SECTION C -- NUTRIENT REQUIREMENTS

In North America, nutrient allocations for sheep are based on the recommendations of the U.S. National Research Council (NRC). These are set out in the publication "Nutrient Requirements for Sheep." In the United Kingdom, the recommendations of the Agricultural Research Council (ARC) are used. The recommendations in the present Guide are based on those given by the NRC and in some cases will reflect information found in the ARC publication "The Nutrient Requirements of Ruminant Livestock."

Before discussing specific nutrient requirements, it will be useful to classify the essential nutrients and, at the same time, point out the interrelationships between classes.

ESSENTIAL NUTRIENTS

Water

This is a nutrient which is often overlooked in designing feeding programs for livestock. Its importance is illustrated by the following anecdote.

In 1978, the Alberta Ram Test Station was housed in a closed building on the Calgary Stampede grounds. Although it was well ventilated, it tended to be a little warm. A complete pelleted ration was designed which would promote maximum growth of the lambs on test. Water was provided in automatic, float-operated fountains. The first groups of lambs got off to a rapid start and grew very well for about six weeks (they were weighed every two weeks). After that, growth began to slow and feed consumption decreased, to the dismay of the management, who began looking for causes. Initially the feed was blamed and a new lot was brought in. Next, the temperature in the barn was considered. Finally, the water was examined. Although the water in the drinking bowl had been kept clean, no attempt had been made to clean the float compartment. Here a healthy population of micro-organisms had developed which was imparting an off-flavor to the water in the drinking bowl. Consequently the lambs were limiting their water intake which was affecting their appetite and thus their growth. As soon as the problem was rectified, rapid gains returned.

The point is this: sheep are fussy drinkers. In addition, if they are forced to subsist on an inadequate water supply in periods when their nutrient requirements are high, production may suffer. As in the case above, insufficient water intake may result in reduced dry matter consumption and often affects salt and mineral intake. In late pregnant ewes, whose requirements are particularly high, inadequate water intake leading to reduced feed consumption may result in pregnancy toxemia.

As a demonstration of the benefit of a clean, fresh water supply, feed consumption of feedlot lambs at Fairview College in Alberta was increased by providing water which was constantly circulated past the lambs thorough rain gutters. The increased intake was apparently the result of appetite stimulation through increased water consumption.

Waterers which are not kept clean (fig. C1) are also a source of disease. Several common health problems which result from fecal contamination are spread through fouled water supplies.

The water consumption of sheep is widely variable, depending on age, stage of production, wool cover, water temperature and environmental temperature and humidity.
TABLE C1 Estimated water intakes for sheep. Values are given as litres of water consumed per kilogram of feed dry matter consumed.

<table>
<thead>
<tr>
<th>Class of Sheep</th>
<th>Environmental Temperature</th>
<th>Water intake (litres/kg DM consumed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>below 16°C</td>
<td>16-20°C</td>
</tr>
<tr>
<td>Lambs (up to 4 weeks)</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Sheep (growing or adult, non-pregnant, dry)</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Pregnant Ewes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mid pregnancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- single</td>
<td>2.5</td>
<td>3.1</td>
</tr>
<tr>
<td>- twins</td>
<td>2.8</td>
<td>3.5</td>
</tr>
<tr>
<td>late pregnancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- single</td>
<td>3.3</td>
<td>4.1</td>
</tr>
<tr>
<td>- twins</td>
<td>4.4</td>
<td>5.5</td>
</tr>
<tr>
<td>Lactating Ewes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>first month</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>second month</td>
<td>3.0</td>
<td>3.7</td>
</tr>
<tr>
<td>late lactation</td>
<td>2.5</td>
<td>3.1</td>
</tr>
</tbody>
</table>
The consumption of clean snow can account for a significant proportion of water intake in winter, but should not be relied upon as the only source. Sheep consuming feeds which are high in water content (silage, pasture) will satisfy a sizable proportion of their requirements from their feed. Table C1 gives some guidelines to expected water consumption.

**Energy**

Inadequate energy limits performance more often than any other nutrient deficiency. In lambs the symptoms are most commonly slow growing and lower resistance to infection. Ewes may experience loss of weight, reduced fertility and lamb birth weights, inadequate milk production, shortened lactation periods and reduced wool quantity and quality. Energy deficiency may be a result of insufficient feed intake or, most commonly in B.C., low ration energy (TDN) content.

As suggested earlier, carbohydrates, fats, oils and proteins can all serve as energy sources although the most significant contribution is from the carbohydrates. The total energy content of a feed can be estimated by burning a sample and measuring the amount of heat produced.

**Digestible Energy**

Of the total energy consumed, some is released by the digestive process or absorbed into the bloodstream while the remainder is contained in indigestible compounds like lignin which are excreted (fig. C2). In the feed analysis procedure, the digestible portion of feed energy is calculated as TDN or DE from measurement of acid detergent fibre (ADF) (see p.4).

Some of the energy which is *apparently digested* is actually lost as gas from the rumen when the animal belches. A second portion is lost through urinary excretion.

**Metabolized Energy**

Digestible energy minus gaseous and urinary losses is termed metabolizable energy (ME). As mentioned in the section on feed analysis, ME is the basis of energy recommendations in the U.K. For most feeds, the assumption is made that ME amounts to 82% of DE.

![Figure C2 The partition of feed energy consumed by the sheep.](image-url)
TABLE C2 Examples showing the partitioning of gross energy intake.

<table>
<thead>
<tr>
<th>Energy Fraction</th>
<th>20 kg lamb gaining 275 grams/day kcal</th>
<th>45 kg lamb gaining 250 grams/day kcal</th>
<th>70 kg ewe during maintenance kcal</th>
<th>70 kg ewe 140 days pregnant with twins kcal</th>
<th>70 kg ewe 70 kg ewe first 8 weeks lactating with twins kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Energy Intake</td>
<td>4397 100</td>
<td>7486 100</td>
<td>5273 100</td>
<td>9259 100</td>
<td>12323 100</td>
</tr>
<tr>
<td>Digestible Energy*</td>
<td>3210 73</td>
<td>5240 70</td>
<td>2900 55</td>
<td>5370 58</td>
<td>8010 65</td>
</tr>
<tr>
<td>Metabolizable Energy</td>
<td>2630 60</td>
<td>4300 57</td>
<td>2380 45</td>
<td>4400 48</td>
<td>6570 53</td>
</tr>
<tr>
<td>Net Energy for:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>1012 23</td>
<td>1380 18</td>
<td>1618 31</td>
<td>1618 17</td>
<td>1618 13</td>
</tr>
<tr>
<td>Pregnancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2765 22</td>
</tr>
<tr>
<td>Gain</td>
<td>1040 24</td>
<td>1400 19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* % Digestible Energy = Ration TDN %
Metabolizable energy is not totally available for production. Some proportion must be utilized for body maintenance, some for physical activity and some for keeping warm, and combating disease and other stresses. What remains for production is termed *Net Energy* and even here, there are costs incurred in the processes by which milk, meat, wool and offspring are produced. These costs are referred to as the *heat of production*.

Finally, energy which is available in excess of that which can be utilized for production is stored, largely in the form of fat. This need not imply that fat is stored only after the animal has reached its maximum potential production. When rations are not balanced with respect to the nutrients they contain, fat may be stored even at lower levels of production. For example, muscular growth may be limited by inadequate protein although adequate energy is provided and the excess of energy over protein will be stored as fat. Stored energy may be later mobilized when energy demand exceeds that available in the ration. A few numerical examples of the way in which energy is utilized are given in table C2.

The *energy concentration* in a ration affects both intake and efficiency of utilization. Figure C3 demonstrates that intake decreases as TDN concentration in the ration increases from 55 to 85%. At TDN levels below 55%, intake decreases as the result of increased fibre which reduces the rate of digestion. As far as possible, as energy level falls, the animal consumes more in an attempt to satisfy energy requirements until the absolute limitations of bulk make this impossible. The second effect of ration energy concentration is shown in table C3. The efficiency of ME utilization increases with increasing energy concentration in the ration.

### TABLE C3  The effect of ration energy concentration (% TDN) on the efficiency of energy (ME) utilization for various functions.

<table>
<thead>
<tr>
<th>Function</th>
<th>50% TDN</th>
<th>75% TDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>33</td>
<td>48</td>
</tr>
<tr>
<td>Ewe maintenance</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>Fetal development</td>
<td>NA</td>
<td>13</td>
</tr>
<tr>
<td>Lactation</td>
<td>NA</td>
<td>66</td>
</tr>
</tbody>
</table>

**Effect of Environment on Energy Requirements**

Figure C4 defines a thermoneutral zone for sheep. This is the temperature range in which the heat demand of the environment is offset by the heat released by productive processes (heat of production, fig C2). The limits of the thermoneutral zone are referred to as the lower and upper critical temperatures. Below the lower critical temperature (LCT) the animal is required to utilize an additional fraction of metabolizable energy (ME) to stay warm through shivering and other heat producing processes.

