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*TECHNICAL BULLETIN No.16*

# *FORMULATION OF RATIONS FOR SHEEP AND GOATS*

ESGPIP

ETHIOPIA SHEEP AND GOAT PRODUCTIVITY IMPROVEMENT PROGRAM


**Further information:**

**Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP)**
**Tel. +251 011 416 6962/3**
**Fax: +251 011 416 6965**
***E-mail:*** **pvamrf_ethiopia@ethionet.et**

# FOREWORD

The supply of nutrients required by animals in adequate quantities and appropriate proportions is vital to optimize productivity. This, in turn, requires knowledge of the art and science of nutrition and ration formulation to meet physiological needs of animals. This technical bulletin titled "*Formulation of rations for sheep and goats*" is the 16th in a series produced by the Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP)". The bulletin is intended to serve as a guide for Subject Matter Specialists (SMS) in the extension system. The SMS can use this guide to identify and formulate rations for use by Kebele Development Agents (KDAs) who are expected to offer technical advice and support to farmers producing sheep and goats. The principles in the bulletin can be applied to other farm animals. It will, also, be useful to commercial animal producers and feed manufacturers.

The bulletin is a self-contained assembly of information one needs to formulate practical rations. The material in the bulletin has been divided into sections. Each of these sections deals with a specific subject and contains information relevant to that topic as it applies to conditions typical to sheep and goat production. First, general background information one needs to formulate practical rations is given. Then, the two among available methods of calculating rations are presented with worked out examples. Tables of nutrient requirements and feed composition are presented in the appendix. These provide general guidelines that can be used in the absence of local values. Local data would be more pertinent to particular situations. A comprehensive glossary and list of abbreviations are also presented in the appendix.

Different forms of expressing nutrients (e.g. TDN, ME, NE etc for energy) are used in the examples and exercises to show that the many alternative methods of ration calculation can be used irrespective of the units of expressing feed composition and nutrient requirements.

At this juncture, I would like to express my thanks to all involved in the preparation and review of this bulletin.

Desta Hamito (Prof.)
Chief of Party
ESGPIP

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# FORMULATION OF RATIONS FOR SHEEP AND GOATS

**Prepared By: Alemu Yami** **Edited by: R.C. Merkel**

## 1. INTRODUCTION

Sheep and goats are most productive when fed a ration balanced according to their nutrient needs. The needed nutrients should also be supplied at lowest possible cost. This can be done if producers use locally available feed ingredients and use purchased feeds only to fill the gap in nutrient supply from the locally available feeds. This technical bulletin is intended to present the basic procedures and methods of formulating simple rations from locally available feed ingredients.

## 2. GENERAL PROCEDURES

There are several approaches in formulating rations. The choice of a method will usually depend on the number of feed ingredients and requirements of nutrients to be considered. However, the following general procedure is valid whatever approach is used.

1. Prepare a list of the requirements of all nutrients to be considered under the given circumstances and target animals. Consult appendix Tables 1.1 to 1.6 for sheep and Tables 2.1 and 2.2 for goats.
2. Determine the feeds that are available for the formulation and consult available information on their use.
3. Prepare a listing of the nutrient composition of the feeds to be used. Consult appendix Table 3 of this bulletin. Consulting several sources may be necessary to cover all nutrients and feeds that may be of interest.
4. Obtain feed costs at the site of mixing.
5. Proceed to balance the ration using the guides for the nutrient requirement of the sheep /goat type (age, physiological condition etc.) in question. Use the upper limit of the dry matter requirement as a general guide for estimated total feed allowance.
6. If the ration is complete, make necessary adjustments by asking the following questions:
   - Have all deficiencies been corrected?
   - Are excesses present?
   - Does the formula appear to be the most economical combination of feeds?
   - What is the cost of the ration per quintal or ton or what does it cost to feed the animal in question daily?
   - What will be needed in addition? e.g. free choice salt, minerals, etc.

## 3. INFORMATION NEEDED FOR RATION FORMULATION

Information on the following is required before going into the mathematics of ration formulation.

### *3.1. List of nutrient requirements*

This can be obtained from standard nutrient requirement tables. It should, however, be remembered that the recommendations should be subject to modification when these are not satisfactory to the particular situation. The following factors should be considered in determining nutrient allowances: age, sex, body size, type of production (growth, lactation, pregnancy etc) and level of production. Generally, protein, energy, calcium and phosphorus are considered in the formulation of rations for sheep and goats.

### *3.2. List of available feeds*

If the producer has more than one type of feed as a source of a nutrient (e.g. protein source), it is good to prioritize the available feeds based on their relative suitability and whether they are the most economical sources of the desired nutrients. Then proceed to list the contribution of each feed of the critical nutrients. Analytical data of the feeds are preferred if available. If not, average composition data from appropriate feed composition tables or other available information sources may be used. The publication "Composition of Ethiopian feeds" produced by the Ethiopian Institute of Agricultural

Research (EIAR) provides such information on common Ethiopian feeds. Calculate the unit cost of the major nutrients (energy, protein, calcium, phosphorus) to determine whether the feed is an economical source of the nutrients. In doing this, the costs of processing, transportation and storage should be considered. Also consider the limitation of the various feed ingredients in selection.

### *3.3. Type of ration to be formulated*

The type of ration to be formulated will determine the needed nutrient content of the ration and the details of the formulation procedure. For instance, it makes a difference whether we intend to formulate a complete feed or a finishing concentrate mix to feed as a supplement to a roughage source. For sheep and goat rations, we would normally consider roughage as the base feed and then determine what nutrients are needed to supplement the roughage.

## 4. CONSIDERATIONS IN THE FORMULATION OF RATIONS

The following points are noteworthy while formulating rations using any of the methods to be elaborated later on.

- Try to keep rations simple. The rule of thumb is that simple nutrient needs can be met by simple feed formulae. Complex formulae do not necessarily guarantee better performance.

- Feed composition data may be given either on dry matter or on an as-fed basis depending on the publication from which the information is taken. Therefore, some recalculation may be required before ration formulation commences. Rations should be formulated on dry basis, especially if wet ingredients such as silage, molasses, etc. are included.

- Formulation can be done on the basis of daily needs (i.e. amounts of nutrients rather than concentration), although this is done rarely in practice. Use of percentage units is the simplest means as the final values can easily be converted to any weight unit.

- Every animal has physical and physiological limits beyond which the dry matter intake cannot go. The dry matter intake of animals fluctuates within these limits depending on several factors: species, body size and physiological state of the animal (e.g. pregnancy); and palatability, texture and bulkiness of the diet.

- Select the same units of measure for nutrient requirement and feed composition. For protein, either Crude Protein (CP) or Digestible Protein (DP); for energy, Total Digestible Nutrients (TDN), Metabolisable Energy (ME) or Net Energy (NE). The important thing is that the units of measure of requirement and feed composition of the nutrient to be supplied have to be in the same units to balance a ration.

## 5. METHODS OF RATION FORMULATION

There are many methods of formulating rations useful for various situations. The end result of using any of the methods is a ration that provides the desired allowance of nutrients in correct proportions economically. An illustration of two of the various methods available for formulating rations (the Pearson square and the trial and error methods) follows.

### *5.1. THE PEARSON SQUARE METHOD*

A definite percentage of protein, energy, calcium, phosphorus or any other nutrient is usually desired in rations. The "Pearson Square" or simply the "Square" method, provides a simple and rapid method that allows blending of two feeds (or feed mixtures) with different nutrient concentrations into a mixture with the desired concentration. It is usually employed in cases of mixing feeds rich in energy with feeds rich in protein. For this method to work, the desired level of a nutrient should be a value between the compositions of the ingredients that constitute the mixture. The square method permits quick substitution of feed ingredients in response to market fluctuations without disturbing the content of the nutrient being

considered. This is important to the feed manufacturer who has to respond quickly to changes in market prices of feed ingredients. Different situations where the Pearson Square Method can be employed are demonstrated below using examples.

### 5.1.1. Scenario 1: When only two feeds are involved

Sometimes it might be necessary to determine what combination of feeds will give a mixture with the desired content of a particular nutrient.

#### Example:

A sheep producer wants to formulate a Concentrate supplement that provides 16% Crude protein. He has shelled corn (9% CP) and Cottonseed cake (40% CP). What combination of the shelled corn and cottonseed cake will provide a mix of 16% CP the producer wants?

