Beef Cattle Nutrition Series
Part 4: Formulating Rations

Shane Gadberry
Professor -
Animal Science

The final step of beef cattle nutrition is correcting nutrient deficiencies. The first approach to correct nutrient deficiencies is to establish an accurate description of the cattle being fed. This topic was discussed in *Establishing Nutritional Requirements* (FSA3079). Once an accurate description of the cattle is established, their nutrient requirements can then be determined from nutrient requirement tables.

The next step is to determine the feeds available for use. List their composition on a dry matter basis from a composition table or a chemical analysis. Now the amounts of the feeds necessary to balance the ration can be determined.

Three common methods to ration balancing include the Pearson Square, substitution formulation and computer-assisted formulation based on substitution or linear programming for least-cost formulation.

Pearson Square

The following example will help in understanding the first method used. The method illustrated is called a **Pearson Square**. A ration will be balanced for a 500-pound steer calf with a desired gain of two pounds per day. The calf is expected to weigh 1,200 pounds at finishing. The requirements are shown in Table 1 and also in *Nutrient Requirement Tables* (MP391), which is available at county Extension offices.

Feeds available and their composition are shown in Table 2. Energy or TDN will be the first nutrient balanced, as the greatest amount of feed goes to satisfy energy needs.

The animal requires a 68 percent TDN ration. To use the Pearson Square method, place the value 68 in the center of the square. Place the TDN values of fescue and shelled corn

Table 1. Nutrient Requirements for a 500-lb Steer (1,200 lb. at Finishing, ADG = 2.0) [1, 2]

Dry Matter	Protein		TDN		Calcium		Phosphorus	
lb	lb	%	lb	%	lb	%	lb	%
12.6	1.63	12.9	8.6	68	0.067	0.53	0.033	0.26

[1] Percentage of nutrient is based on percent of diet, dry matter basis.
[2] 1996 Nutrient Requirements of Beef Cattle

Table 2. Nutrient Composition of Various Feedstuffs, Dry Matter Basis

Feed	% Dry Matter	% TDN	% Protein	% Ca	% P
Fescue Hay	90	52	10.0	0.30	0.26
Shelled Corn	90	90	9.8	0.03	0.32
Soybean Meal	89	84	49.9	0.40	0.71

on the left diagonals of the square and subtract across the diagonal, **smallest number from largest**. Now, add the two numbers on the right-hand side of the square. These numbers mean that 22 parts of fescue and 16 parts of corn will give a 68 percent TDN mixture.

Fescue   52   22

$$68$$

Shelled 90   16
Corn   38

There are 38 total parts in the ration. Divide the two numbers on the right side of the square by the total to determine the preliminary percentage of fescue and corn in the ration.

Fescue $22 \div 38 = 0.58$ (58%)
Corn $16 \div 38 = 0.42$ (42%)

The next step is to calculate the percentage of crude protein in the fescue/shelled corn mixture and compare with the animal's requirement. If the requirement is met or exceeded, the ration is balanced. If the requirement is not met, protein supplementation and additional balancing are needed.

Determine the percentage of crude protein in the fescue/shelled corn mixture by multiplying the percentage of each ingredient in the mix by its percentage of crude protein. Add the two resulting values for the percentage of crude protein in the total mixture. For example, fescue is 58 percent of the mix and contains 10 percent crude protein. Shelled corn is 42 percent of the mix and contains 9.8 percent crude protein.

Fescue $0.58 \times 10.0 = 5.8\%$
Corn $0.42 \times 9.8 = 4.1\%$
                              9.9%

The crude protein content of the total mix is 9.9 percent (5.8 + 4.1 = 9.9%). The animal requires 12.9 percent crude protein in the ration. A deficiency of 3 percentage units (12.9 – 9.9 = 3%) exists, therefore protein supplementation is needed.

Use the square method to balance the fescue/shelled corn mix and soybean meal for a 12.9 percent crude protein mixture. Place 12.9 in the center and 9.9 and 49.9 on the left diagonals and subtract as before. Add the two figures on the right side of the square (37 + 3) to determine the total parts of the ration (40). Divide each number on the

right diagonal (37 and 3) by the total parts in the ration (40) to determine the percentage of the mixture composed of fescue and shelled corn (92.5%) and soybean meal (7.5%).

