what the nutrition of that feed consumed is to an individual animal, may be different. Sheep, if given the option, will select higher quality components out of a ration and often leave the less digestible coarse components behind. Thus, the maximum NDF as a % of body weight is based on the nutrient analysis of the feed and may be overestimated when sheep eating behaviours are not considered. Sheepbytes color codes NDF as a % of body weight to be red when over 1.5% to account for their selective eating behaviours. Each feed must have an NDF and eNDF (effective NDF) value to ensure a proper rumen microbial protein synthesis calculation.

If NDF as a % of BW is colour coded yellow or red it is indicating that the ration contains too much fibre and you may need to provide more concentrates or grains and less roughages (or provide better quality roughages) to balance the ration. Rations containing low quality roughages like straw must be carefully monitored by viewing this NDF as a % of BW to ensure the values are within recommended levels. Failure to do so may result in animals not being able to consume the nutrients required from the DMI supplied or may result in compaction of the rumen.

Forage DM as %BW

Forage intake is limited by the total amount of NDF consumed. For a mature ewe, intake is limited when NDF intake approaches 1.4% of body weight. Straw and poor quality forages that contain 60% NDF or greater, are consumed at 1.0 to 1.5% of body weight, while excellent quality forages can be consumed at 4 – 5% of body weight. Grinding or chopping low quality forages may increase intake when particle size is 2 cm or shorter. If there is insufficient effective fibre in the ration, metabolic problems such as acidosis and bloat may occur. Sheep are very selective if given the opportunity to select certain components out of a ration. Therefore, when limited or only poor quality feeds are provided the NDF value must be considered when balancing the ration. However, if better quality feeds and/or an abundance of them are provided, NDF will be of lesser concern.

% Forage (DM)

This represents the amount of forages in the total ration, as a percentage, on a dry matter basis. Producers feeding animals for a certified organic market may also be concerned with the % Forage on a DM basis as there are rules and limitations with amounts that can be fed. Typically, as an example, a certified organic producer may not want to exceed 60% grains or concentrates in the ration leaving the balance as 40% forages.

Concentrate: Forage

This represents the relationship between concentrates (grains and supplements) and the forages (hays and silages). Mature sheep rations are typically comprised of 80% or more forages while finishing lamb rations may be in excess of 80% concentrates.

NDF %

Neutral detergent fibre (NDF) is expressed as a percentage of dry matter. NDF is a fibre estimate of the feed and is the sum of ADF (acid detergent fibre) plus hemi-cellulose. NDF affects rumen fill. The maximum NDF intake is close to 1.4% of body weight. Each feed must have an NDF and eNDF (effective NDF) value to ensure a proper rumen microbial protein synthesis calculation. Sheepbytes uses the NDF and the eNDF to calculate the required amount of digestible intake protein (DIP).

However, the protein yield decreases as the rumen becomes more acidic – when eNDF is less than 20%, or more alkaline when eNDF is higher than 56%. Therefore, if NDF and eNDF columns are left with a zero value for a feed, the recommended amounts of DIP and CP could be underestimated.

For feed samples where the NDF and the eNDF have not been determined, use the equivalent NDF and eNDF figures given in the Default Feed Table in Sheepbytes. Some guidelines for the percent of NDF as eNDF are:
30% if grains (except corn, use 60%)
100% if straw
95 – 98% if long hay
80% if chopped hay greater than 29% over 1 inch length
65% if ground hay at ¼ inch length
60% if silage

Know the DIP and UIP percentages in the feedstuffs. The figures listed in the Default Feed Table can be used as guidelines if those values are not available.

DIP and UIP

There are two types of protein categories:

Degradable in take protein (DIP), or rumen degradable protein, and Undegradable intake protein (UIP), or digestible undegradable protein. Crude Protein contents in feed ingredients= DIP + UIP. Sheepbytes calculates the DIP based on being approximately 13% of the animal's energy requirements from TDN. UIP is calculated based on the approximation that all animals require about 33% of CP as UIP.

Bacteria in the rumen require a supply of DIP so they can break down the forage in the diet and produce protein in a form that the animal can digest in the small intestine. Without the intervention of these rumen bacteria, sheep could not utilize the energy locked up in the grass and forage. DIP provides most of the sheep's needs throughout the year. However, a plentiful supply of high quality UIP is essential for prolific ewes in the last three weeks of pregnancy for udder development and milk production. UIP is protein that avoids breakdown in the rumen and is absorbed directly from the ewe's intestines. As an example, a good source of UIP is soybean meal.