#### Solution:

a. Draw a square at the left side of the page;
b. Insert the % CP desired in the final mixture (16) in the middle of the square;
c. Place corn with its percent CP (9) on the upper left corner and the cottonseed cake with its CP (40) on the lower left corner;
d. Subtract the % CP desired (16) from the % CP in corn (9) and place the difference (7) without the negative sign at the corner of the square diagonally opposite the corn (on the lower right side of the square);
e. Subtract the % CP desired in the final mix (16) from the % CP in the cottonseed cake (40) and place the difference (24) at the corner of the square diagonally opposite from the groundnut cake (at the upper right corner of the square). The above remainders represent proportions of the two feeds that will provide a mix containing the desired % CP.
f. The amounts can then be converted to a percentage basis and then to any other weight basis (e.g. quintal / ton) as desired for mixing purposes.

| INGREDIENT | | PROPORTIONS | ON % BASIS | ON A QUINTAL BASIS |
|---|---|---|---|---|
| Corn | 9 | 24 | (24/31)*100=77.4 | 77.4%*100= 77.4Kg corn |
| | 16 | | | |
| CS Cake | 40 | 7 | (7/31)*100=22.6 | 22.6%*100=22.6Kg CS Cake |
| **TOTAL** | | **31 parts** | **100** | **100 Kg (Quintal)** |

Thus, mixing 77.4% corn (9%CP) and 22.6% Cottonseed cake (40%CP) will provide a mix of 16% CP.

#### Check:

One can check whether the final mix really contains the desired Crude Protein (CP) level by calculating the contributions of the ingredients constituting the mixture (corn and CS cake) and summing up.

- Contribution of corn = (9*77.4)/100=7
- Contribution of CS Cake = (40*22.6)/100=9

**Total CP in mix = 7+9 = 16%**

### 5.1.2. Scenario 2: When three or more feeds are involved

It is common practice to use more than just two feeds in formulating a feed mixture to attain a specific nutrient level.

## Example:

What combination of corn (10% CP), Wheat bran (13%CP) and cottonseed Meal (CSM-40%CP) will provide a mix of 16% CP?

## Solution:

Construct the Pearson Square and do the following:

a. Categorize the feeds into two groups since the square can handle only two categories at a time;
b. Specify the proportion of each feed in each group;
c. Calculate the weighted average % protein in each group.

For this example, let us assume that corn and wheat bran are grouped together in the proportion of 2:1 with cottonseed meal being used alone. The weighted average % CP in the corn/bran must then be calculated as follows:

| | |
|---|---|
| 2 parts corn contributes 2*10(%CP) | = 20 |
| 1 part wheat bran contributes 1*13 (%CP) | = 13 |
| **TOTAL** | **33** |

A mixture of 2 parts corn and 1 part bran (total of 3 parts) will, therefore, contain 33/3 = 11% CP. This %CP will be used for the "2 parts corn + 1 part bran" designated as CB to occupy one corner of the square and the cottonseed meal the other corner.

Proceed with the calculations as in the previous example.
Divide the final figure for "corn + bran" into 2/3 corn and 1/3 bran (the proportion of each feed in each group must always be indicated initially and complied with in the final mixture)

| INGREDIENT | | PROPORTIONS | ON % BASIS | ON A TON BASIS |
|---|---|---|---|---|
| CB | 11 | 24 | (24/29)*100=82.76 | 82.76%*1000=827.6Kg CB |
| | 16 | | | |
| CSM | 40 | 5 | 5/29*100=17.24% | 17.24%*1000=172.4Kg CSM |
| **TOTAL** | | **29 parts** | **100** | **1000** |

Ration composition will, therefore, be as follows:

| | |
|---|---|
| Corn (2/3*82.76) | = 55.17% |
| Wheat bran (1/3*82.76) | = 27.59% |
| Cotton seed meal | = 17.24% |
| **TOTAL** | **100.0%** |

## Check:

To check your calculations, multiply the last ration composition by the CP of each feed source as follows:

| | |
|---|---|
| Corn contributes (55.2/100)*10 | = 5.52 |
| Wheat bran contributes (27.6/100)*13 | = 3.59 |
| CSM contributes (17.2/100)*40 | = 6.89 |
| **TOTAL CP IN MIX =** | **16.00%** |

### 5.1.3. Scenario 3: With a fixed percentage of one or more ration components

It may sometimes be desirable to formulate a mixture using more than two different ingredients containing a particular percentage of a nutrient such as protein but with a fixed percentage of one or more ration components.

**EXAMPLE:**

Let us assume that a sheep/goat producer wishes to formulate a 14% CP mixture using corn (9%CP), oats (12%CP), Noug seed meal (NSM-35%CP) and a mineral/vitamin supplement (0%CP). If he decides to include exactly 20% oats and 3% mineral/vitamin supplement in the mixture, what combination of Corn and Noug seed meal can be used to make up the remaining 77% of the final mixture?

**SOLUTION:**

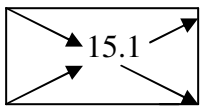
A CP level of 14% is desired for the overall mixture. This means 14 kg of protein per 100 kg of mixture. Since 20 kg of each 100 kg of mix is oats (20%) it would supply 2.4% (12% of 20 kg). The 3% mineral/vitamin supplement provides no protein. Thus, the 23 Kgs of oats and mineral/vitamin premix per 100 kg of mix would provide 2.4 kg CP (2.4+0). The remainder of the 14 kg of CP needed i.e. 11.6(14-2.4) must come from the 77 (100-23) kg of corn and Noug seed meal. In order to determine what combination of 77 kg of corn and Noug seed meal will provide the needed 11.6 kg of protein, an adaptation of the square method can be used.

To do this, it is first necessary to calculate what % Crude Protein will be needed in the corn and Noug seed meal combination to provide 11.6 kg of crude protein per 77 Kgs as follows:

77 Kg should contain 11.6 kg
100 Kg should contain ?
=> (11.6/77)*100= 15.1 (the needed CP% of the corn and Noug seed meal mix)

This figure is then used in conjunction with the square method as follows:

Per 77 parts (calculated by ratio)




| | | | | |
|---|---|---|---|---|
| Corn | 9 | 19.9 | 19.9/26= x/77; | x= 58.93 parts corn |
| NSM | 35 | 6.1 | 6.1/26= x/77; | x= 18.07parts NSM |
| **TOTAL** | | **26 parts** | | **77.00** |

Therefore, the constitution of the final ration will be:

| | |
|---|---|
| Oats | 20.00 |
| Mineral/Vitamin supplement | 3.00 |
| Corn | 58.93 |
| Noug seed meal | 18.07 |
| **Total** | **100.00** |

One can check whether the final mix provides the desired level of protein by summing up the contributions of protein by each of the constituent feed ingredients.

| | |
|---|---|
| Contribution of Oats 20*(12/100) | =2.4 |
| Contribution of Mineral/Vitamin supplement 3*(0/100) | =0.0 |
| Contribution of Corn 58.93*(9/100) | =5.3 |
| Contribution of Noug seed meal 18.07*(35/100) | =6.3 |
| **Total % Crude Protein in final (100%) Mix** | **14.0** |

### 5.1.4. Scenario 4: When definite amounts of two nutrients are required

Under normal circumstances, rations are formulated to meet animal requirements for many nutrients at the same time. A modification of the Pearson's Square Method known as the "Double Pearson's Square" method can be used to formulate a ration mixture that has exact amounts of two nutrients. Consideration of more than two nutrients using this method becomes too complicated. The use of alternative methods like the trial and error method illustrated later in this bulletin may be more convenient. The use of the Double Pearson Square method to formulate a ration that meets two nutrients is demonstrated by the following example.

**EXAMPLE:**

Suppose we want to formulate a mix with 16% CP and 2.8 Megacalories/Kg (Mcal/Kg) Metabolizable Energy (ME) by using the following feeds:

a. Corn - 9% CP and 3.4 Mcal/Kg ME;
b. Cottonseed meal-42% CP and 2.86 Mcal/Kg ME;
c. Alfalfa hay- 18% CP and 2.49 Mcal/Kg ME

**SOLUTION:**

To solve this problem, one has to go through two squares and get a mix exact for one of the nutrients. Any one of the nutrients can be taken first. Let us take CP. The first step is to formulate two different mixes - one having exactly 16% CP and ME greater than the desired (>2.8Mcal/Kg); and another mix with 16% CP and ME less than the desired level (<2.8 Mcal/Kg ME). At least three feedstuffs are needed to do this.