Figure C3 The relationship between ration energy (TDN) content and the intake of dry matter and TDN.

![Figure C3](image)

Figure C4 The thermoneutral zone is dependent upon animal size, level of production and amount of insulation.

![Figure C4](image)
Likewise, above the upper critical temperature (UCT), heat of production becomes a burden to the animal and ME is required to dissipate heat through panting.

The actual values for LCT and UCT are dependent on several factors including the size of the animal, the level of production and the amount of insulation (fat and fleece).

**TABLE C4** The effects of wool cover and feeding level on the lower critical temperature for ewes.

<table>
<thead>
<tr>
<th>Wool Cover, Feeding Level</th>
<th>LCT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm fleece, maintenance</td>
<td>28</td>
</tr>
<tr>
<td>5 mm fleece, fasting</td>
<td>31</td>
</tr>
<tr>
<td>5 mm fleece, maintenance</td>
<td>25</td>
</tr>
<tr>
<td>5 mm fleece, full feed</td>
<td>18</td>
</tr>
<tr>
<td>10 mm fleece, maintenance</td>
<td>22</td>
</tr>
<tr>
<td>50 mm fleece, maintenance</td>
<td>9</td>
</tr>
<tr>
<td>100 mm fleece, maintenance</td>
<td>-3</td>
</tr>
</tbody>
</table>

Small animals have a large surface area relative to their body size and, therefore, lose heat rapidly. Animals on a high plane of nutrition release more heat of production. Therefore, both their LCT and their UCT are lower. The same is true of animals with a significant covering of fleece. Although upper critical temperatures have seldom been measured experimentally, estimates of LCT under various conditions are given in table C4. For ewes in the maintenance period with varying amounts of wool cover, percent increases in energy cost per degree Celsius below the Lower Critical Temperature are given in table C5.

In addition to its effects on nutrient requirements, the environment can influence both feed intake and nutrient digestibility. In sheep, dry matter intake can be expected to decrease by about 0.5% for every 1°C increase in temperature from -5 to 35°C. Conversely, the digestibility of ration dry matter increases by about .2% for every 1°C rise in temperature in the same range. The net effect of these opposite effects on the performance of growing lambs is shown in table C6.

**TABLE C5** Extra insulation reduces the effect of cold temperatures on increasing energy requirements for maintenance.

<table>
<thead>
<tr>
<th>Fleece Length (mm)</th>
<th>% Increase in Maintenance Cost per 1°C below LCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5.8</td>
</tr>
<tr>
<td>40</td>
<td>5.4</td>
</tr>
<tr>
<td>50</td>
<td>5.2</td>
</tr>
<tr>
<td>60</td>
<td>4.7</td>
</tr>
<tr>
<td>70</td>
<td>4.6</td>
</tr>
<tr>
<td>80</td>
<td>4.6</td>
</tr>
</tbody>
</table>

It should be appreciated that although this discussion has centred on temperature; wind, humidity and rainfall can all modify the effects of temperature. Wind effectively raises the thermoneutral zone while humidity lowers the UCT. Rainfall can reduce the insulative value of the fleece, again raising the thermoneutral zone.

**TABLE C6** Gain and growth efficiency of lambs raised at different environmental temperatures and fed ad lib (without restriction).

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Gain (grams/day)</th>
<th>Gain per Unit of Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>73</td>
<td>0.04</td>
</tr>
<tr>
<td>-20</td>
<td>130</td>
<td>0.08</td>
</tr>
<tr>
<td>-10</td>
<td>170</td>
<td>0.11</td>
</tr>
<tr>
<td>0</td>
<td>192</td>
<td>0.15</td>
</tr>
<tr>
<td>10</td>
<td>197</td>
<td>0.14</td>
</tr>
<tr>
<td>20</td>
<td>184</td>
<td>0.13</td>
</tr>
<tr>
<td>30</td>
<td>107</td>
<td>0.08</td>
</tr>
<tr>
<td>35</td>
<td>41</td>
<td>0.04</td>
</tr>
</tbody>
</table>

**Effect of Physical Activity on Energy Requirements**

Table C7 summarizes the available estimates on the energy costs of physical activity. Although the cost of standing over lying and the cost of changing position are relatively small, it has been found that the heat lost by sheep in the standing position in a cold environment can be 70% greater than that when lying. Thus, the total energy savings in an undisturbed flock lying on dry, well bedded grounds in winter may be considerable.

The energy cost of walking may be significant for ewes on extensive pastures. This points out another advantage of intensive grazing management where animals are confined to relatively small areas while satisfying their nutrient requirements.
TABLE C7  The energy requirements for muscular activity. These quantities are in addition to those for maintenance and other productive functions.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Grams TDN (70 kg ewe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking 1 km on level ground</td>
<td>12.1</td>
</tr>
<tr>
<td>Walking 1 km while ascending 100 metres</td>
<td>142.8</td>
</tr>
<tr>
<td>Lying down from a standing position and standing up again</td>
<td>1.2</td>
</tr>
<tr>
<td>Energy cost of standing over lying down (per day)</td>
<td>45.6</td>
</tr>
</tbody>
</table>

Energy Sources

Energy (TDN) levels of typical B.C. feeds are given in Appendix 1. As suggested earlier, sheep rations should be forage-based with the grains being considered energy supplements. The exception might be the feeding of lambs to produce high rates of gain. In this case high-grain rations are required to achieve the required energy intake.

Protein

Inadequate ration protein levels result in appetite reduction, lowering intake. In addition, feed which is consumed is less efficiently utilized. The combined effects of reduced intake and inefficient feed utilization extract a heavy toll on production and reproduction including poor growth, muscular development and reduced reproductive efficiency. Extreme protein deficiencies, most commonly the result of parasitism or disease (e.g., Johne’s disease), are often seen in the form of anemia and edema (bottle jaw). When ration protein levels approach those found in straw, even the rumen microbial population cannot be maintained, resulting in severe digestive disturbances.

It should be obvious from the discussion on protein digestion that even when adequate energy is provided, microbial protein synthesis cannot progress without a supply of ammonia in the rumen. It was also pointed out that the ammonia and the energy must be present in the same time frame (fig. B12). Thus, energy and protein (ammonia) supply must be balanced in both amount and time.

The total crude protein provided in feed can be partitioned in much the same way as energy was partitioned above. This is illustrated in figure C5.

Digestible Protein

Crude protein (CP) is an estimate of the total protein available to the ruminant (p.4). Some proportion of CP is completely unavailable to the animal (e.g., heat damaged protein) and is excreted in the feces. However, fecal protein also contains contributions from microbial protein which has escaped digestion, from spent digestive enzymes and from tissue which was sloughed and abraded from the lining of the digestive tract. These contributions are collectively termed metabolic fecal protein. The difference between crude protein and fecal protein is referred to as apparent digestible protein:

\[
\text{Apparent Digestible Protein} = \text{Crude Protein} - \text{Fecal Protein}
\]

and

\[
\text{Apparent Protein Digestibility} = \frac{\text{Apparent Digestible Protein}}{\text{Crude Protein}}
\]

True digestible protein is a measure of the difference between the crude protein consumed in the ration and that portion of fecal protein which was derived directly from the ration. The latter is very difficult to measure and, therefore, true digestible protein is seldom used in ration formulation. The digestible protein requirements given in the NRC publication “Nutrient Requirements of Sheep” refer to apparent digestible protein. In fact, the apparent and true digestibility of the protein in concentrate rations (grain, protein supplements) is in close agreement.

However, roughages having higher fibre and lower crude protein levels demonstrate decreasing apparent protein digestibility. This is the result of an increased contribution of metabolic fecal protein to total fecal protein excretion. In other words, apparent protein digestibility is a rather poor estimate of true protein digestibility for many roughages. The NRC digestible protein recommendations are, however, derived for roughage-based rations.
Metabolizable Protein

Protein which is eventually digested and absorbed as amino acids in the small intestine can be used to meet the protein requirements of the animal body. The efficiency of this process depends to some extent, on protein quality which, as discussed earlier (p. 14), is dependent upon the balance of amino acids absorbed. The contribution of bypass protein to this balance has also been mentioned. These concepts are illustrated in figure B11.

Determination of bypass protein requirement has been the topic of a great deal of research. However, it is not yet possible to make firm recommendations on the basis of the information available.

A second factor which determines the efficiency with which amino acids are used to manufacture new protein is the level of energy nutrition. When the energy demand of an animal is not fully met by non-protein sources, then the energy deficit may be met by using amino acids. This effectively reduces the amount of amino acids available for protein synthesis. This again points out the critical importance of nutrient balance when formulating rations. Amino groups released from amino acids used as energy sources are subject to either urinary excretion or recycling through saliva in the form of urea (fig B11).