Nitrates

SheepBytes reports Nitrates as %NO3, however, nitrate levels may be reported in three different ways depending on the analytical procedure used. The results may be reported as nitrate (N03), nitrate nitrogen (N03-N) or potassium nitrate (KN03). Be sure you know which method was used before trying to interpret the results. Refer to the following table.

Category	% NO3	%NO3-N	% KNO3	Remarks
1	<0.5	<0.12	<0.81	Generally safe for beef cattle and sheep
2	0.5 - 1.0	0.12 - 0.23	0.81 - 1.63	Caution - some subclinical symptoms may appear in pregnant horses, sheep and beef cattle
3	1.0	0.23	1.63	High nitrate problems - death losses and abortions can occur in beef cattle and sheep
4	<1.23	<0.28	<2.00	Maximum safe level for horses. Do not feed high nitrate forages to pregnant mares.

*The values quoted above are on a dry (moisture free) basis.

Adapted from Agdex 400/60-1 Barry Yaremcio, Alberta Agriculture, Ag Info Centre

Nitrate is the form of nitrogen that plant roots take up from the soil. It is transported to the leaves where it is eventually converted into protein. Excess nitrates accumulate in plants when they are stressed. Drought or hot dry winds put forage under water stress often resulting in nitrate accumulation. Damage caused by hail or frost impairs photosynthesis resulting in excess nitrates. Cool cloudy weather can also cause the problem.

When any of these conditions occur within a few days of harvest or grazing, the potential for nitrate poisoning exists. If the stress is removed and the plants recover, nitrate levels should return to normal within several days. If there is any doubt then test the feed.

When ruminants consume a high nitrate feed, some of the nitrate cannot be immediately converted to nitrite and finally to ammonia. This causes both nitrate and nitrite to accumulate in the rumen. Nitrate is continually released from the feed being digested in the rumen. The addition of new nitrate into the rumen intensifies the problem.

Nitrate poisoning occurs when the nitrite level in the rumen exceeds the capacity of the microbes to convert it to ammonia. When this happens, nitrate and nitrite are absorbed through the rumen wall into the bloodstream. It is the nitrite that causes toxicity. Nitrite combines with hemoglobin to form methemoglobin. Hemoglobin carries oxygen to body tissues while methemoglobin is unable to do so. When enough hemoglobin is converted to methemoglobin the animal begins to suffer from oxygen starvation.

Environmental Factors
Yardage

The Yardage calculator is an additional feature in the Sheepbytes program to help you calculate your costs as this may be useful to add to the feed only costs the program provides. Yardage is the total cost of housing an animal in the yard and is a significant component of a livestock system, whether backgrounding, custom-feeding or operating a feedlot.

There are three main components to yardage costs: fixed costs, variable costs and labour costs. Fixed costs are all the costs that will be incurred by the livestock operation whether there are sheep in the yard or not. Fixed costs include the total cost associated with purchasing the land (including interest rates), equipment and structures. In addition to the initial purchasing cost of these items, interest and insurance costs should also be included, as they will be paid over a number of years.

Variable costs represent all the costs that are associated with running the facility. These include electricity, natural gas, repairs, fuel, etc. The final component is labour costs. There is some debate whether or not labour should be included in yardage cost, but it is important to attach a value to the total cost of labour, which should include the time to feed the animals in addition to time spent on managing the operation and book keeping. Labour does not necessarily have to be included in yardage, as long as labour is not overlooked when compiling a complete cost of feeding livestock.

Yardage costs are a major component in the total cost of feeding sheep, and it is necessary to calculate your own yardage cost, as it will vary significantly from operation to operation. There are several ways to manage yardage costs. The first is to maximize the use of the facilities to ensure that you are generating maximum returns from the facilities that are in place. The second is to manage variable cost and look for cost-savings, where possible.

Managing yardage costs is a crucial part of managing a livestock operation. If an operation is unable to recover its variable costs, it may be best to not operate for that given year. However, if the operation will break even with variable cost or exceed the variable cost, it is in the best interest of the operation to continue.

Adapted from the Saskatchewan Department of Agriculture, www.agriculture.gov.sk.ca
Agriculture Knowledge Centre "Evaluating Yardage Costs" written by Craig Klemmer and Christy Winquist Livestock Development Oct. 2008

Water

A continual supply of good quality water is essential. Clean troughs regularly to ensure water is not contaminated with feed, dust and faeces. Water sources should contain less than 3500 parts per million (ppm) soluble salts. Water intake is dependent on ambient temperature, fleece length, water quality and availability, salt content of water and feed, water temperature, familiarity with water delivery devices, trough size, flow rates, genotypes and dry matter intake.