**Step 1. Mix 1 (*16% CP; >2.8 Mcal/kg ME*)**

| INGREDIENT | | PROPORTIONS | ON % BASIS | CALCULATE ME |
|---|---|---|---|---|
| Corn | 9 | 26 | (26/33)*100=78.7% | 78.7%*3.4=2.68 |
| | 16 | | | |
| Cotton SM | 42 | 7 | 7/33*100=21.3% | 21.3%*2.86=0.61 |
| **TOTAL** | | **33 parts** | **100** | **3.29** |

This mix supplies 16% CP and 3.29 Mcal/kg ME (greater than the desired 2.8 Mcal/Kg ME level)

**Step 2. Mix 2 *(16% CP; <2.8 Mcal/kg ME)***

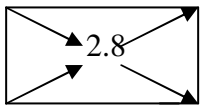
| INGREDIENT | | PROPORTIONS | ON % BASIS | COMPUTE ME |
|---|---|---|---|---|
| Corn | 9 | 2 | (2/9)*100=22.2% | 22.2%*3.4=0.75 |
| | 16 | | | |
| Alfalfa | 18 | 7 | 7/9*100=77.8% | 77.8%*2.49=1.94 |
| **TOTAL** | | **9 parts** | **100** | **2.69** |

This Mix supplies 16% CP and 2.69 Mcal/kg ME (less than the desired ME level)

## Step 3. Then solve for ME

Mixing the two mixes formulated in steps 1 and 2 above in any proportion will not change the CP composition of the final mix since both contain 16% CP. The nutrient that will vary would be the ME. The last step is, therefore, to find the proportions of the two mixes that should be combined to give 2.8 Mcal / kg ME.

Mix 3 (final mix) 16% CP and 2.8 Mcal / kg ME

| INGREDIENT | | PARTS | ON % BASIS |
|---|---|---|---|
| Mix 1 3.29 |  | 0.11 | (0.11/0.60)*100=18.3% |
| Mix 2 2.69 | | 0.49 | 0.49/0.6*100=81.7% |
| **TOTAL** | | **0.60 parts** | **100** |



## Step 4. Calculate ingredient composition in final mix

### Corn:

-In mix 1, 78.7 (18.3% of mix 1 in mix 3) = (78.7*18.3/100) =14.40
-In mix 2, 22.2 (81.7% of mix 2 in mix 3) = (22.2*81.7/100) =18.14
Total Corn = 14.4+18.14=**32.54%**

### Cotton Seed Meal:

-Only in mix 1, 21.3 (18.3% of mix 1 in mix 3) = (21.3*18.3/100)) **=3.90**

### Alfalfa

-only in mix 2, 77.8 (81.7% of mix 2 in mix 3) = (77.8*81.7/100) =**63.56**

Therefore, the ingredient composition of final ration will be: -

| | |
|---|---|
| Corn | 32.54 |
| CSM | 3.90 |
| Alfalfa | 63.56 |
| **Total** | **100.00** |

One can check whether the final mixture meets the desired levels of the nutrients by summing up the contributions of nutrients by each ingredient in the final mix.

**ME:**

| | | |
|---|---|---|
| From Corn | = 32.54% of 3.4(ME content of corn) | = 1.11 |
| From CSM | = 3.90% of 2.86(ME content of CSM) | = 0.11 |
| From Alfalfa | = 63.56% of 2.49(ME content of Alfalfa) | = 1.58 |
| **Total ME in mix** | **=** | **2.8Mcal/Kg (*Correct!*)** |

**CP:**

| | | |
|---|---|---|
| From Corn | = 32.34% of 9 (CP content of corn) | = 2.93 |
| From CSM | = 3.9% of 42 (CP content of CSM) | = 1.63 |
| From Alfalfa | = 63.56% of 18(CP content of Alfalfa) | =11.44 |
| **Total CP in mix** | **=** | **16% (*Correct!*)** |

## *5.2. THE TRIAL AND ERROR METHOD*

When using the trial and error method, one starts with a primary feed ingredient and modifies the fundamental ration formula step by step to compensate for any nutrient deficiencies found in the primary feed.

This method utilizes the Pearson's square and other procedures like the algebraic method (not illustrated in this bulletin) as tools to arrive at a suitable feed formula. The following steps are generally followed to formulate a ration mixture using the trial and error method.

**Step 1:** Make a list of the ingredients with their nutrient compositions available for possible inclusion in the ration to be formulated

**Step 2:** Fix the requirements of the ration to be composed

**Step 3:** Proceed to balance the ration as follows:

- **Step 3.1 :** Reserve 2% for minerals / vitamins.
- **Step 3.2 :** Include ingredients a certain minimum percentage of which needs to be incorporated for various reasons.
- **Step 3.3 :** Include ingredients with an energy value higher than that required in the ration to constitute 30%. Here, priority should be given to those ingredients with the lowest price per unit of energy. You should, however, be careful not to exceed the safe maximum levels for the ingredients.
- **Step 3.4 :** Include ingredients with protein contents higher than the required level in the ration you want to prepare. To start with, limit the level of inclusion of such ingredients to 18%. Here, again, priority should be given to those ingredients with the lowest price per unit of protein without exceeding the safe maximum levels.
- **Step 3.5 :** Now, add the percentage and quantities of the various nutrients and compare the nutrient quantities with requirements of the target class of animal.
- **Step 3.6 :** Select an ingredient that is a good source of the nutrient (energy, protein) missing the most. The selected ingredient is included to constitute 10% of the final ration. Continue to do the same until you reach 100% by repeating step 3.5 after every addition.
- **Step 3.7 :** It may be necessary to substitute some ingredients by others in order to obtain proper levels and ratios of the required nutrients. This is usually done when proceeding from 90 to 100%.

The steps outlined above are general guidelines to be followed to formulate rations using the trial and error method. The method will be better clarified by worked out examples that follow.

### 5.2.1. WORKED OUT EXAMPLES OF RATIONS FOR SHEEP AND GOATS

#### Step 1

Make a list of the ingredients available for possible inclusion in the ration to be formulated. List the following information or data for each feed ingredient available for formulation:

- Dry matter (%);
- Energy content (TDN, NEm, $NE_g$, $NE_l$);
- Protein (Crude or Digestible-in %);
- Price/quintal;
- Price/unit of energy;
- Price/unit of Protein;
- Safe maximum percentage;
- Absolute maximum percentage

## Step 2

Fix the requirements of the ration to be composed:

- Acceptable range for TDN considering price per unit of TDN (another measure of energy e.g. ME may be used). This gives the opportunity to select feeds that are cheaper sources of energy.
- Range of acceptable crude protein or digestible protein values (maximum and minimum) and price per unit of protein, etc.

The information compiled in steps 1and 2 can be summarized as in the table below:

## TABLE 1. DATA ON AVAILABLE FEED INGREDIENTS

| Ingredient | Energy (%TDN) | Dig protein (%) | Price/ 100kg | Price/unit energy (TDN) | Price/unit protein | Safe max. | Abs. max. |
|---|---|---|---|---|---|---|---|
| **Wheat bran** | 60 | 11.4 | 60 | 1.00 | 5.26 | 50 | 100 |
| **Rice bran** | 52 | 6.10 | 50 | 0.97 | 8.2 | 40 | 100 |
| **Maize bran** | 67 | 6.30 | 55 | 0.82 | 8.73 | 50 | 100 |
| **Brewer's dried grains** | 62 | 14.1 | 30 | 0.48 | 2.13 | 25 | 100 |
| **Cotton seed cake** | 65 | 16.6 | 50 | 0.77 | 3.01 | 50 | 100 |
| **Sunflower seed cake** | 68 | 23.3 | 70 | 1.02 | 3.01 | 50 | 100 |
| **Groundnut cake** | 68 | 28.4 | 80 | 1.18 | 2.82 | 50 | 100 |
| **Sesame cake** | 77.6 | 36.8 | 80 | 1.03 | 2.17 | 50 | 100 |

## Step 3

Start constituting the ration as follows:

- Reserve 2% for premix;
- Include 30% ingredient(s) with % TDN higher than the desired TDN level in the final ration. Give priority to those ingredients with the lowest price/unit of TDN;
- Include 18% ingredient(s) with % digestible protein higher than the desired level in the final ration. Here again, priority should be given to ingredients with the lowest price per unit of protein among the available ingredients;
- In the selection of both energy and protein sources, care should be taken not to include ingredients beyond the recommended absolute maximum levels.