32% SHEEP SUPPLEMENT
REG. No. 22365

INGREDIENTS
The ingredients in this feed are those named in the Certificate of Registration. This feed contains added selenium at 1.0mg./kg.

GUARANTEED ANALYSIS

<table>
<thead>
<tr>
<th>Component</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein *</td>
<td>32.0%</td>
</tr>
<tr>
<td>Fat</td>
<td>4.0%</td>
</tr>
<tr>
<td>Fibre (Max.)</td>
<td>9.0%</td>
</tr>
<tr>
<td>Salt</td>
<td>4.0%</td>
</tr>
<tr>
<td>Calcium (Actual)</td>
<td>2.3%</td>
</tr>
<tr>
<td>Phosphorus (Actual)</td>
<td>1.0%</td>
</tr>
<tr>
<td>Iron (Actual)</td>
<td>0.04%</td>
</tr>
<tr>
<td>Iodine (Actual)</td>
<td>0.0008%</td>
</tr>
<tr>
<td>Fluorine (Max.)</td>
<td>0.02%</td>
</tr>
<tr>
<td>Vitamin A (Min.)</td>
<td>45,000 I.U./kg</td>
</tr>
<tr>
<td>Vitamin E (Min.)</td>
<td>200 I.U./kg</td>
</tr>
</tbody>
</table>

* This includes not more than 20.0% equivalent crude protein from Urea.

Figure C6 The analysis of a typical 32% protein pellet suitable for lambs.

Protein Sources

As far as possible, protein requirements should be met through forage due to the high cost of supplementation. Where supplements are required, the most common form is the 32-50% crude protein pellet. A wide variety of formulations are available, many containing urea. Subject to the considerations on urea feeding discussed earlier, most can be used for sheep. When protein supplements contain urea, this will be noted on the label as “ECP from NPS”, meaning equivalent crude protein from non-protein sources. Fig C6 shows the analysis of a 32% urea-free protein pellet suitable for all classes of sheep.

Minerals

Fifteen minerals have been demonstrated as essential in sheep nutrition. Of these, seven are termed macromineral nutrients implying that they are required in relatively large quantities. These are:

- sodium
- chlorine
- calcium
phosphorus
magnesium
potassium
sulphur

The remaining eight essential minerals are referred to as trace or micromineral nutrients:

iodine
cobalt
iron
manganese
zinc
selenium
copper
molybdenum

Although these are required in relatively small quantities, it should not be inferred that they are any less important.

Table C8 describes the functions and symptoms of deficiency of the essential minerals. Notice in the column entitled “special considerations” that reference is made to interactions between minerals and between specific minerals and vitamins. Some of these demand particular attention because they are often involved in practical feeding problems.

Mineral Interaction

Calcium and Phosphorus

These two minerals require adequate magnesium and vitamin D for proper utilization. In addition, the ratio of calcium to phosphorus in rations should be in the 1:1 to 5:1 range. Higher proportions of calcium can reduce phosphorus absorption and, conversely, high phosphorus levels can reduce calcium availability. This is yet another situation where balance is important.

Copper, Molybdenum and Sulphur

Many B.C. feeds are deficient in copper. Furthermore, feeds which contain adequate copper levels in company with high molybdenum levels are effectively copper deficient. Molybdenum reduces copper availability and high sulphur levels amplify this effect. Ration copper levels should be 5 times those for molybdenum when sulphur levels are not abnormally high.

Selenium and Vitamin E

Both selenium and vitamin E are involved in the maintenance of tissue membranes. As a result they have a “sparing” effect on one another. Levels of selenium which are more than adequate can reduce the requirements for vitamin E and vice versa. There is no good evidence to suggest that either nutrient influences the absorption of the other.

Cobalt and vitamin B₁₂

Cobalt is an essential component of Vitamin B₁₂. When cobalt intake is inadequate, B₁₂ synthesis by the rumen microbes is reduced and symptoms of vitamin deficiency develop.

Mineral Sources

Since most of the feeds grown in B.C. are mineral deficient, the need for supplementation is virtually inevitable. Many mineral mixes are available and it is essential that an appropriate formulation is chosen to satisfy both the type and degree of deficiency being treated.

Salt

Salt simply consists of sodium and chloride and provides no other minerals in significant amounts. It is available loose and in blocks (licks) and is distinguishable by the white colour.

Iodized Salt

Iodine deficiency is universal and, in fact, white salt for human consumption is iodized by law. Iodized salt for animals is dyed a rust colour and again is available loose or in licks.

Cobalt-Iodized Salt

This is the common blue salt used for ruminant animals. The loose form should be used as a supplement for sheep when the ration contains adequate levels of the other essential nutrients. It is preferable to either plain salt or iodized salt because of prevalent cobalt deficiencies in our feeds.
salt for animals is dyed a rust colour and again is available loose or in licks.

*Cobalt-Iodized Salt*

This is the common blue salt used for ruminant animals. The loose form should be used as a supplement for sheep when the ration contains adequate levels of the other essential nutrients. It is preferable to either plain salt or iodized salt because of prevalent cobalt deficiencies in our feeds.
### TABLE C8  Essential minerals; their functions, deficiency and toxicity symptoms and special considerations relating to flock management.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Primary Functions</th>
<th>Deficiency Symptoms</th>
<th>Special Considerations</th>
</tr>
</thead>
</table>
| Sodium (Na) and Chlorine (Cl) Salt (NaCl) | - body fluid balance  
- appetite stimulant | - chewing wood, licking dirt, eating toxic amounts of poisonous plants  
- decreased appetite  
- decreased feed efficiency | - when mixed with rations or minerals mixes, maybe used to limit their consumption |
| Calcium (Ca)     | - bone formation  
- muscle contraction | - abnormal development of bone and in severe cases death and tetany | - deficiency symptoms develop slowly as calcium is drawn from the bones |
| Phosphorus (P)   | - enzyme activity  
- energy metabolism | - slow growth, depraved appetite such as wool picking  
- unthriftiness  
- listlessness  
- poor reproductive performance affecting conception and lambing rate | - vitamin D required for proper utilization of both Ca and P  
- Ca:P ration should be in 1:1 to 5:1 range  
- mature brages are often low in Phosphorus  
- deficiency common in British Columbia |
| Magnesium (Mg)   | - enzyme activity  
- nerve activity | - tetany (most often on fast growing pasture in the form of grass tetany)  
- irritability | - function and metabolism of Mg closely tied to that of Ca and P |
| Potassium (K)    | - appetite stimulant  
- enzyme, muscle and nerve function  
- rumen microbial activity | - poor appetite and feed efficiency  
- dry wool  
- stiffness progressing from front to rear  
- urinary calculi | - K supplementation (as potassium chloride) may help to reduce the incidence of urinary calculi in rams  
- deficiency most common when high concentrate rations are fed |
| Sulphur (S)      | - synthesis of some essential amino acids particularly prevalent in wool | - similar to protein deficiency  
- excess salivation, runny eyes and wool shedding | - dietary nitrogen (CP:6.25): sulfur ratio should be in 10:1 range  
- diets high in urea may be low in sulfur |
| Iodine (I)       | - formation of the hormone thyroxin in thyroid gland | - enlargement of the thyroid gland (goiter)  
- lambs born dead, weak or without wool  
- reduced wool yield and conception rate | - salt, except when used to limit ration intake, should always be iodized  
- deficiency common when non-iodized salt is fed |
| Cobalt (Co)      | - co-factor in vitamin B12 synthesis by rumen microbes | - poor appetite  
- unthriftiness  
- emaciation, weakness and anemia  
- decreased productivity and fertility | - should always be present in free-choice salt mix |
<table>
<thead>
<tr>
<th>Mineral</th>
<th>Primary Functions</th>
<th>Deficiency Symptoms</th>
<th>Special Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>- hemoglobin formation</td>
<td>- anemia</td>
<td>- anemia may be associated with feeding lambs on slotted floors or with heavy intestinal parasite loads</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>- related to absorption of iron</td>
<td>- muscular incoordination in nursing lambs (swayback)</td>
<td>- copper requirement depends on molybdenum level in diet-- Cu:Mo ratio should be 5:1</td>
</tr>
<tr>
<td></td>
<td>- wool formation</td>
<td>- steely or stringy wool lacking in crimp and tensile strength</td>
<td>- Cu consumed at high levels over long periods accumulates in the liver-- stress results in rapid release, jaundice and death</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- loss of wool colour in black sheep</td>
<td>- deficiency common in B.C.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- TOXICITY produces sudden death</td>
<td></td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>- aids digestive process but interferes with Cu absorption</td>
<td>- high levels (1+ ppm) may provoke copper deficiency</td>
<td>- Cu:Mo ratio should be in 5:1 range</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>- development of bone</td>
<td>- in goats, deficiency is related to delayed onset of estrus, poor conception rate, low birth weight of kids</td>
<td>- exact requirements and deficiency symptoms for sheep are not known with any certainty</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>- male reproduction</td>
<td>- impaired growth of testes in ram lambs</td>
<td>- deficiency common in B.C.</td>
</tr>
<tr>
<td></td>
<td>- growth processes through role in protein utilization</td>
<td>- cessation of sperm production</td>
<td>- healthy hooves require Zn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- wool loss, swelling and lesions around hooves and eyes, excess salivation, loss of appetite, wool picking, listlessness, reduced growth</td>
<td></td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>- enzyme activity</td>
<td>- reduced growth</td>
<td>- Se deficiency is common in B.C. and in cattle it has been linked with high levels of calf loss</td>
</tr>
<tr>
<td></td>
<td>- vitamin E metabolism</td>
<td>- white muscle disease</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- impaired fertility</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- lambing problems</td>
<td></td>
</tr>
<tr>
<td>Fluorine</td>
<td>- not known</td>
<td>- TOXICITY produces loss of appetite and degenerative changes in bones and teeth</td>
<td>- excess F intake may be due to water supply or use of non-deflourinated rock phosphate</td>
</tr>
</tbody>
</table>
TRACE MINERALIZED SALT
for
EWES, BEEF COWS AND REPLACEMENT BEEF HEIFERS
REG. No. 22440