Young lambs less than 20 kg body weight may be getting a significant portion of their water intake from milk from their dam and thus the formula for predicting water intake that is based on dry matter intake of the animals has been adjusted for this scenario since dry matter intakes are very low at this stage.

Managing Snow as Water

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Snow can be used as a water source provided the following is understood:

Ewes and cows prefer to consume soft, powdery, clean snow when there is no access to water. For ewes, no signs of abnormal behaviour, such as bleating, were observed after 24 hours of providing only snow. Cows had a brief adjustment period of 3–5 days, but adapted to not having a liquid source of water after that. Once they learn to eat snow, cows can switch quickly from eating snow to drinking water and back again, without becoming stressed. Pasturing an experienced snow eating cow in with cows that have never eaten snow before can help speed the transition. For a successful transition to using snow as the sole water source, provide:

- shelter from the wind and extreme temperatures (animals must have adequate fleece or hair coat)
- soft, wet snow for eating (snow with hard granular ice particles in it may cause lower intake and result in decreased feed intake as well)

If hard granular, wind-blown snow or trampled and/or soiled snow is the only snow available, supplement it with liquid water. To make snow covered by ice available, drive a tractor over the ice to break through to the powdery snow below. Dry pregnant ewes and beef cows must be healthy and should be maintained in good body condition (3.0 or better in a 1–5 system) throughout the period they are relying upon snow as their water source. Check animals daily and have a back-up plan for getting liquid water to animals or animals to liquid water if snow conditions deteriorate. If animals continue to be restless after making the switch from liquid water to snow or decrease their feed consumption, the snow quantity or quality may not be adequate.

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Fleece

The term full fleece in the Sheepbytes program refers to animals with wool or hair longer than 50 to 60 mm or equivalent to 2-2.5 inches. The term newly shorn refers to animals having been shorn within the last 4 weeks and/or fleece lengths being less than 10 mm or equivalent to about 0.4 inches. For fleece lengths between these values the user will need to determine if the animals should be classified as full fleece or newly shorn based on the time that has passed since shearing and the current/existing weather conditions.

Generally, shorn sheep seem to tolerate hot and humid environments better than full fleece sheep, while full fleece sheep tolerate hot and dry or cold conditions better than shorn sheep (Beatty et al., 2008). Sheep are at the greatest risk of becoming hypothermic when the air temperature drops below the normal range for the season, in combination with rain and windy conditions. The sooner after shearing the adverse weather occurs, the more likely the sheep are to be affected. Although a couple of weeks of wool growth does offer some protection, high mortalities have occurred among sheep up to four weeks after shearing. Season of shearing, age and fat level of sheep are all factors that determine how the sheep will react to sudden weather changes at shearing time. Young animals are highly susceptible because of their low body fat reserves. When sheep are shorn in late winter or spring, they have already been exposed to cold weather in winter. This acclimatization takes about two weeks to develop and lasts about two months. Once acclimatized, sheep are less likely to die from hypothermia, even if a cold spell occurs immediately after shearing. Sheep that have been shorn in the summer are used to very high temperatures, and if adverse weather occurs after shearing, they will be at a higher risk of dying from hypothermia. This is because they have not been acclimatized to the cold and they cannot adapt to the sudden drop in temperature.

adapted from *Hypothermia in Shorn Sheep,* Western Australia Department of Agriculture Farm Note, 2005 by Don Moir, District Veterinary Officer, State of Western Australia.

Beatty. D.T., Barnes, A., Fleming, P.A., Taylor, E., and Maloney, S.K. 2008. The effect of fleece on core and rumen temperature in sheep. Journal of Thermal Biology Vol 33, issue 8, pp 437-443.

Wind and Rain

Environmental parameters that affect intake and energy requirements are temperature, wind and rain. Weather information for your region can be sourced through you favourite provincial or national weather website.
The Sheepbytes program considers “windy” to be wind speeds above 18 km/hr while calm would be winds blowing at less than this speed. The program makes only one adjustment to nutrient requirements when going from no wind to windy. For example, a ration adjusted for a wind speed of 20 km/hr will not have any further adjustments should the wind change to 45 km/hr. However, animal type and stage of production, plus fleece length and conditions of rain/wet snow will all influence these nutrient requirements.