## Step 4

Now, you have 50% of your ration constituted; check the composition of the ration against the requirements. Then, start building further on a step-by-step basis adding 10% of the ingredient that is the cheapest source of the most limiting nutrient until 100% of the ration containing the required nutrient levels at lowest cost is constituted.

## *EXAMPLE:*

A farmer wants to formulate a creep supplement for lambs that contains 64% (61-66) TDN and 21% (20-22) Digestible Protein (DP). He has wheat bran, rice bran, maize bran, Brewer's dried grains, Cotton seed cake, Sunflower cake, groundnut cake, and Sesame cake at his disposal. Help him to achieve his goals!

## *SOLUTION:*

Make a listing of the available feed ingredients with necessary or useful data as in Table 1. You can now go ahead and do the formulation based on the guidelines given earlier.

- Reserve 2% for premix;
- Include 30% of ingredients with TDN greater than the level desired in the ration.
  - The cheapest TDN source among the available feeds with greater than the desired TDN level (i.e. 64%) is cottonseed meal. Therefore, include 30% cottonseed meal!

- Include 18% of ingredient(s) with DP greater than the level desired in ration.
  - The cheapest DP source among the available feeds with DP higher than the desired level (i.e. 21) is Sesame cake. Therefore, include 18% Sesame cake.
- Now check the composition of the 50% ration constituted against the requirements.

## TDN:

- Minimum that needs to be supplied at 50% = 61*50% = 30.5
- Maximum that needs to be supplied at 50% = 66*50% = 33

Amount supplied by the constituted ration:-

| | | |
|---|---|---|
| Premix | 2%*0 | = 0.0 (Doesn't contain any energy) |
| Cotton seed meal | 30%*65 | = 19.5 |
| Sesame seed cake | 18%*77.6 | = 14.0 |
| | **Total** | **33.5 The TDN requirement is, thus, met.** |

## DP:

- Minimum that needs to be supplied at 50% = 20*50% = 10%

Amount supplied by the feeds: - 0+ (30%*16.6) + (18%*36.8) = 11.6: Therefore, minimum DCP also fulfilled.

**Step 5.** So, continue building up 10% at a time by taking the cheapest TDN source.

**TABLE 2. FORMULATION SHEET**

| **Step1. Reserve 2% for premix** | | | | |
|---|---|---|---|---|
| | % | TDN | %DP | Price (Birr/100kg) |
| *Premix* | 2 | 0 | 0 | 1500 |
| **Step2. Include 30% of ingredient(s) with TDN greater than level desired in ration** | | | | |
| *Cotton seed cake* | 30 | (30%x 65)=19.5 | (30%x 16.6)=5 | 30% x 50= 15.00 |
| **Step3. Include 18% of ingredient(s) with DP greater than level desired in ration** | | | | |
| *Sesame cake* | 18 | (18%x 78)=14 | (8% x 35.8)= 6.6 | 18%x80)=14.40 |
| **Step4. check the composition of the 50% ration constituted against the requirements** | | | | |
| **Total@50%** | **50** | **33.5** | **11.6** | **29.40** |
| **Step 5. Continue building up 10% at a time by taking the cheapest TDN source.** | | | | |
| *BDG* | 10 | (10%x 62)=6.2 | (10%x 14)= 1.4 | 10% x 30 =3.00 |
| **Total@60%** | **60** | **39.7** | **13** | **32.40** |
| *BDG* | 10 | 6.2 | 1.4 | 3.00 |
| **Total@70%** | **70** | **45.9** | **14.4** | **35.40** |
| *BDG* + *Cotton seed cake* | 5<br><br>5 | 3.1<br><br>3.3 | 0.7<br><br>0.8 | 1.5<br><br>2.5 |
| **Total@80%** | **80** | **52.3** | **15.9** | **39.40** |
| *Sesame cake* | 10 | 7.8 | 3.7 | 8 |
| **Total@90%** | **90** | **60.1** | **19.6** | **47.40** |
| *Rice bran* | 10 | 10%*52=5.2 | 10%*6.1=0.61 | 10%*50=5 |
| **FINAL MIX (100%)** | **100** | **65.3** | **20.21** | **52.40** |
| | | | | |
| **Requirements:** | | | | |
| **-Optimum** | | **64** | **21** | |
| **- Range** | | **61-66** | **20-22** | |

The cheapest TDN source is Brewer's dried grains. Therefore, include 10% BDG.

## CHECK (at 60%)

Minimum TDN ⇨ 61*60% = 36.6
Supplied ⇨ 33.5 + (10%*62) = 39.7, therefore, fulfilled!

Minimum DP ⇨ 20*60% =12
Supplied ⇨ 11.6 + (10%*14) = 13, therefore, fulfilled!

Again add 10% BDG, the cheapest TDN source.

## CHECK (at 70%)

Minimum TDN ⇨ 61*70% = 42.2
Supplied ⇨ 39.7+ (10%*62) = 45.9, therefore, fulfilled!

Minimum DP ⇨ 20*70% =14
Supplied ⇨ 13 + (10%*14) = 14.4, therefore, fulfilled!

Now you are free to take any feed ingredient. So, take those ingredients having cheap TDN with caution not to exceed their safe maximum levels. If you reach safe maximum level of the most appropriate (cheapest) ingredient, then, take the next cheapest one.

- Thus we can still add 5% of BDG before exceeding the set safe maximum level of 25%. We add 5% of the next cheapest TDN source i.e. Cottonseed meal.

## CHECK (at 80%)

Minimum TDN 61*80% = 48.8
Supplied45.9+ (5%*62) + (5%*65) = 52.3, therefore, fulfilled!

Minimum DCP 20*80% =16
Supplied14.4+ (5%*14) + (5%*16.6) = 15.9, not fulfilled

Therefore, you now select 10% of the cheapest DCP source i.e. Sesame cake.

## CHECK (at 90%)

Minimum TDN 61*90% = 54.9
Supplied52.3+ (10%*77.6) = 60 **fulfilled!**

Minimum DP 20*90% =18
Supplied15.9+ (10%*36.8) = 19.6, therefore, **fulfilled!**

This is the last chance you have (i.e. the last 10%) where all the fine-tuning should be done. We should now select a feed that fulfils the following requirements:

- a minimum of 9% TDN (0.9 i.e. 61-60.1) should be fulfilled by the last 10% (that would be 0.9*100/10 in percentage terms);
- a maximum of 59% TDN [(66-60.1)*100/10];
- a minimum DP of 4% (20-19.6)*100/10 ;
- a maximum DP of 24% [(22-19.6)*100/10]

Only wheat bran and rice bran fulfill the above requirements (TDN between 9 and 59%; DP between 4 and 24%). In this case, we go for the cheapest ingredient. Rice bran and cotton seed cake have the lowest cost per quintal. Cotton seed cake contains far higher TDN and protein needed from the last 10%: Therefore, it would be better to include the rice bran in absence of any other consideration that makes inclusion of cotton seed cake more convenient or advantageous.

The final ration will, therefore, have the following composition:-

| | |
|---|---|
| Cotton seed cake | 35% |
| Brewer's Dried grains | 25% |
| Sesame cake | 28% |
| Rice bran | 10% |
| Premix | 2% |
| **Total** | **100%** |

## What can the Kebele Development Agent (KDA) do regarding formulation of rations?

This technical bulletin targets subject matter specialists (SMS) involved in sheep and goat extension. The SMS can do the following to promote sheep and goat productivity in his/her area by doing the following:

- Identify the types of feeds available in his/her area;
- Identify the compositions and characteristics of the identified feeds for sheep and goats;
- Follow the instructions outlined in this technical bulletin to formulate alternative rations for different classes of sheep and goats;
- Prepare the rations in the form of a small flier, fact sheet or another type of manuscript and make it available for use by KDAs and/or any other producer.