INGREDIENTS
Salt (NaCl), Zinc Oxide, Ferrous Carbonate, Manganese Oxide, Copper Oxide, Calcium Iodate, Cobalt Carbonate, Iron Oxide, Mineral Oil (dust control agent), Sodium Selenate or Sodium Selenite.

This feed contains Selenium at 25 gm/tonne.

GUARANTEED ANALYSIS
Salt ...................................(actual) 96.50%
Zinc ..................................(actual) 0.04%
Iron ...................................(actual) 0.16%
Manganese .......................(actual) 0.12%
Copper ..............................(actual) 0.033%
Iodine ..............................(actual) 0.010%
Cobalt ..............................(actual) 0.004%

Figure C7  Typical analysis of a trace mineralized salt with selenium.

TM Salt

Trace mineralized salt formulations are generally 95-97% salt with several of the essential micromineral nutrients added. Figure C7 shows a typical analysis containing selenium at 25 grams/tonne. This is the highest level permitted without a veterinary prescription. Minor deficiencies can be overcome by feeding these in loose form (in a covered feeder) free-choice. For sheep, the copper level in these supplements should be in the 0.01-0.05% range.

Mineral Mixes

Livestock mineral mixes are almost infinite in variety. They commonly contain 18-20% Calcium and Phosphorus, (1:1 mineral), no salt and all of the essential trace minerals except molybdenum and selenium. Others contain up to 30% salt and several include selenium at 25 mg/tonne (or higher on prescription). For most conditions under which sheep are raised in B.C., the following guidelines should be followed:

- 15-20% Calcium
- 15-20% Phosphorus
- up to 30% salt
- 0.01-0.05% copper

A typical analysis which meets these criteria is shown in figure C8.

When sheep are being fed large amounts of alfalfa, a mineral mix containing high phosphorus with little calcium might be required. Conversely, lambs receiving high concentrate rations will require the higher proportion of calcium found in a 2:1 mineral mix (typically 18-20% calcium: 9-10% phosphorus).

Sheep producers should be particularly concerned about the copper content of the mineral supplements they use. Many of those available in B.C. (formulated for cattle) have copper levels in excess of 0.2%. The use of these products have resulted in several cases of copper poisoning.

Mineral feeding practices will be further discussed under Feeding Management (p.50).

Limestone

Limestone is simply a calcium supplement which is used to complement high grain rations which are calcium deficient. Its main application is in supplementing concentrate rations for growing lambs.

Injectable Vitamin E – Selenium

Selenium in combination with vitamin E is available in preparations designed to prevent the occurrence of white muscle disease in lambs. These are administered to the ewe a few weeks before lambing and, as extra insurance to the newborn lamb.

Vitamins

The tissues of ruminant animals require the same range of vitamins required by other mammals. However, rumen microbes synthesize the full range of B-vitamins in amounts adequate to satisfy requirements. These B vitamins are listed in table C9.

As mentioned earlier, cobalt is required for the synthesis of vitamin B₁₂ and the symptoms of inadequate cobalt intake are simply those of B₁₂ deficiency. Thiamine (vitamin B₁) deficiency is not uncommon in growing lambs where it is recognized as polioencephalomalacia. However, the deficiency is apparently not the result of inadequate thiamine production but, rather, of the destruction of the vitamin by a rumen enzyme of microbial origin. The conditions which promote the production of this enzyme are poorly understood.
TABLE C9 The water-soluble B-complex vitamins. Sheep ration need not contain any of these since they are all synthesized by bacteria in the rumen.

<table>
<thead>
<tr>
<th>vitamin</th>
<th>pantothenic acid</th>
<th>para amino benzoic acid</th>
<th>pyridoxine (B6)</th>
<th>riboflavin (B2)</th>
<th>thiamin (B1)</th>
<th>niacin</th>
</tr>
</thead>
<tbody>
<tr>
<td>vitamin B12</td>
<td>biotin</td>
<td>choline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SHEEP MINERAL
Reg. No. 740002

INGREDIENTS
Tricalcium phosphate, Dicalcium phosphate, Monoammonium Phosphate, Limestone, Iron Oxide, Ethylenediamine Dihydroiodide, salt, zinc oxide, Manganese Oxide, Cobalt Sulfate, Cupric Oxide, Vitamin A Acetate, Animal Sterol irradiated (Source Vitamin D3), Mineral Oil, Molasses, Diatomaceous Earth, Anise.

GUARANTEED ANALYSIS
Calcium (actual) ........................................ 19.0%
Phosphorus (actual) ..................................... 17.0%
Fluorine (max) ........................................... 2,000 mg./kg.
Iron (actual) ........................................... 10,000 mg./kg.
Iodine (actual) .......................................... 100 mg./kg.
Zinc (actual) ............................................. 10,000 mg./kg.
Manganese (actual) ...................................... 5,000 mg./kg.
Cobalt (actual) .......................................... 50 mg./kg.
Copper (actual) .......................................... 50 mg./kg.
Vitamin A (min.) ......................................... 500,000 I.U./kg.
Vitamin D (min.) ......................................... 50,000 I.U./kg.

DIRECTIONS FOR USE
Feed free choice or allow 10-15 gms. per head per day. For convenience this mineral may be mixed half and half with salt or trace mineralized salt.

Note: Sheep are susceptible to copper deficiency and copper toxicosis. Consult a qualified nutritionist or veterinarian to determine the suitability of this feed to local conditions.

Figure C8 A mineral mix suitable for most B.C. sheep flocks.

Vitamin A
Vitamin A is essential in the maintenance of epithelial (surface) tissues such as those lining the digestive, respiratory, urinary and reproductive tracts as well as that covering the eyes. Deficiency results in night blindness, a decreased resistance to infection, wool loss and the birth of malformed, weak or dead lambs.

Sheep normally derive their vitamin A requirements from carotene which is a yellow pigment found in forages in association with chlorophyll. Forages which have been badly weathered for long periods before storage are low in carotene. Likewise, winter range is a poor source of carotene. In general, green forages contain levels providing for adequate vitamin A synthesis.

Vitamin A is stored in the liver where it is synthesized in excess of requirements. In fact, enough may be stored to maintain production for up to 4 months when animals are fed low carotene rations.

Vitamin D
Classically, vitamin D was identified as the factor responsible for the prevention of rickets. This is due to its essential role in calcium absorption, deposition in and mobilization from bone. Vitamin D deficiency is not a common problem. Like vitamin A, it is derived from green forages, but, in addition, it is synthesized in the skin on irradiation by sunlight. Vitamin D stored in the liver can be drawn upon when intake and synthesis are inadequate.

Vitamin E
Nursing lambs up to 8 weeks of age require vitamin E but, otherwise, it seems to be of little importance in sheep nutrition. Deficiency of vitamin E is seen as white muscle disease. As suggested earlier, vitamin E and selenium have mutual “sparing” effects. That is, the vitamin E requirement is decreased when adequate selenium is available.

Vitamin E is widely distributed in feeds, although it is subjected to loss by oxidation. Therefore, feeds which have been weathered, heated or stored for prolonged periods (over a year) are poor sources while pasture is ideal.

Vitamin K
This vitamin is normally synthesized in large amounts by rumen microbes. In addition, green leafy materials either stored or fresh, are good sources. However,
apparent vitamin K deficiency may occur when mouldy hay is fed. In particular, sweet clover hay contains coumarin, the substance responsible for its sweet smell. Moulds convert coumarin to dicoumarol which effectively reduces the activity of vitamin K in the blood clotting process, resulting in hemorrhage and death.