Rain or wet snow will impact an animal’s lower critical temperature. Excessive rain that wets the fleece down to the hide will have a greater impact on nutrient requirements than a light rain only affecting the surface of the fleece. Sheepbytes allows for the user to select either “wet” or “dry” as animal descriptors to further modify the nutrient requirements; particularly the dry matter intake and energy values.

Heat Stress

Heat stress can be variable among different classes of animals and behavior should be taken seriously when panting and open mouth panting occurs. Sheepbytes defines heat stress for all classes and sub-classes of animals at temperatures over 25°C, if they are in full fleece. When there is no or low wind, this heat stress will result in a decrease in dry matter intake of approximately 15% and an increase in energy TDN of 11%. If conditions are such that there is wind, then the resulting decrease in DMI is 12% and the increase in TDN will be 7% (animals consuming less dry matter will require a more nutrient dense ration to meet their nutrient requirements).

If the animals have been shorn, heat stress is assumed to occur at temperatures over 29°C. Heat stressed newly shorn animals will have the same percentages of DMI decrease and TDN increase as is listed in the full fleece heat stressed animals above depending on the wind conditions.

Cold Stress

Generally, digestibility decreases during cold conditions as the rate of passage of nutrients through the digestive system increases. This is due to the fact that in cold conditions, blood flow to internal organs increases making the feed pass more quickly through the digestive system.

However, the increased rate of passage means less time is allowed for nutrient absorption, thereby, resulting in lower digestibility of the feed. Sheepbytes increases the lower critical temperature (LCT) by 5°C for each additional stressor (wind, wet, shorn).

The lower critical temperature (LCT) for fully fed, acclimatized sheep with long wool is -40°C in calm air indoors. Rain, wind and length of wool fleece strongly influence the amount of heat loss while the level of feeding influences heat production. Both can change the LCT (Blaxter, 1964; Joyce et al., 1966; and Webster, 1976). For practical purposes, mature sheep in outdoor Canadian conditions can easily adapt to temperatures of -20°C while young weaned lambs can handle temperatures of 10°C before changes to nutrition and management are applied. Young lambs are particularly susceptible to cold due to their larger surface area and lower body fat reserves. However, time to acclimatize to changing environments is equally important and must not go unaddressed as a manager of sheep and lambs. Refer to the section on fleece for additional information related to cold and heat stress.

Well fed sheep survive in colder environments by huddling together, seeking shelter and activating several physiological mechanisms to maintain homeostasis below the thermoneutral zone. Being below LCT only means that the animal must increase its heat production (and start to use more maintenance feed) to keep body temperature up (Berge, 1997).

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Appendix 1: Energy Comparisons

Equivalent Energy Levels in Different Energy Systems

TDN%	DE Mcal/kg	ME Mcal/kg	Nem Mcal/kg	Neg Mcal/kg	TDN%	DE Mcal/kg	ME Mcal/kg	Nem Mcal/kg	Neg Mcal/kg
38.9	1.71	1.40	0.56	0.03	54.8	2.41	1.98	1.13	0.57
39.3	1.73	1.42	0.58	0.05	55.5	2.44	2.00	1.15	0.59
40.0	1.76	1.44	0.60	0.07	55.9	2.46	2.02	1.17	0.61
40.5	1.78	1.46	0.62	0.09	56.6	2.49	2.04	1.19	0.63
40.9	1.80	1.48	0.64	0.11	57.0	2.51	2.06	1.21	0.64
41.6	1.83	1.50	0.66	0.13	57.7	2.54	2.08	1.23	0.66
42.0	1.85	1.52	0.68	0.15	58.2	2.56	2.10	1.25	0.68
42.7	1.88	1.54	0.70	0.17	58.9	2.59	2.12	1.26	0.69
43.2	1.90	1.56	0.72	0.19	59.3	2.61	2.14	1.28	0.71
43.9	1.93	1.58	0.74	0.21	59.8	2.63	2.16	1.30	0.73
44.3	1.95	1.60	0.76	0.23	60.5	2.66	2.18	1.32	0.75
45.0	1.98	1.62	0.78	0.24	60.9	2.68	2.20	1.34	0.77
45.5	2.00	1.64	0.80	0.26	61.6	2.71	2.22	1.36	0.78
45.9	2.02	1.66	0.82	0.28	62.0	2.73	2.24	1.38	0.79
46.6	2.05	1.68	0.84	0.30	62.7	2.76	2.26	1.39	0.81
47.0	2.07	1.70	0.86	0.32	63.2	2.78	2.28	1.41	0.83
47.7	2.10	1.72	0.88	0.34	63.6	2.80	2.30	1.43	0.84
48.2	2.12	1.74	0.90	0.36	64.3	2.83	2.32	1.45	0.86
48.9	2.15	1.76	0.92	0.38	64.8	2.85	2.34	1.46	0.88
49.3	2.17	1.78	0.94	0.40	65.5	2.88	2.36	1.48	0.90