# APPENDIX 1. NUTRIENT REQUIREMENTS OF SHEEP

## *APPENDIX 1.1. Daily Nutrient requirements of Sheep (Ewes and Lambs- Maintenance, Growth, non-lactating and first 15 weeks of gestation)*

| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/day | % Live W | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 10 | 0 | .33 | 3.3 | .52 | .14 | 26 | 12 | 2.2 | 1.5 |
| | 25 | .36 | 3.6 | .64 | .18 | 30 | 15 | 2.2 | 1.5 |
| | 50 | .39 | 3.9 | .76 | .21 | 35 | 18 | 2.3 | 1.5 |
| | 100 | .42 | 4.2 | 1.00 | .28 | 43 | 24 | 2.3 | 1.6 |
| | 150 | .39 | 3.9 | 1.24 | .34 | 49 | 30 | 2.4 | 1.6 |
| 15 | 0 | .45 | 3.0 | .71 | .20 | 36 | 17 | 2.7 | 1.7 |
| | 25 | .49 | 3.3 | .87 | .24 | 42 | 21 | 2.7 | 1.7 |
| | 50 | .53 | 3.5 | 1.04 | .29 | 49 | 25 | 2.8 | 1.8 |
| | 100 | .56 | 3.7 | 1.37 | .38 | 58 | 33 | 2.9 | 1.9 |
| | 150 | .52 | 3.5 | 1.69 | .47 | 65 | 41 | 3.0 | 2.0 |
| 20 | 0 | .55 | 2.8 | 0.88 | .24 | 44 | 21 | 3.2 | 2.1 |
| | 25 | .61 | 3.0 | 1.08 | .30 | 52 | 26 | 3.2 | 2.2 |
| | 50 | .66 | 3.3 | 1.29 | .36 | 59 | 31 | 3.3 | 2.3 |
| | 100 | .71 | 3.6 | 1.69 | .47 | 72 | 41 | 3.4 | 2.4 |
| | 150 | .65 | 3.3 | 2.10 | .58 | 81 | 50 | 3.6 | 2.4 |
| 25 | 0 | .65 | 2.6 | 1.04 | .29 | 53 | 25 | 4.0 | 2.6 |
| | 25 | .72 | 2.9 | 1.28 | .36 | 61 | 31 | 4.1 | 2.7 |
| | 50 | .78 | 3.1 | 1.52 | .42 | 70 | 36 | 4.1 | 2.7 |
| | 100 | .83 | 3.3 | 2.00 | .55 | 85 | 48 | 4.2 | 2.8 |
| | 150 | .77 | 3.1 | 2.48 | .69 | 96 | 60 | 4.3 | 2.9 |
| 30 | 0 | .75 | 2.5 | 1.19 | .33 | 59 | 27 | 4.4 | 3.0 |
| | 50 | .89 | 3.0 | 1.74 | .48 | 81 | 42 | 4.6 | 3.1 |
| | 100 | .95 | 3.0 | 2.29 | .63 | 98 | 55 | 4.8 | 3.2 |
| | 125 | .94 | 3.1 | 2.57 | .72 | 103 | 60 | 4.9 | 3.3 |
| | 140 | .87 | 2.9 | 2.73 | .75 | 106 | 66 | 5.0 | 3.3 |
| 35 | 0 | .85 | 2.4 | 1.34 | .37 | 68 | 32 | 5.6 | 3.1 |
| | 50 | .99 | 2.8 | 1.96 | .54 | 100 | 47 | 5.7 | 3.1 |
| | 100 | 1.07 | 3.1 | 2.58 | .71 | 111 | 62 | 5.8 | 3.2 |
| | 125 | 1.06 | 3.1 | 2.89 | .80 | 117 | 69 | 5.9 | 3.3 |
| | 140 | .98 | 2.8 | 3.07 | .85 | 121 | 74 | 5.9 | 3.4 |

**Source**: Kearl, 1982

## *APPENDIX 1.2. Daily Nutrient requirements of Sheep (Early weaned lambs of 5 to 30 Kg)*

| Maintenance and Growth | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 5 | 50 | .10 | 2.0 | .44 | .12 | 36 | 29 | 1.8 | 1.3 |
| | 100 | .12 | 2.3 | .50 | .14 | 45 | 36 | 1.8 | 1.3 |
| | 150 | .13 | 2.7 | .57 | .15 | 48 | 38 | 1.9 | 1.3 |
| | 200 | .15 | 3.0 | .64 | .17 | 54 | 43 | 1.9 | 1.3 |
| | 250 | .16 | 3.2 | .69 | .19 | 58 | 46 | 2.0 | 1.4 |
| 10 | 50 | .18 | 1.8 | .73 | .20 | 61 | 49 | 2.1 | 1.5 |
| | 100 | .21 | 2.1 | .84 | .23 | 70 | 56 | 2.1 | 1.5 |
| | 150 | .24 | 2.4 | .96 | .27 | 80 | 64 | 2.2 | 1.5 |
| | 200 | .27 | 2.7 | 1.07 | .30 | 90 | 72 | 2.3 | 1.6 |
| | 250 | .30 | 3.0 | 1.18 | .33 | 99 | 79 | 2.4 | 1.7 |
| 15 | 50 | .26 | 1.7 | .99 | .27 | 82 | 66 | 2.6 | 1.8 |
| | 100 | .30 | 2.0 | 1.14 | .31 | 95 | 76 | 2.7 | 1.8 |
| | 150 | .34 | 2.3 | 1.30 | .36 | 109 | 87 | 2.7 | 1.9 |
| | 200 | .38 | 2.5 | 1.45 | .40 | 121 | 97 | 2.8 | 2.0 |
| | 250 | .42 | 2.8 | 1.60 | .44 | 134 | 107 | 2.9 | 2.0 |
| 20 | 100 | .41 | 2.0 | 1.42 | .39 | 119 | 95 | 3.1 | 2.2 |
| | 150 | .46 | 2.3 | 1.61 | .44 | 135 | 108 | 3.2 | 2.2 |
| | 200 | .51 | 2.6 | 1.80 | .50 | 150 | 120 | 3.4 | 2.4 |
| | 250 | .57 | 2.8 | 1.99 | .55 | 166 | 133 | 3.5 | 2.4 |
| 25 | 100 | .47 | 1.9 | 1.47 | .41 | 122 | 98 | 4.0 | 2.8 |
| | 150 | .55 | 2.2 | 1.69 | .47 | 141 | 113 | 4.0 | 2.8 |
| | 200 | .62 | 2.5 | 1.91 | .53 | 160 | 128 | 4.1 | 2.8 |
| | 250 | .69 | 2.8 | 2.14 | .59 | 179 | 143 | 4.2 | 2.9 |
| | 300 | .76 | 3.0 | 2.36 | .65 | 198 | 158 | 4.3 | 3.0 |
| 30 | 100 | .64 | 2.1 | 1.92 | .53 | 161 | 129 | 4.6 | 3.2 |
| | 150 | .73 | 2.4 | 2.18 | .60 | 182 | 146 | 4.7 | 3.2 |
| | 200 | .81 | 2.7 | 2.44 | .67 | 204 | 163 | 4.8 | 3.3 |
| | 250 | .90 | 3.0 | 2.69 | .74 | 225 | 180 | 4.9 | 3.3 |

**Source**: Kearl, 1982

## *APPENDIX 1.3. Daily Nutrient requirements of Sheep (Maintenance, Growth, Non-lactating and First 15 weeks of Gestation)*

| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 40 | 0 | .93 | 2.3 | 1.48 | .41 | 75 | 36 | 5.7 | 3.1 |
| | 50 | 1.10 | 2.8 | 2.16 | .60 | 100 | 52 | 5.7 | 3.1 |
| | 100 | 1.19 | 3.0 | 2.85 | .79 | 121 | 68 | 5.9 | 3.2 |
| | 125 | 1.18 | 3.0 | 3.19 | .88 | 131 | 77 | 6.0 | 3.3 |
| | 140 | 1.10 | 2.7 | 3.40 | .94 | 133 | 82 | 6.1 | 3.4 |
| | | | | | | | | | |
| 50 | 0 | 1.10 | 2.2 | 1.75 | .48 | 89 | 42 | 5.9 | 3.1 |
| | 50 | 1.30 | 2.6 | 2.56 | .71 | 118 | 61 | 6.0 | 3.3 |
| | 100 | 1.41 | 2.8 | 3.37 | .93 | 144 | 81 | 6.1 | 3.4 |
| | 125 | 1.40 | 2.8 | 3.77 | 1.04 | 154 | 90 | 6.2 | 3.4 |
| | 140 | 1.30 | 2.6 | 4.01 | 1.11 | 157 | 96 | 6.3 | 3.5 |
| | | | | | | | | | |
| 60 | 0 | 1.27 | 2.1 | 2.00 | .55 | 102 | 48 | 6.0 | 3.1 |
| | 50 | 1.50 | 2.5 | 2.93 | .81 | 135 | 70 | 6.2 | 3.3 |
| | 100 | 1.60 | 2.7 | 3.85 | 1.06 | 164 | 92 | 6.4 | 3.5 |
| | 125 | 1.60 | 2.7 | 4.32 | 1.19 | 177 | 104 | 6.5 | 3.5 |
| | 140 | 1.48 | 2.5 | 4.60 | 1.27 | 180 | 110 | 6.5 | 3.6 |