**Vitamin Sources**

Under normal feeding conditions, the only vitamins required in the diet are A, D and E. As suggested in the previous discussion, all are provided in green, leafy forages. When these are unavailable, the vitamins may be supplemented by intramuscular injection. Since they are stored in the liver, there is no need to supplement more often than every three months, with the first supplement being given three months after suitable feeds become unavailable.

Mineral mixes often contain vitamins A, D and E. However, they should not be considered reliable sources since all three vitamins are subjected to oxidation. When mineral mixes become moist, a common occurrence in B.C., destruction of the vitamins is rapid.

Vitamins A, D and E with selenium are available from some veterinarians on prescription as a powdered premix. This is either added to the feed or mixed fresh with mineral as it is put out.

Since vitamin E is apparently only required by the young lamb, supplements in the form of vitamin E-selenium preparations may be administered to the ewe before lambing or to the lamb at birth.

**Balanced Rations**

*Nutrient balance* has been frequently mentioned in the previous discussion. The importance of balance is clearly illustrated by the most *limiting nutrient concept* which states that production is restricted to the level which can be supported by the most limiting nutrient. This is shown diagrammatically in figure C9. The net result of *imbalanced* rations is the inefficient use of feed resources.

![Figure C9](image)

Figure C9  Production is restricted to the level which can be supported by the most limiting nutrient. Here crude protein is most limiting.

**Priority for Nutrients**

Nutrients which are absorbed from the digestive tract are allocated to satisfy the animal’s requirements. Some requirements have priority over others. For example, the nutrients available to a growing lamb must satisfy a requirement for body maintenance and a requirement for gain in weight. It should be obvious that the maintenance requirement has priority over the requirement for gain since a lamb cannot grow until it first replaces tissue lost to the process of turnover.

This concept has fundamental importance to the management of lamb feeding. Figure C10 demonstrates the point for a 30kg lamb receiving various amounts of a ration balanced to support maximum growth. Maintenance requires 1.3 kg of ration and with this amount, no growth occurs. A further 0.4kg supports maintenance in addition to a daily gain of 0.25kg while 2.1kg of ration results in a daily gain of 0.5kg.

The concept of nutrient priority also applies to the ewe during gestation and lactation. In these situations, maintenance has a lower priority than production of either fetus or milk. Figure C11 illustrates the point for the late pregnant ewe.
Figure C10 Nutrients consumed by the growing lamb are first allocated to maintenance. Additional nutrients are available for grain.

The restriction of energy intake down to 80% of the recommended level has little effect on fetal size at birth while significantly reducing the ewe's gain in weight before lambing. Likewise, animals which have the genetic capacity to lactate heavily will produce milk at the expense of body tissue.

Figure C11 The pregnant ewe may sacrifice the maintenance of her own body to the production of a viable lamb.

Liveweight and Condition Score Targets

Objectives for the feeding of ewes can be stated in terms of liveweight and condition score targets at various stages of the reproductive cycle. These are suggested for ewes giving birth to twins in figure C12. The left hand axis gives relative liveweight as a percentage of liveweight when condition score is 3.5 (the practice of condition scoring is described in Section E). Condition scores are given along the top. One condition score should be roughly equivalent to 10kg (22lbs) or 15% of mature liveweight.

Why use both liveweight and condition score targets? Clearly the ewe's weight change during pregnancy may be quite independent of her condition. In fact, the targets given in figure C12 suggest that a 13kg (29lb) weight gain should be accompanied by a 5 kg (11lb) drop in condition (score decrease of 0.5). The 18kg (40lb) discrepancy is accounted for by growth of wool, the products of conception (fig.C13) and the development of the udder.

NUTRIENT REQUIREMENTS OF EWES

Tables of nutrient requirements for ewes are given in Appendix II. These are based on those given in the NRC publication, "Nutrient Requirements of Sheep." Modifications are footnoted.
Feed Intake

Feed consumption by the ewe is controlled by several factors. The most obvious is the amount of feed actually offered. When hay, silage or grain are fed and there is enough bunk space for all animals to eat at once, then intake can be restricted by the flock manager. This usually results in more efficient use of feed resources than is the case when ewes are fed ad lib. The latter refers to the practice of allowing animals to consume feed to satisfy their appetites and often results in wasted feed as shown in figure E4 (p.49). Even when ewes are fed ad lib, however, the amount of feed consumed will vary between 3 and 3.5% of body weight depending upon the quality of the feed and the physiological state of the ewe.

In terms of feed quality, two factors affect feed intake:

1. The energy concentration of the ration. When rations of reasonable quality are offered, animals will eat to satisfy their energy requirements. Therefore, as the TDN content of the feed increases, intake will decrease so that a marginally increased amount of total energy will be consumed (fig. C3).

2. The fibre content of the ration. When poor quality roughages are fed (TDN less than 55%) intake is limited because of the time it takes to digest the fibre. On very poor quality rations there are often insufficient nutrients to even maintain a healthy microbial population, further slowing fibre breakdown.

Feed intake will vary during different periods of the reproductive cycle even when the same feeds are fed throughout. For example:

1. Intake may decline in late pregnancy. In most situations this is a result of physical restriction of rumen size. Overfat ewes bearing large multiple fetuses are particularly constrained in the amount of feed they can consume. It is, therefore, important not to allow ewes to become overfat (condition score 3.5+) in mid pregnancy. If intake does decline markedly in late pregnancy, the quality of the ration should be increased to meet the nutrient (particularly energy) requirements of the ewe. When an excess of fat is called upon to contribute substantially to energy requirements, pregnancy toxemia may result.

2. Feed consumption may increase sharply within a few days after lambing. Maximum ad lib intakes usually occur at about six weeks, shortly after peak milk production has been reached. Ewes nursing multiple lambs often consume 10-20% more feed than ewes with singles.

Projected feed intakes for ewes are given in Appendix II.

Other factors which affect voluntary feed intake include ration palatability and water quality and availability. Several experiments have demonstrated that water deprivation and even unpalatable water can depress feed consumption.

Under pasture conditions it is very difficult to determine feed consumption, especially when ewes are grazed extensively. Under intensive grazing management it is possible to control intake to some extent by regulating the amount of pasture being offered and the height to which it is grazed before rotating. When grazing animals are allowed to become selective, intake will be affected by the forage species available and their maturity. Most forage species become less palatable as they approach the reproductive stage.

Maintenance

The maintenance period extends from weaning until the beginning of flushing. During this time it is possible to compensate for failure to realize targets during pregnancy and lactation. The feeding level here will therefore depend upon the ewes’ condition scores at weaning. Those that are overconditioned
may be allowed to lose some weight, yielding an opportunity to utilize inventories of lower quality feeds. Ewes in lean to medium condition should not be allowed to lose weight. It is an absolute fallacy to believe that ewes should be starved during this period in order to achieve a good flushing response.

The goal for nutrition during the maintenance period is to produce a healthy ewe with a solid 3 condition score three weeks before breeding begins. This should apply to each individual ewe rather than the flock average. Midway through the maintenance period ewes should be scored and the leanest ewes separated for preferential treatment. These are often the most productive ewes which, because they have nursed multiple lambs deserve special attention. It may be possible at this time, for example, to use high scoring ewes to clean up rank pasture while using pastures in better condition for the lean ewes. Since pasture conditions often decline as the season progresses, it is usually much easier to add weight to the ewes early in the season with an eye to simply maintaining it later.

At the end of the maintenance period, ewes should again be scored. Since this often coincides with the end of the pasture season, it is also an opportune time to deworm and hoof trim the flock. Individuals that stand out as unresponsive to improved nutrition should be considered for culling. They may be subjected to one of several health problems which will severely limit future productivity. These include chronic pneumonia, Johne’s disease and caseous lymphadenitis. At this same time ewes should be examined for lumpy udders, broken mouths, abscesses (caseous lymphadenitis) and external parasites. Any one of these may limit an animal’s response to even the best nutritional management.

Flush Management

Feeding management during the flushing period has been the subject of considerable controversy in the past because of a lack of clear experimental evidence. It can be confidently stated, however, that the goal of flushing is to achieve a condition score of 3.5 at breeding. Beyond this point, ovulation rate cannot be expected to increase significantly. Furthermore, the level of current nutrition apparently has little effect when this condition score has been achieved. That is, ovulation rate at this point is little affected whether the ewe is gaining or simply maintaining weight. Weight loss will, however, have a negative effect. Current feeding level has more relevance for ewes with condition scores in the 2 to 3 range. In these cases, weight gain has a positive effect on ovulation rate. Conversely, in these ewes weight loss may produce the opposite effect. Where condition scores at breeding are below 2, little can be done to improve ovulation rate.

The effect of condition score at breeding on ovulation rate differs between breeds. For example, prolific breeds like the Finnish Landrace are significantly less responsive than either Suffolks or Dorsets.

Although research results are inconclusive, flushing probably has less effect on ovulation rate when ewes are bred during the peak of the breeding season (October- November) than it does at either end.