50.0	2.20	1.80	0.96	0.41	65.9	2.90	2.38	1.50	0.91
50.5	2.22	1.82	0.98	0.43	66.6	2.93	2.40	1.52	0.93
50.9	2.24	1.84	1.00	0.45	67.0	2.95	2.42	1.54	0.94
51.6	2.27	1.86	1.02	0.47	67.7	2.98	2.44	1.55	0.96
52.0	2.29	1.88	1.04	0.49	68.2	3.00	2.46	1.57	0.97
52.7	2.32	1.90	1.06	0.50	68.6	3.02	2.48	1.59	0.98
53.2	2.34	1.92	1.08	0.52	68.9	3.04	2.49	1.60	0.99
53.9	2.37	1.94	1.10	0.54	69.3	3.05	2.50	1.61	1.00
69.8	3.07	2.52	1.62	1.02	83.6	3.68	3.02	2.05	1.39
70.5	3.10	2.54	1.64	1.03	84.3	3.70	3.04	2.06	1.40
70.9	3.12	2.56	1.66	1.05	84.8	3.73	3.06	2.08	1.42
71.6	3.15	2.58	1.68	1.06	85.5	3.76	3.08	2.10	1.43
72.0	3.17	2.60	1.69	1.08	85.9	3.78	3.10	2.11	1.44
72.7	3.20	2.62	1.71	1.10	86.4	3.80	3.12	2.13	1.46
TDN%	DE Mcal/kg	ME Mcal/kg	Nem Mcal/kg	Neg Mcal/kg	TDN%	DE Mcal/kg	ME Mcal/kg	Nem Mcal/kg	Neg Mcal/kg
73.2	3.22	2.64	1.73	1.11	87.0	3.83	3.14	2.15	1.47
73.6	3.24	2.66	1.75	1.13	87.5	3.85	3.16	2.16	1.48
74.3	3.27	2.68	1.76	1.14	88.2	3.88	3.18	2.18	1.50
74.5	3.29	2.70	1.78	1.16	88.6	3.90	3.20	2.19	1.51
75.5	3.32	2.72	1.80	1.17	89.3	3.93	3.22	2.21	1.53
75.9	3.34	2.74	1.81	1.19	89.8	3.95	3.24	2.23	1.54
76.6	3.37	2.76	1.83	1.20	90.5	3.98	3.26	2.25	1.56
77.0	3.39	2.78	1.85	1.21	90.9	4.00	3.28	2.26	1.57

77.5	3.41	2.80	1.86	1.23	91.4	4.02	3.30	2.28	1.58
78.2	3.44	2.82	1.88	1.24	92.0	4.05	3.32	2.29	1.59
78.6	3.46	2.84	1.90	1.26	92.5	4.07	3.34	2.31	1.61
79.3	3.49	2.86	1.93	1.27	93.2	4.10	3.36	2.32	1.62
79.8	3.51	2.88	1.93	1.29	93.6	4.12	3.38	2.34	1.63
80.5	3.54	2.90	1.95	1.30	94.3	4.15	3.40	2.36	1.65
80.9	3.56	2.92	1.97	1.32	94.8	4.17	3.42	2.37	1.66
81.6	3.59	2.94	1.98	1.33	95.5	4.20	3.44	2.39	1.67
82.0	3.61	2.96	2.00	1.35	95.9	4.22	3.46	2.40	1.69
82.5	3.63	2.98	2.01	1.36	96.4	4.24	3.48	2.42	1.70
83.2	3.66	3.00	2.03	1.37	97.0	4.27	3.50	2.43	1.71

1 kg TDN = 4.409 Mcal DE
1 lb TDN = 2.000 Mcal DE

ME = DE times 0.82
NEm = 1.370ME – 0.138ME^2 + 0.0105ME^3 - 1.12
NEg = 1.427ME – 0.174ME^2 + 0.0122ME^3 - 1.65

Note:

To convert to Mcal / pound of feed divide DE, ME, NEm, and NEg, values by 2.204
(1 Mcal is equivalent to 4.184 Megajoules)

(Adapted from Dr. G. Mathison, Professor Emeritus, University of Alberta)