**Source**: Kearl, 1982

## *Appendix 1.4. Daily Nutrient requirements of Sheep (Last 6 weeks of Gestation or Last 8 Weeks of Lactation)*

| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 20 | 100 | .90 | 4.5 | 2.31 | .64 | 103 | 62 | 3.9 | 3.7 |
| 30 | 125 | 1.20 | 4.0 | 3.42 | .94 | 148 | 92 | 3.9 | 3.7 |
| 40 | 100 | 1.48 | 3.7 | 3.90 | 1.08 | 174 | 105 | 4.0 | 3.8 |
| 50 | 75 | 1.70 | 3.4 | 4.20 | 1.16 | 191 | 113 | 4.1 | 3.9 |
| 60 | 50 | 1.80 | 3.0 | 4.35 | 1.20 | 199 | 117 | 4.4 | 4.1 |
| 70 | 25 | 1.96 | 3.8 | 4.37 | 1.21 | 206 | 118 | 4.5 | 4.3 |

**Source**: Kearl, 1982

## *Appendix 1.5. Daily Nutrient requirements of Sheep (First 8 weeks of Lactation)*

| Body weight (kg) | Daily gain (g) | Dry matter intake Kg/day | Energy | | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 20 | 5 | .99 | 5.0 | 2.34 | .55 | 105 | 60 | 9.5 | 6.9 |
| 30 | 5 | 1.35 | 4.5 | 2.99 | .75 | 143 | 82 | 9.8 | 7.1 |
| 40 | -10 | 1.67 | 4.2 | 3.37 | .93 | 176 | 101 | 10.4 | 7.4 |
| 50 | -20 | 1.97 | 3.9 | 3.99 | 1.10 | 209 | 120 | 10.9 | 7.8 |

**Source**: Kearl, 1982

## *Appendix 1.6. Daily Nutrient requirements of Sheep (Rams)*

| Maintenance and Growth | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 30 | 120 | 1.15 | 3.8 | 2.59 | .72 | 113 | 62 | 5.9 | 3.2 |
| 40 | 110 | 1.43 | 3.6 | 3.07 | .85 | 137 | 74 | 6.3 | 3.5 |
| 50 | 100 | 1.69 | 3.4 | 3.48 | .96 | 159 | 84 | 6.8 | 3.8 |
| 60 | 100 | 1.94 | 3.2 | 3.99 | 1.10 | 181 | 96 | 7.2 | 4.0 |
| 70 | 80 | 2.18 | 3.1 | 4.08 | 1.13 | 194 | 98 | 7.5 | 4.3 |

**Source**: Kearl, 1982

- TDN calculated as 1 kg TDN = 3.62 Mcal ME; Maintenance requirements during the last trimester calculated as 171% of maintenance.
- Ten percent (10%) added to above nutrient values for first lamb ewes (20 and 30 kg ewes) to compensate for body growth.

**Note:** Calcium and phosphorus, values taken from the NRC (1975) or the MAFF (1979).
When sheep are grazing open range, add 25% to the above nutrient requirements: where conditions are harsh with long distances to water, add 50% to the above requirements; and when grazing sparsely vegetated mountainous country, add 75% to the above requirements.

Add 25% to the nutrient requirements for twin bearing ewes.
An estimated value of 6.7 Mcal ME is provided to an animal for each kg of body weight loss (MAFF, 1979)
Add 1.25 Mcal ME and 54 g DP, 9 g calcium, and 7 g phosphorus for each additional kg of milk above one.

# APPENDIX 2. NUTRIENT REQUIREMENTS OF GOATS

## *Appendix 2.1 Daily Nutrient Requirements of Goats (Maintenance, Growth and Early Gestation*

| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 5 | 0 | .19 | 3.8 | .35 | .10 | 15 | 10 | .5 | .4 |
| | 25 | .22 | 4.4 | .52 | .14 | 22 | 15 | .8 | .6 |
| | 50 | .21 | 4.2 | .69 | .19 | 29 | 20 | 1.1 | .9 |
| 10 | 0 | .32 | 3.2 | .58 | .16 | 25 | 17 | .9 | .7 |
| | 25 | .36 | 3.6 | .75 | .21 | 32 | 22 | 1.2 | .9 |
| | 50 | .37 | 3.7 | .92 | .25 | 39 | 26 | 1.5 | 1.2 |
| | 75 | .35 | 3.5 | 1.09 | .30 | 46 | 31 | 1.9 | 1.5 |
| 15 | 0 | .44 | 2.9 | .79 | .22 | 33 | 23 | 1.2 | .9 |
| | 25 | .45 | 3.0 | .86 | .24 | 36 | 25 | 1.5 | 1.1 |
| | 50 | .50 | 3.3 | 1.13 | .31 | 48 | 33 | 1.9 | 1.4 |
| | 75 | .50 | 3.3 | 1.30 | .36 | 55 | 37 | 2.2 | 1.7 |
| 20 | 0 | .54 | 2.7 | .98 | .27 | 41 | 28 | 1.5 | 1.1 |
| | 25 | .58 | 2.9 | 1.15 | .32 | 49 | 33 | 1.8 | 1.3 |
| | 50 | .60 | 3.0 | 1.32 | .36 | 56 | 38 | 2.1 | 1.6 |
| | 75 | .62 | 3.1 | 1.49 | .41 | 63 | 43 | 2.4 | 1.9 |
| | 100 | .62 | 3.1 | 1.66 | .46 | 70 | 48 | 2.8 | 2.1 |
| 25 | 0 | .64 | 2.7 | 1.16 | .32 | 49 | 33 | 1.8 | 1.3 |
| | 25 | .68 | 2.7 | 1.33 | .37 | 56 | 38 | 2.1 | 1.5 |
| | 50 | .71 | 2.8 | 1.50 | .41 | 63 | 43 | 2.4 | 1.8 |
| | 75 | .73 | 2.9 | 1.67 | .46 | 71 | 48 | 2.7 | 2.1 |
| | 100 | .74 | 3.0 | 1.84 | .51 | 78 | 53 | 3.1 | 2.3 |
| | 125 | .71 | 2.8 | 2.03 | .56 | 86 | 58 | 3.4 | 2.5 |
| 30 | 0 | .74 | 2.5 | 1.33 | .37 | 56 | 38 | 2.1 | 1.5 |
| | 25 | .77 | 2.6 | 1.50 | .41 | 63 | 43 | 2.4 | 1.7 |
| | 50 | .80 | 2.7 | 1.67 | .46 | 71 | 48 | 2.7 | 2.0 |
| | 75 | .83 | 2.8 | 1.84 | .51 | 78 | 53 | 3.1 | 2.3 |
| | 100 | .84 | 2.8 | 2.01 | .56 | 89 | 58 | 3.4 | 2.5 |
| | 125 | .84 | 2.8 | 2.18 | .60 | 92 | 63 | 3.7 | 2.7 |
| | | | | | | | | | |
| 40 | 25 | .95 | 2.4 | 1.82 | .50 | 77 | 53 | 2.8 | 2.1 |
| | 50 | .98 | 2.4 | 2.00 | .55 | 85 | 58 | 3.1 | 2.4 |
| | 75 | 1.01 | 2.5 | 2.17 | .60 | 92 | 62 | 3.5 | 2.7 |
| | 100 | 1.04 | 2.5 | 2.34 | .65 | 99 | 67 | 3.8 | 2.9 |
| | 125 | 1.05 | 2.5 | 2.51 | .69 | 106 | 72 | 4.1 | 3.1 |