Fescue/Shelled Corn Mix

9.9   37 $37 \div 40 = 92.5\%$

$$12.9$$

Soybean Meal   3 $3 \div 40 = 7.5\%$
49.9   40

Now, determine the pounds of dry matter each feed ingredient contributes to the total. This is done by multiplying the pounds of daily dry matter consumed (12.6 from Table 1) by the percentage each ingredient contributes to the total. The protein supplement, in this case soybean meal, must be calculated first.

Daily dry matter intake	**x**	**% Soybean meal**	**=**	**Soybean meal dry matter**
12.6 pounds	x	0.075	=	0.95 pound

Next, determine the pounds of daily dry matter available for fescue and shelled corn by subtracting the pounds of protein supplement dry matter from the daily dry matter.

Daily dry matter intake	**–**	**Soybean meal dry matter**	**=**	**Pounds of fescue/ corn dry matter**
12.6 pounds	–	0.95	=	11.65 pounds

There are 11.65 pounds of dry matter composed of the fescue/shelled corn mixture.

To determine the individual pounds of fescue and shelled corn, multiply the pounds of dry matter composed of the fescue/shelled corn mixture by the percentage of fescue or shelled corn determined in the first square. Subtract this value from the total pounds of fescue/shelled corn dry matter to obtain the pounds of dry matter of the second ingredient.

Pounds of fescue dry matter:
$11.65 \times 0.58 = 6.76$ pounds of fescue dry matter

Pounds of shelled corn dry matter:
$11.65 – 6.76 = 4.89$ pounds of shelled corn dry matter

Each dry matter quantity must be converted to as-fed quantity to supply the correct amount of feed. This is done by dividing the pounds of dry matter by

the percent dry matter of the feed ingredient as shown in Table 2.

Fescue = 6.76 ÷ 0.90 = 7.51 pounds as fed
Shelled Corn = 4.89 ÷ 0.90 = 5.43 pounds as fed
Soybean Meal = 0.95 ÷ 0.89 = 1.07 pounds as fed

Thus, the daily ration for this steer becomes 7.51 pounds of fescue, 5.43 pounds of shelled corn and 1.07 pounds of soybean meal.

Determine the calcium and phosphorus supplied by each ingredient and compare to the daily requirements to decide if a mineral supplement is needed. This is done by multiplying the dry matter pounds of each feed in the ration by its calcium and phosphorus content (Table 2) and adding the results. The results are compared to the animal's needs; then an excess or deficiency can be determined.

Pounds of feed dry matter	x % Ca	=	lb Ca
Fescue	6.76 x 0.003	=	0.020
Shelled Corn	4.89 x 0.0003	=	0.001
Soybean Meal	0.95 x 0.0040	=	0.004
		Total	0.025

Pounds of feed dry matter	x % P	=	lb P
Fescue	6.76 x 0.0026	=	0.018
Shelled Corn	4.89 x 0.0032	=	0.016
Soybean Meal	0.95 x 0.0071	=	0.007
		Total	0.041

Calcium need – intake = excess or deficiency
0.067 – 0.025 = 0.042 deficiency

Phosphorus need – intake = excess or deficiency
0.033 – 0.041 = 0.008 excess

Phosphorus level of the ration is adequate, but a deficiency of calcium exists. Minerals are supplied by free-choice supplementation with commercial mineral supplements or formulated into the ration. A Pearson Square solution with multiple ingredients is not always this simple or precise. For example, if corn gluten feed was the supplemental protein source, balancing first for protein using corn gluten feed would result in a 0.13 pound per day deficiency in protein, while balancing first for TDN using corn would result in a 0.27 pound per day surplus of TDN.

Substitution Method

A second method of ration balancing may simply be termed **substitution method**. In this method, a ration is estimated, and the nutrient content calculated. These results are then compared to the nutrient needs of the animal for which the ration is being balanced. Deficiencies are corrected by changing proportions of feeds in the rations or by substituting or adding ingredients.

Knowledge of animal nutrient requirements, feeds available and their nutrient composition are still necessary. For this example, a 1,100-pound lactating cow (2 months since calving, 10 lb peak milk) will be used. Her nutrient requirements are shown in Table 3. The same feeds as in the previous example will be used. See their nutrient composition in Table 2.

Since hay is the main source of nutrients for most cows, this example will assume that all of the dry matter being consumed is coming from fescue hay. This means the cow is eating 26 pounds of actual fescue hay daily (lb of dry matter 23.5 divided by the percentage of dry matter 0.90 equals 26 pounds).