Adequate condition at breeding time is important for reasons other than ensuring high ovulation rates. As seen in figure C12, a sizable increase in weight during pregnancy may be accompanied by a reduction in body reserves (decrease in condition). Likewise, heavy lactation is accompanied by depletion of reserves. Many management systems are based on the utilization of low-cost feeds of mediocre quality during early pregnancy. In order to maintain high level of reproductive performance, it is important that the ewe begins the process in good condition.

Before proceeding with the discussion of nutrient requirements during pregnancy and lactation, it should be appreciated that we are ultimately concerned with the management of the entire flock of ewes. Although it is important to recognize the requirements of individuals within that flock, in practice feeding is done on a group basis to satisfy the average needs of that group. Of course, the smaller the groups become, the less variation there should be in the requirements of individuals within the group, and the more accurately can their requirements be met.

Flush Management

When ewes are in good condition at mating and rams are fertile, breeding should be 90% complete within 3 weeks. Even under these conditions, nutritional management must be a compromise between the requirements of the early and late breeders. In most large flocks (except where estrus synchronization is practiced) no attempt is made to identify and group ewes on the basis of breeding date although this practice can result in significant feed savings. Therefore, it should be realized that the following discussion on nutrient requirements is focused on individual needs and that these must ultimately be put in the context of practical flock management. This will be attempted in the section on Feed Testing and Ration Formulation and Feed Management.
Early Pregnancy (First Month)

Depending upon breed and nutritional management, up to five eggs (ova) may be shed into the uterus at ovulation. Mating with a fertile ram should result in the fertilization of all of these, although on a flock basis a 5-10% rate of non-fertilization may occur. After conception has taken place the fertilized egg (later the embryo) floats freely in the fluids of the uterus for about two weeks. During the third week the embryo begins to attach to the lining of the uterus, a process which takes a further two to three weeks.

Nutritional management in the first month after breeding is critical in minimizing embryo loss due to their failure to implant. As much as 25% of the potential lamb crop may be lost during this period. In particular, short periods of severe under-nourishment increase embryo mortality. As well, an excessively high level of nutrition after mating may impair survival. Continued underfeeding of ewes in poor condition at mating (score less than 2) can result in high rates of loss while ewes in good condition (3+) at mating produce more ova with fewer embryo losses even when moderately undernourished in early pregnancy.

Ideally, the target for nutritional management in this first month of pregnancy would be maintenance to a slight increase in weight. NRC recommendations suggest a post flushing gain of 0.03 kg (0.07 lbs)/day. As mentioned earlier, it should be appreciated that feeding management is practiced on a flock basis. Figure C12 suggests that flushing continues 3 weeks after the rams are turned in. Therefore, if the suggested targets are realized, ewes bred on the first day might gain somewhat over 3 kg (7lbs) in their first month of pregnancy while those bred on the twenty-first days would gain slightly less than 1kg (2lb).

Mid-Pregnancy (up to 100 days)

By the end of the fifth week after breeding, the developing embryos are well established within the uterus although their weights are insignificant (fig. C13). During the second and third months, the placenta develops rapidly from the initial site of embryo attachment. By 100 days it has reached its ultimate size while the fetuses are less than 20% of their birth rates.

The total weight of the products of conception in the ewe carrying twins is about 3kg (7lbs) at this time. Figure C12 suggests a target liveweight increase amounting to approximately 2kg (4lb) in months two and three, meaning that the ewe has actually lost 1kg (2lb) from her own tissues. Such a loss is tolerable and, in fact, British recommendations suggest that losses of up to 7.5kg (17lb) may have little detrimental effect on ewes in good (3+) condition at the beginning of the period providing that they result from sustained but mild undernutrition. As in early pregnancy, severe undernutrition for even short periods can profoundly affect fetal development as can any degree of undernutrition in ewes who are already in poor condition.

It should be recognized that when weight is lost at any time during the ewe’s reproductive cycle, it must ultimately be regained at a later date. In terms of total nutrient requirements, it is more costly to lose and regain weight than to simply maintain it. However, there may be some economic advantage to losing weight at a time when feed costs are high (e.g., during winter) and regaining weight when costs are lower (e.g., on pasture).

Undernutrition in mid-pregnancy has its effects on the growth of both the fetus and placenta. Although good nutrition in late pregnancy may compensate for limited fetal size at the end of the third month, restriction of placental growth may be more difficult to offset. It has
been suggested that the birth of small lambs by apparently well nourished ewes may relate to inadequate nutrition in mid-pregnancy which has inhibited placental development. An underdeveloped placenta is simply unable to deliver adequate nutrients to the fetus in late pregnancy even when the ewe is well fed.

Overfeeding during mid-pregnancy can also be detrimental. Increasing the ewe’s condition score above 3.5 at this time is wasteful, resulting in increased feed cost. In addition, an excess of abdominal fat combined with the increased size of the uterus can physically restrict the ewe’s feed consumption in late pregnancy. Overfat ewes are particularly subject to pregnancy toxemia in late pregnancy when fat is mobilized to meet increased fetal energy demands which cannot be met through additional feed intake.

**Late Pregnancy (last six weeks)**

As seen in figure C13, approximately 70% of fetal growth takes place during the final six weeks of pregnancy. In terms of nutrient requirements, this is a very expensive process. In fact, the efficiency with which metabolizable energy is used for fetal gain amounts to only about 13%. This can be compared with the efficiencies of other productive processes in table C3.

Rapid fetal growth with its low efficiency combined with the growth of other products of conception, mammary development, colostrum synthesis and the sizable maintenance requirement result in a substantially increased total nutrient demand. In many ewes this demand cannot be completely satisfied because of either restricted intake or feed costs. As a result, a limited decrease in condition amounting to no more than 0.5 condition score may be accepted. To emphasize a point made earlier, excessively fat ewes which are forced to lose condition at this time are particularly susceptible to toxemia.

Although the ewe may lose condition to some extent in late pregnancy, fetal growth may be only minimally affected because of its high priority for nutrients. This concept was explained earlier and is illustrated in figure C11.

Nutrient intake in this period can also have a marked effect on the ewe’s potential milk production after lambing. Figure C14 shows the results of an experiment where three different levels of energy were fed to ewes in late pregnancy. Notice the effect that lower energy intakes had on subsequent milk production. There are probably two main reasons for this. First, since 95% of udder development takes place before lambing, inadequate nutrition in late pregnancy may limit the amount of milk-producing tissue which is formed. Second, a high level of milk production is dependent upon the utilization of body reserves. Unless the ewe has maintained adequate reserves through late pregnancy, heavy lactation cannot be sustained.

Poor nutrition in late pregnancy can also affect the onset of lactation. This results in very little milk in the udder at lambing followed by a very slow increase in milk yield.

![Figure C14](image)

**Lactation**

The nutrient requirements of the ewe are higher in lactation than at any other time during the production cycle. In the first four weeks of life, the growth of the lamb is almost totally dependent upon the ewe’s milk
production since the nutrient contribution by solid feed during this period is relatively insignificant.

A rough estimate of milk production can be made by assuming a 1:1 conversion of milk dry matter to lamb liveweight gain. For example, twin lambs with a combined average daily gain of 0.6kg (1.3 lb) will be consuming 0.6kg (1.3 lb) of milk dry matter each day. Since ewes' milk is approximately 20% dry matter (compared with the cows' 12%), fluid milk production must be about 3kg (7 lb) daily. Metabolizable energy is utilized for milk production at an efficiency of about 66% (table C3).

Nutrient requirements for lactating ewes are set out in Appendix II. These are based on the NRC recommendation with one important exception. Research done in the U.K indicates that the protein requirements recommended by the NRC may be adequate to sustain milk production when the ewe’s milk production potential is limited and little loss in condition score is experienced. However, in ewes with high potential milk production, maximum feed intake usually cannot supply sufficient nutrients for this potential to be realized. As a result, body reserves may be drawn upon to meet the energy deficit.

In fact, the utilization of body reserves may contribute 25 to 30 percent of energy requirements in the first month after lambing. In order to make efficient use of this process, additional protein should be added to the ration since body protein can contribute very little to milk production. This is another situation where the principle of the most limiting nutrient applies. Unless protein is supplied in the ration to complement the energy being drawn from body reserves, much of that energy is wasted. Appendix II suggests supplementary protein levels for ewes at two levels of decrease in liveweight.

It should be obvious that the ewe beginning lactation with a condition score less than 2.5 is in a poor position to realize her potential for milk production.

Non-Nutritional Factors Affecting Milk Production

Ultimately the realization of the ewe’s milk production potential depends upon adequate nutrition. However, several other factors may influence both the level and pattern of lactation.

A ewe suckling twins will produce approximately 40% more milk than the same ewe suckling a single. Conversely, a twin lamb will receive only about 70% as much milk as a single. In addition, ewes suckling twins will reach a higher peak yield usually about three weeks after lambing whereas the lower peak for singles occurs two to three weeks later. As might be expected, the decline in production with twins is faster after the peak has been reached (fig. C15).