**Appendix 2.1 (Continued).**

| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 50 | 0 | 1.08 | 2.2 | 1.94 | .54 | 82 | 56 | 3.0 | 2.3 |
| | 50 | 1.15 | 2.3 | 2.28 | .63 | 96 | 66 | 3.6 | 2.8 |
| | 100 | 1.20 | 2.4 | 2.62 | .72 | 111 | 75 | 4.3 | 3.3 |
| | 125 | 1.23 | 2.5 | 2.79 | .77 | 118 | 80 | 4.6 | 3.5 |
| | 150 | 1.24 | 2.5 | 2.96 | .82 | 125 | 85 | 5.0 | 3.8 |
| | 175 | 1.24 | 2.5 | 3.13 | .86 | 132 | 90 | 5.3 | 4.1 |
| | | | | | | | | | |
| 60 | 0 | 1.24 | 2.1 | 2.23 | .62 | 94 | 64 | 3.4 | 2.6 |
| | 50 | 1.31 | 2.2 | 2.57 | .71 | 109 | 74 | 4.0 | 3.1 |
| | 100 | 1.37 | 2.3 | 2.90 | .80 | 123 | 84 | 4.7 | 3.6 |
| | 125 | 1.40 | 2.3 | 3.17 | .88 | 134 | 91 | 5.0 | 3.8 |
| | 150 | 1.42 | 2.4 | 3.34 | .92 | 141 | 96 | 5.4 | 4.1 |
| | 175 | 1.42 | 2.4 | 3.51 | .97 | 148 | 101 | 5.7 | 4.4 |
| | | | | | | | | | |
| 70 | 0 | 1.40 | 2.0 | 2.50 | .69 | 106 | 72 | 3.9 | 2.9 |
| | 50 | 1.46 | 2.1 | 2.84 | .78 | 120 | 82 | 4.5 | 3.4 |
| | 100 | 1.52 | 2.2 | 3.18 | .88 | 135 | 92 | 5.2 | 3.9 |
| | 125 | 1.55 | 2.2 | 3.35 | .93 | 142 | 96 | 5.5 | 4.1 |
| | 150 | 1.57 | 2.2 | 3.52 | .97 | 149 | 101 | 5.9 | 4.4 |
| | 200 | 1.59 | 2.3 | 3.86 | 1.07 | 163 | 111 | 6.2 | 4.9 |

**Source**: Kearl, 1982

## *Appendix 2.2.Daily Requirements of Goats (Last 8 weeks of Gestation & Last 8 weeks of Lactation)*

| Body weight (kg) | Daily gain (g) | Dry matter intake | | Energy | | Protein | | Ca (g) | P (g) |
|---|---|---|---|---|---|---|---|---|---|
| | | Kg/day | % Live weight | ME (Mcal) | TDN (Kg) | Total (g) | Digestible (g) | | |
| 20 | 100 | .72 | 3.6 | 2.17 | .60 | 92 | 90 | 3.0 | 2.1 |
| 25 | 100 | .85 | 3.4 | 2.57 | .71 | 109 | 95 | 3.0 | 2.1 |
| 30 | 100 | .98 | 3.3 | 2.71 | .75 | 115 | 100 | 4.0 | 2.8 |
| 35 | 120 | 1.10 | 3.1 | 2.76 | .76 | 117 | 110 | 4.0 | 2.8 |
| 40 | 120 | 1.21 | 3.0 | 3.05 | .84 | 129 | 115 | 4.0 | 2.8 |
| 50 | 120 | 1.43 | 2.9 | 3.61 | 1.00 | 153 | 120 | 5.0 | 3.5 |
| 60 | 120 | 1.65 | 2.8 | 4.13 | 1.14 | 175 | 129 | 5.0 | 3.5 |
| First 10 Weeks of Lactation | | | | | | | | | |
| 20 | -20 | 1.13 | 5.6 | 2.74 | .76 | 116 | 88 | 4.0 | 2.8 |
| 25 | -20 | 1.34 | 5.4 | 3.02 | .83 | 128 | 97 | 4.0 | 2.8 |
| 30 | -20 | 1.53 | 5.1 | 3.29 | .91 | 139 | 105 | 5.0 | 3.5 |
| 35 | -20 | 1.72 | 4.9 | 3.54 | .98 | 150 | 113 | 5.0 | 3.5 |
| 40 | -20 | 1.90 | 4.8 | 3.79 | 1.05 | 160 | 121 | 5.0 | 3.5 |
| 50 | -20 | 2.25 | 4.5 | 4.16 | 1.15 | 176 | 133 | 6.0 | 4.2 |
| 60 | -20 | 2.58 | 4.3 | 4.71 | 1.30 | 199 | 151 | 6.0 | 4.2 |

**Source:** kearl, 1982

- Dry matter intake calculated as 76.3 g/Wkg0.75.
- Twenty percent was added to the ME requirement for first kidding goats (20 to 25 kg weights) and 10% for second kidding goats ( 40 kg weight) to compensate for body growth.
- Includes ME requirement for 1 kg 4% FCM.

# Appendix 3. FEED COMPOSITION

| Feed name and description | Dry matter % | Protein | | Energy for small ruminants | | | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|---|
| | | CP (%) | Dig. Protein (%) | DE (Mcal/Kg) | ME (Mcal/Kg) | TDN (%) | | |
| Poultry litter | 89 | 26.1 | 14.8 | 2.57 | 2.15 | 60 | 2.25 | 1.80 |
| Cottonseed meal, solv. extd. | 91 | 41.6 | - | 2.99 | 2.57 | 72 | 0.23 | 1.07 |
| Cottonseed meal, mech, extd. | 92 | 36.5 | 21.2 | 3.23 | 2.81 | 68 | 0.25 | 1.15 |
| Peanut meal, w pods mech extd. | 93 | 45.3 | 40.4 | 3.33 | 2.92 | 81 | 0.21 | 0.64 |
| - w some pods solv. extd. | 90 | 30.8 | 38.4 | 2.81 | 2.39 | 67 | - | - |
| - w/o pods mech. extd. | 92 | 48.5 | 42.6 | 3.51 | 3.10 | 80 | 0.22 | 0.71 |
| -w/o pods mech. extd. | 94 | 46.4 | 42.2 | 4.68 | 4.27 | 90 | 0.17 | 0.57 |
| Soybean meal, solv. extd. | 92 | 46.4 | 42.8 | 3.53 | 3.12 | 88 | 0.33 | 0.72 |
| Sunflower meal, solv. extd. | 88 | 19.6 | - | 1.72 | 1.34 | 37 | 0.25 | 0.85 |
| Brewers grains, dried | 92 | 21.7 | - | 2.52 | 2.13 | 60 | 0.27 | 0.50 |
| Brewers grains, wet | 24 | 7.1 | 3.8 | 0.68 | 0.58 | 16 | 0.07 | 0.12 |
| Barley, Grain | 90 | 9.8 | 7.8 | 3.10 | 2.72 | 76 | 0.08 | 0.30 |
| Corn, grain dent white | 87 | 8.1 | 5.0 | 3.29 | 2.93 | 82 | 0.04 | 0.26 |
| - bran | 90 | 9.6 | 6.9 | 2.86 | 2.48 | 71 | 0.04 | 0.14 |
| -ears, ground | 86 | 7.6 | 4.6 | 2.99 | 2.63 | 73 | 0.04 | 0.47 |
| Cotton, seeds | 90 | 19.9 | - | 2.84 | 2.46 | 69 | 0.16 | 0.65 |
| Oats, grain | 88 | 10.8 | 9.0 | 2.75 | 2.39 | 67 | 0.11 | 0.34 |
| Sorghum, grains | 89 | 11.0 | 7.6 | 3.28 | 2.92 | 82 | 0.03 | 0.31 |
| Sun flower, seed | 94 | 16.8 | - | 3.12 | 2.73 | 76 | 0.17 | 0.52 |
| Wheat, grain | 93 | 11.5 | 9.1 | 3.41 | 3.02 | 84 | 0.15 | 0.34 |
| - bran | 90 | 13.3 | 8.5 | 2.81 | 2.35 | 65 | 0.14 | 1.27 |
| - mill run, < 9.5% fbr | 91 | 15.6 | 14.0 | 2.74 | 2.36 | 69 | 0.45 | 0.23 |
| Oat straw | 93 | 4.6 | 0.9 | 2.00 | 1.60 | 45 | 0.24 | 0.09 |
| Soybean straw | 89 | 3.9 | 0.4 | 1.77 | 1.39 | 39 | 1.30 | 0.05 |
| Wheat straw | 92 | 3.1 | 0.9 | 1.97 | 1.57 | 45 | 0.21 | 0.07 |
| Corn Stover | 85 | 5.9 | 1.4 | 2.09 | 1.73 | 48 | 0.45 | 0.08 |
| Corn cobs | 90 | 2.5 | 0.8 | 1.89 | 1.51 | 42 | 0.11 | 0.04 |

**Source:** Seyoum and Zinash, 1989; Evaldsson, 1970; Ensminger et al., 1990

# Appendix 3. FEED COMPOSITION (Cont'd...)

| Feed name and description | Dry matter % | Protein | | Energy for small ruminants | | | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|---|
| | | CP (%) | Digestible protein (%) | DE (Mcal/Kg) | ME (Mcal/Kg) | TDN (%) | | |
| Hay | ?? | ?? | ?? | ?? | ?? | ?? | ?? | ?? |
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# Appendix 4. GLOSSARY OF TECHNICAL TERMS

**Additives:** Products other than those commonly called feedstuff and added to a feed mix in small quantities to fortify the basic mix and help fulfill a specific need.