Next, calculate the nutrients supplied by fescue and compare them to the cow's need. The nutrients supplied are determined by multiplying the pounds of dry matter of the feed consumed by the feed's nutrient content on a dry matter basis. In this example, fescue supplies 12.2 pounds of TDN, 2.35 pounds of crude protein, 0.071 pound of calcium and 0.061 pound of phosphorus. A comparison with nutrient needs shown in Table 3 reveals an energy deficiency of 1 pound of TDN.

Adding corn grain is necessary for extra energy. We cannot simply add corn because the daily dry matter intake could be exceeded and cattle might not be able to consume this amount. Corn must be substituted for fescue. This means we will gain nutrients from corn, but we will also lose nutrients from the fescue. The net effect of substituting corn for fescue must be determined.

Table 3. Nutrient Requirements for a 1,100-lb Mature Lactating Cow (2 months since calving, 10 lbs Peak Milk)[1, 2]

Dry Matter lb	Protein lb	%	TDN lb	%	Calcium lb	%	Phosphorus lb	%
23.5	2.10	8.9	13.2	56.3	0.060	0.25	0.040	0.17

[1] Percentage of nutrients is based on percent of diet, dry matter basis.
[2] 1996 Nutrient Requirements of Beef Cattle.

One pound of fescue dry matter contains 0.52 pound of TDN while one pound of corn dry matter contains 0.90 pound of TDN. The net effect of replacing 1 pound of fescue dry matter with 1 pound of corn dry matter is a gain of 0.38 pound of TDN (0.90 – 0.52 = 0.38).

A deficiency of 1 pound of TDN exists. Dividing the pounds of nutrient deficiency by the pounds of nutrient net gain by substituting corn for fescue will tell us the pounds of dry matter to substitute. For example:

$$\frac{1 \text{ pound TDN needed}}{0.38 \text{ pound TDN net gain}} = \begin{array}{l} 2.6 \text{ pounds of corn dry matter} \\ \text{substituted for 2.6 pounds} \\ \text{of fescue dry matter} \end{array}$$

Now the ration is 20.9 pounds of fescue dry matter and 2.6 pounds of shelled corn dry matter.

Calculate the nutrients supplied by the substituted ration and compare to the cow's nutrient need. The comparison is shown in Table 4. As can be seen, all nutrient needs are met or exceeded. The ration is adequate for the nutrients desired.

Now, convert pounds of dry matter to pounds as-fed as done for the previous ration. Divide pounds of dry matter by percent dry matter. Thus the daily ration actually fed becomes 23.2 (20.9 ÷ 0.90) pounds of fescue and 2.9 (2.6 ÷ 0.90) pounds of shelled corn. In most cases, hay will be fed free choice with actual intake unknown. Corn, however, will be supplemented daily at the calculated intake rate.

Computer Assisted Formulation

Most spreadsheet based computer programs that are used to formulate rations use the substitution methodology. There are several advantages to utilizing a computer program for ration balancing. Some programs generate the nutrient requirements after entering the animal description; therefore, looking up nutrient requirements from a table is not required. Computer programs also provide a list of feed ingredients and standard values for nutrient composition. Computer programs show the balance of all nutrients simultaneously. This eliminates the additional time involved in balancing and rechecking each individual nutrient, and allows for easier balancing of rations containing several feed ingredients. Formulas are built into the program, so mathematical mistakes are also eliminated.

Animals will gain more efficiently and economically with a balanced ration. By using these guidelines, you should be able to balance rations that will meet the needs of most farm animals.

Table 4. Nutrient Content of the Substituted Ration and Comparison with Requirements

Feed		Dry Matter (lb)	TDN (lb)	Crude Protein (lb)	Calcium (lb)	Phosphorus (lb)
Fescue Hay		20.9	10.87	2.09	0.063	0.054
Shelled Corn		2.6	2.34	0.25	- - -	0.008
	Total	23.5	13.21	2.34	0.063	0.062
Animal Requirements		23.5	13.2	2.10	0.060	0.040

Complementary Publications

Composition of Some Beef Cattle Feeds (FSA3043)
Alternative Feeds for Beef Cattle (FSA3047)

Beef Cattle Nutrition Series Publications

Part 1. Nutrient Basics (FSA3078)
Part 2. Establishing Nutritional Requirements (FSA3079)
Part 3. Nutrient Requirement Tables (MP391)
Part 4. Formulating Rations (FSA3080)

Printed by University of Arkansas Cooperative Extension Service Printing Services.

SHANE GADBERRY, Ph.D., is professor - animal science, University of Arkansas System Division of Agriculture, Department of Animal Science, Little Rock.