Ewes suckling triplets will produce approximately 10% more than those with twins. Again it follows that triplet lambs will receive only slightly more than 50% as much milk as a single.

In addition to the number of lambs nursing, their size and vigour and, thus, the demands they place on the ewe will affect milk output.

The age of the ewe will also affect her milk production, with the maximum potential being reached at the third lactation and extending usually to the sixth. Yield in the first lactation will be approximately 80% of the mature yield with the rate of decline in later years being affected by nutrition, health and dentition.

Milking Sheep

With the increasing availability of milking sheep genetics from Europe, several producers in B.C. have begun marketing ewe’s milk. In most cases, lambs are allowed to nurse for 30-50 days at which time they
are weaned and the ewe is milked by machine. Figure C16 compares lactation patterns when dairy ewes are managed in this way versus allowing lambs to continue nursing or exclusive machine milking. Notice the increased productivity realized with suckling followed by machine milking.

Figure C16  Dairy ewes are normally allowed to nurse their lambs for 30-50 days.

Separate Feeding of Ewes with Multiple Lambs

The nutrient requirements of ewes with multiple lambs are significantly higher than those with singles. In terms of efficient utilization of feed resources, therefore, ewes should be grouped and fed according to requirements. Otherwise, either twin suckling ewes are being underfed, or singles overfed. The practice of further segregating ewes with triplets into groups of five to ten in a small area has become common practice in highly prolific flocks. This permits an extra high level of feeding, facilitates interaction between ewe and lambs and reduces dependence on expensive milk replacer.

Because the milk production of ewes suckling multiple lambs peaks earlier and declines faster, an extra effort should be made to introduce their lambs to creep feed. This practice will assure the continued efficient growth of these lambs.

Special Requirements of Ewe Lambs

The discussion above has focused on the requirements of the mature ewe. However, 15-20% of the ewes in a productive commercial flock will be ewe lambs. Economics demand that these animals be bred to lamb at twelve to fifteen months of age since it is extremely difficult to recover the cost incurred in raising females to two years of age before their first lambing.

With the goal of first-year lambing in mind, the nutritional management of these ewe lambs is critical if their full productive potential is to be realized. Their pre-breeding nutrition will be discussed in the section on Nutrient Requirements of Lambs where the objective is to grow them out to 75% of their expected mature body weight with a condition score of 3.5. If these objectives are not realized, it may be next to impossible to maintain condition in late pregnancy and to stimulate sufficient milk production to meet the growth requirements of the offspring.

It is common practice to delay the breeding of ewe lambs by two or three months behind the main flocks. This is advantageous for a number of reasons:

(1) It allows extra time for growth;
(2) It usually means higher conception rates especially when a high proportion of white-face breeds is present since they tend to reach puberty somewhat later than Finns or the Down breeds;
(3) It allows available ram power to be spread out more efficiently (ewe lambs should be mated to mature, experienced rams); and
(4) At lambing time special attention can be given to the frequent problems associated with ewe lambs.

This practice also has a few disadvantages:

(1) Mothering problems which arise with ewe lambs cannot be as easily solved because experienced foster ewes are unavailable.
(2) If lambing of these young ewes is delayed too long, other time conflicts may arise (e.g. spring field work).
(3) Colostrum will have to be stored frozen since few ewe lambs will have an excess supply to share with those who produce too little.

Targets for Ewe Lambs

Figure C17 suggests targets for ewe lambs. The main difference in liveweight gains applies to early and mid-pregnancy when a sustained increase should be seen.
This is because, in addition to growth of the products of conception, it is expected that the ewe lamb will gain a further 10-15% of her mature body weight.

![Liveweight targets for ewe lambs assuming a breeding weight equivalent to 75% of expected mature weight and a condition score of 3-3.5 at mating. The dashed line represents the growth of the non-pregnant ewe lamb.](image)

With the rapid growth of the fetus in late pregnancy there is little opportunity to make a contribution to the ewe lamb’s own body at this time. Table II1 recommends increased TDN and CP intakes to accommodate these requirements.

Ewe lambs are more susceptible to the effects of under-nutrition on embryo loss. It is therefore particularly important that feeding levels be maintained after breeding.

**NUTRIENT REQUIRMENTS OF LAMBS**

Nutrient requirements for lambs are given in Appendix II. These are derived from Jordan’s modifications of the recommendations found in “Nutrient Requirements of Sheep” (see footnote to Table II1).

Before discussing the feeding of lambs at various stages of development, any explanation of the growth process and some of the factors influencing growth is in order.
How Lambs Grow

A typical pattern for the growth of a lamb on full feed from birth is shown in figure C18. Tentative growth during the first week or two is followed by a rapid increase in growth rate which declines as the lamb ages. Although the absolute limit of growth rate is genetically determined, in practice gain is usually limited by nutrient intake. Inadequate milk during the first month of life can prolong the tentative early growth phase. Later, nutrient intake may be restricted by feed of low nutrient quality or limited availability of feed (e.g., overstocked pasture). The effect of limited nutrient intake is to prolong the feeding period to market by reducing the relative amount of nutrients available for gain.

Feed Intake

Figure C19 gives rough guidelines for ad lib feed intakes of lambs. Dry feed intake is normally insignificant prior to three weeks of age. However, intake can be significantly influenced by a well executed creep-feeding program. This topic is discussed in detail later. Although intake will normally vary between 3.5 and 4% in feeder lambs, Jordan suggests that total dry matter intake does not increase linearly with weight when high concentrate diets are fed. He found that intake increased to a peak six weeks after going on feed and then reached a plateau. Actual intake will also depend upon size, condition, age and whether the lambs are growing to compensate for a previous period of undernutrition.

Other factors which influence intake include:
(1) amount of feed offered;
(2) competition for available feed;
(3) palatability;
(4) physical form of feed (long, chopped, rolled, pelleted, etc.)
(5) ease of harvesting (pastures);
(6) energy and fibre content of feed (p. 20);
(7) ambient temperature and humidity (p. 21);
(8) availability and quality of water.

Figure C18  Typical pattern of lamb growth when nutrient requirements are fully satisfied.
It should also be recognized that what is assumed to be intake often includes a good measure of waste.

Figure C19  *Ad lib* feed intakes for lambs. Fine rations include concentrates as well as milled and pelleted roughages. Coarse feeds consist of long or chopped roughages, silages and grazed herbage. Within these two ration types, intake is markedly affected by the energy (TDN) concentration in the feed (see page 20).

### Maintenance and Gain

Earlier, the concept of *priority for nutrients* was introduced. The lamb’s daily nutrient intake is partitioned between a requirement for maintenance and a requirement for gain. The priority requirement is for maintenance with any remaining nutrients being available for gain. Clearly, when nutrient intake is just sufficient for maintenance no growth occurs. If this continues, the lamb will never reach market weight. Conversely, the fastest gains occur when lambs are fed high quality feed to appetite (*ad lib*) because, here, a high proportion of intake is available beyond the

<table>
<thead>
<tr>
<th>Breed</th>
<th>Average Daily Gain (50-100 days, kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suffolk</td>
<td>0.34</td>
</tr>
<tr>
<td>Hampshire</td>
<td>0.32</td>
</tr>
<tr>
<td>Columbia</td>
<td>0.31</td>
</tr>
<tr>
<td>Rambouillet</td>
<td>0.30</td>
</tr>
<tr>
<td>NC Cheviot</td>
<td>0.27</td>
</tr>
<tr>
<td>Oxford</td>
<td>0.27</td>
</tr>
<tr>
<td>Leicester</td>
<td>0.25</td>
</tr>
<tr>
<td>Dorset</td>
<td>0.24</td>
</tr>
<tr>
<td>Landrace</td>
<td>0.22</td>
</tr>
<tr>
<td>Southdown</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**Table C10** Average daily gains for recorded purebred lambs on in Canada. Based on 50 and 100 day weights adjusted for sex, weaning number (single, twin, etc.) and age of dam.

Breed Variation

Marked variability is seen between the growth rates of common breeds. Table C10 gives 50 to 100 day average daily gains for lambs on ROP in Canada. Figure C20 compares the growth curve of a typical Suffolk ram lamb with that of a typical Dorset. The rate of decline in average daily gain as a lamb ages is a reflection of its ultimate mature size.

Figure C20  The effect of breed on the growth of ram lambs. The dashed lines show times taken to reach a market weight of 45kg.
Difference in growth rates between breeds is partially due to differences in feed consumption. In addition, breed differences for gain are influenced by the efficiencies of feed utilization for fat and lean deposition. Fat has an energy content 2.25 times that of lean so that average daily liveweight gain is lower when fat is being deposited.