***Ad libitum:*** Feeding system where animals are given unlimited access to feed. Synonymous terms include full feeding, free choice, self-feeding.

**Air- dry basis**: Expression of the composition of feedstuffs. This may be actual i.e. referring to feed that is dried by means of natural air movement in the open or an assumed dry matter content. Assumed to be 90% dry matter.

**Animal Protein**: Protein of animal origin derived from slaughterhouses, animal product processing plants that can be used as ingredients in feed mixtures.

**Appetite**: Desire to eat; could also be used to refer to the weight of feed dry matter consumed as a percentage of live weight.

**As fed:** refers to feed as normally fed to animals. The term "as collected" is used for materials which are normally not fed to animals i.e. faeces, urine.

**Average Daily Gain (ADG)**: The mean daily increase in the live weight of an animal.

**Balanced Daily Ration**: A combination of feeds fed at a time or in portions at intervals, as will provide the essential nutrients in such amounts as will properly nourish an animal for a 24-hour period.

**Balanced Ration**: A combination of feeds that provides essential nutrients in proper amounts and proportions to adequately nourish a particular animal.

**Blend:** A mixture, such that, the constituent parts are rendered indistinguishable from one another.

**Brand name**: Any word, name, symbol or any combination of these identifying the commercial feed of a distributor and distinguishing it from that of others.

**By-product feeds:** Secondary products from plant and animal processing and industrial manufacturing that may be used for animal feeding.

**Cake (press cake)**: Material resulting as a by-product from the processing of oil seeds to remove oil using the mechanical or expeller method.

**Calorie:** amount of heat energy required to raise the temperature of one gram of water from 14.5 to 15.5°C used as a measure of feed energy.

**Chaff:** Glumes, husks, or other feed covering together with other plant parts, separated from seed in threshing or processing.

**Commercial Feeds**: Feeds mixed by commercial feed manufacturers that specialize in the business as opposed to home mixing.

**Complete Ration**: All feedstuff (forages, grains, processed feeds etc.) combined in one feed mixture that is nutritionally adequate for a specific animal in a specific physiological state.

**Concentrate:** A class of feedstuff low in fiber (< 18% Crude Fiber)

**Crop- residue**: Portion of plant growth that remains after harvesting grain or seed crop e.g. Straws, stalks, husks, cobs etc.

**Decortication**: removal of the bark, hull, husk or shell from a plant seed or root.

**Deficiency:** Lack or shortage of one or more basic nutrients.

**Dehulled**: Outer covering removed from grains or other seeds.

**Diet:** Feed ingredient or mixture of ingredients including water regularly offered to or consumed by an animal.

**Digestibility**: The proportion of feed that is not excreted in the faeces and, thus, assumed to be absorbed.

**Digestion**: Process of changing food to a form that can be absorbed from the digestive tract by the body tissues (mainly the intestines).

**Dry matter basis**: an expression of the level of a nutrient contained in a feed on the basis that the material contains no moisture. Synonymous with 100% Dry matter basis, moisture free, Oven dry.

**Energy feeds**: feeds high in energy and low in fiber (< 18% Crude Fiber) e.g. Grains.

**Expeller process:** A process for the mechanical extraction of oil from oil seeds involving the use of a screw press.

**Feed (feedstuff)**: Any naturally occurring material suitable for feeding animals.

**Feed Additives:** Non-nutritive products that improve animal performance or preserve feeds.

**Feeding Standards**: Estimates of nutrient requirements for a specific function in a given environment.

**Feedlot**: A lot or plot of land on which animals are fed or finished for marketing.

**Fibrous Feed**: Feed high in cellulose and/ or lignin.

**Fodder:** Coarse feeds such as corn or Sorghum Stover.

**Forage**: Vegetative parts of plants fed to livestock in the fresh, dried or ensiled form.

**Formula Feed**: Feed mixture consisting of ingredients mixed and processed in specific proportions.

**Fortify**: Add one or more nutrients to a feed to improve it nutritionally.

**Free choice**: A feeding system by which animals are given unlimited access to the separate components or groups of components constituting the diet.

**Full Feed**: A situation where animals are being offered as much feed as they will consume safely without going off-feed.

**Hulls:** outer covering of dry grain or other seed, especially when dry.

**Ingredient:** Constituent feed of a feed mixture.

**Joule:** a measure of energy. It is the work done when a force of one Newton is applied through a distance of one meter. 4.184 Joules = 1calorie.

**Laxative:** Feed that induces bowl movement and relieves constipation.

**Maintenance ration**: The minimum amount of feed required to maintain the essential body processes at their optimum rate without gain or loss in body weight or change in body composition.

**Mash**: An expression of the physical form of a mixture of ingredients in the form of a meal.

**Meal**: An expression of the physical form of an ingredient that has been ground or otherwise reduced to a particle size somewhat larger than flour.

**Mechanically Extracted**: Fat extraction procedure from oil seeds by the application of heat and mechanical pressure.

**Metabolic Body Weight**: Measure of body size expressed as the body weight of the animal raised to the three-fourths power ($W^{0.75}$).

**Micro-ingredient**: Any ration component normally measured in milligrams or micrograms per kilogram or in parts per million (ppm) e.g. Trace minerals, vitamins.

**Nutrient:** Any chemical substance in feed that has specific functions in the nutritive support of animal life.

**Nutrient Requirements**: Minimum nutrient needs of animals without margins of safety for maintenance, growth, reproduction, lactation and work. Nutrient requirements plus a safety margin is called "nutrient allowance".

**Palatable Feed**: Feed that is well liked and is eaten with relish.

**Pellets**: Agglomerated feed formed by compacting and forcing the material through openings by a mechanical process.

**Plant proteins**: A category of feeds of plant origin high in their protein content e.g. Cottonseed meal, peanut meal etc. Also called vegetable protein.

**Premix**: A uniform mixture of one or more micro-ingredients (vitamins, trace minerals, amino acids, or medicine) and a diluent or carrier (or both) used to facilitate uniform distribution of the micro ingredients within a large mixture. Essential nutrients may sometimes be added to the water if they are water-soluble.

**Production Ration**: Additional allowance of ration for production over and above maintenance requirements.

**Protein Supplements**: Feedstuff that contain more than 20% protein or protein equivalent.

**Ration**: The total amount of feed or a mixture of feeds allotted to an animal for a 24-hour period with no reference to quantity or quality.

**Rolling:** Changing the shape and /or size of particles by compressing between rollers. It may entail tempering or conditioning.

**Roughage**: Feedstuff of plant origin that is high in Crude Fiber but low in digestibility and protein.

**Solvent Extraction**: a method of extracting oil from oil seeds using solvents.

**Steamed:** ingredients treated with steam to alter physical and/or chemical properties. Similar terms: steam cooked, steam rendered, tanked.

**Supplement:** A semi-concentrated source of one or more nutrients used to improve the nutritional value of a balanced ration e.g. Protein supplement, mineral supplement.

**Trace Mineral**: A mineral nutrient required by animals in micro amounts only.

# Appendix 5. LIST OF ABBREVIATIONS AND SYMBOLS

| Abbreviations/ symbols | Meanings |
|---|---|
| Abs. | Absolute |
| Ca | Calcium |
| Cal | Calories |
| CP | Crude Protein |
| DP | Digestible Protein |
| EE | Ether Extract |
| GE | Gross Energy |
| J | Joules |
| Kcal | Kilo calories |
| LWG | Live weight gain |
| Max | Maximum |
| Mcal | Mega calories |
| ME | Metabolisable Energy |
| Min | Minimum |
| MJ | Mega Joules |
| NDF | Neutral Detergent Fiber |
| NE | Net Energy |
| NEg | Net Energy gain |
| NEl | Net Energy lactation |
| NEm | Net Energy maintenance |
| NFE | Nitrogen free Extract |
| NRC | National Research Council |
| OM | Organic Matter |
| P | Phosphorus |
| ppm | Parts per million |
| TDN | Total Digestible nutrients |
| W | Weight |
| $W Kg^{0.75}$ | Metabolic body weight |