In terms of the choice of breeds for market lamb production, the Meat and Livestock Commission in the U.K. suggests that optimum slaughter weight is about one-half of mature weight. To project an optimum slaughter weight for a group of crossbred lambs, the mature weight of the ram breed added to the mature weight of the ewe breed can be divided by four.

In general, large breeds like the Suffolk and Hampshire grow faster and produce a heavier carcass at a given degree of fatness than smaller breeds like the Dorset or Southdown and hair breeds like St. Croix and Barbados Blackbelly. Conversely, if Dorsets and Suffolks are slaughtered at the same weights, the Dorsets will be fatter than the Suffolks. There are, of course, exceptions to these rules. For example, the Columbia breed, although larger than the Dorset at maturity, takes significantly more time to get there.

**Effect of Sex**

Ewe lambs have significantly lower voluntary feed intakes than either rams or wethers. In addition, female lambs deposit more fat in their gains than males. As a result, female lambs grow more slowly and are less efficient converters of feed to liveweight gain. The same degree of fatness will be obtained with rams 10% above, wethers 5% above and ewes 10% below the optimum slaughter weights calculated earlier.

**Ratio of Fat to Lean**

The amount of fat deposited in the carcass is proportional to the rate of gain. Within breed type and sex, fast growing lambs will reach a given degree of finish before those which grow more slowly. Again, fat is relatively costly to grow since its energy content is higher and its water content lower than lean.

**Stages of Lamb Growth**

**Pre-Weaning**

As mentioned earlier, in the first weeks of life, the growth of the lamb is absolutely dependent upon the ewe’s milk production. The process is relatively efficient with an average 66% of the metabolizable energy consumed by the ewe being converted to milk energy followed by an almost 100% efficient process of conversion of milk solids to lamb liveweight gain. Lambs can compensate for inadequate milk supply to some extent by increasing consumption of solid feed. However, it is important to realize that:

1. significant amounts of solid feed cannot be consumed before two to three weeks of age;
2. the solid feed consumed will in no measure compensate for inadequate milk unless it is of high quality; and
3. approximately 3-5 units of feed dry matter intake is required to replace 1 unit of milk dry matter because of the high digestibility of milk and the efficiency with which it is used for growth.

Rumen development is accelerated as the lamb consumes solid feed. This was discussed earlier in the section on the The Sheep Digestive System (p.10). As lactation progresses, the efficiency of converting feed through the ewe declines and with the lamb’s ability to convert dry feed increasing, weaning may be considered as early as three weeks after birth although the lamb is not fully ruminant for another 1-2 months.

Weaning cannot be considered unless the lambs are consuming at least a half pound per day of nutritious dry feed. If this precaution is not observed a serious setback in growth may occur requiring a two to three week period for recovery. Weaning practices are discussed later (p.57).

Finally, the young lamb cannot be expected to utilize non-protein nitrogen efficiently until it is fully ruminant at about three months of age. Therefore, urea has little place in creep rations for lambs or in rations for early weaned lambs.

**Post Weaning**

As mentioned, weaning may produce a setback in growth in some lambs. This setback can be minimized by making the transition to independence as smooth as possible. It is often advantageous to move the ewes away from the lambs so that the lambs continue to have access to the pre-weaning creep ration in familiar surroundings until independence is well established.

One the basis of work done by Dr. Malcolm Tait at the University of British Columbia, it has been recommended that concentrate rations for lambs be based on whole barley supplemented with a 32% protein supplement pellet. The use of these
ingredients makes it very simple to adjust ration protein levels by altering the proportions of barley to supplement. This will be discussed more fully later (p.59). Whatever rations are used for growing lambs, care should be taken to assure smooth transitions from one to the next. Often a heavy penalty is paid when lambs lose performance by going off feed.

The rations fed to weaned lambs will depend upon the age of the lambs at weaning. Lambs weaned at 25-35 pounds tend to gain at an accelerating rate with increased weight. They will gain 15 to 20 per cent faster and will consume one to two percent more feed per unit of body weight than older lambs full-fed a high energy diet. In fact, it is important to recognize that the potential feed conversion efficiencies of young lambs is much greater than lambs reaching the end of their feeding periods. Table C11 gives guidelines to these decreasing efficiencies. The reason for this lies in the fact that maintenance requirements increase with body size. The practical importance is that it is much more efficient to feed a pound of grain to a two month old lamb than to a six month old lamb.

**TABLE C11** Feed efficiency decreases as lambs increase in age. These are rough estimates which will vary with energy content in ration and many other factors.

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Feed Efficiency (kg feed:kg gain)</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>2:1</td>
</tr>
<tr>
<td>3</td>
<td>3:1</td>
</tr>
<tr>
<td>4</td>
<td>4:1</td>
</tr>
<tr>
<td>5</td>
<td>5:1</td>
</tr>
<tr>
<td>6</td>
<td>6:1</td>
</tr>
<tr>
<td>7</td>
<td>7:1</td>
</tr>
</tbody>
</table>

**Finishing**

The traditional market demands a finished lamb yielding a carcass of 40-50 pounds. Although many lambs have the ability to grow well beyond these limits without becoming excessively fat, an equal number tend to be over finished even at the lower end of the range. It is important, therefore, to be able to assess market readiness in the live lamb. To this end, a method of condition scoring market lambs is described later under Feeding Management (p.47).

The annual lamb price cycle in North America (Figure C21) has had an effect on lamb feeding strategies as well as decisions affecting lamb season. Winter-born lambs are usually put on full feed to reach market before prices decline in early summer. Late born lambs, often pastured until September and October, are often finished in dry lot during the fall and winter. It is not an uncommon practice to attempt to prolong this feeding period in order to market lambs in February and March when prices are high.

![Figure C21](image)

This is risky business, in view of what has been said about maintenance requirements. Unless feed costs are very low, the increase in market price has to be significant to offset the extra feed cost incurred in prolonging the finishing period.

Urea may have some application in lengthy finishing periods. It was suggested that a two-week adaptation period is required before non-protein nitrogen is utilized efficiently. The resultant production penalty usually outweighs the price advantage for lambs full-fed high energy rations. However, when urea is fed over a two to four month period, the significance of the period of adaptation is reduced. Under these conditions lambs can efficiently utilize urea at a level of 1% of the ration dry matter which would contribute an additional 2.5-3% equivalent crude protein (ECP) to the finishing ration. As suggested earlier (p.16) a readily fermentable source of carbohydrate must also be available.

**Growing Replacement Ewe Lambs**

It is often suggested that replacement ewe lambs should not be full-fed high-concentrate rations because of its long-term effect on reproduction and longevity. It has already been pointed out that rapid gains are associated with increased fat deposition. However, under most management conditions there is little risk in growing out replacement ewe lambs.
alongside market lambs at least until they reach 50% of their expected mature body weight.

In fact, it is important to do this in order to make an objective assessment of the merit of prospective flock replacements. When a performance appraisal program is used, all lambs should be raised under similar conditions until the 100-day test is done. On the basis of performance index together with other criteria, replacement lambs should be selected and further grown out on high quality forage based rations. The objective should be to reach a minimum 75% of mature body weight at a condition score of 3.5 in time for mating.

**NUTRIENT REQUIREMENTS OF RAMS**

In the commercial flock, rams are frequently purchased as ram lambs at 6-8 months of age. Under these circumstances there are two critical periods in meeting the nutrient requirements of flock studs.

1. From the time they are purchased until they reach mature size; and
2. Before and during the breeding season.

Any ram worth purchasing should have achieved 50% of its mature body weight at six months of age. The projected mature body weights of rams purchased as meat sires should be well above the average for rams of that breed. For example, the average mature Suffolk ram in Canada weighs about 120kg (265 lb). If a Suffolk ram is purchased as a terminal meat sire, its potential mature weight should be at least 140kg (309 lb) meaning that its weight at 6 months should be minimum 70kg (154 lb).

Rams purchased as sires for replacement ewe lambs are of course, selected on other criteria, but to achieve adequate breeding status in the first year, they too should be 50% of their expected mature weight at 6 months of age.

As was the case for replacement ewe lambs, the breeding target from ram lambs is 75% of mature weight at a condition score of 3.5. After purchase or selection from within the home flock, steady growth on high-quality forage based rations is the goal. Ram lambs should not be expected to mate with more than 25 ewes (during a 3 week breeding session) in their first season. On completion of the first breeding season, ram lambs should continue to be grown out on quality forage to reach 95% of their ultimate size by the second breeding season.

From this point on, rams are simply maintained during most of the year. However, they should be managed much as the ewe flock is managed prior to the breeding season. Hooves should be trimmed, testicles checked for swelling, the penis for any abnormalities. External and internal parasites should be controlled and a survey of overall health and function conducted. When the ewes are flushed, the nutrient intake of the rams must be increased as well. Rams which are conscientious about their function may lose a full condition score during a three to four week breeding cycle. A ram with a very strong libido may have to be removed from the ewe flock for short periods of feeding.

Nutrient allocations for rams are suggested in Appendix II.