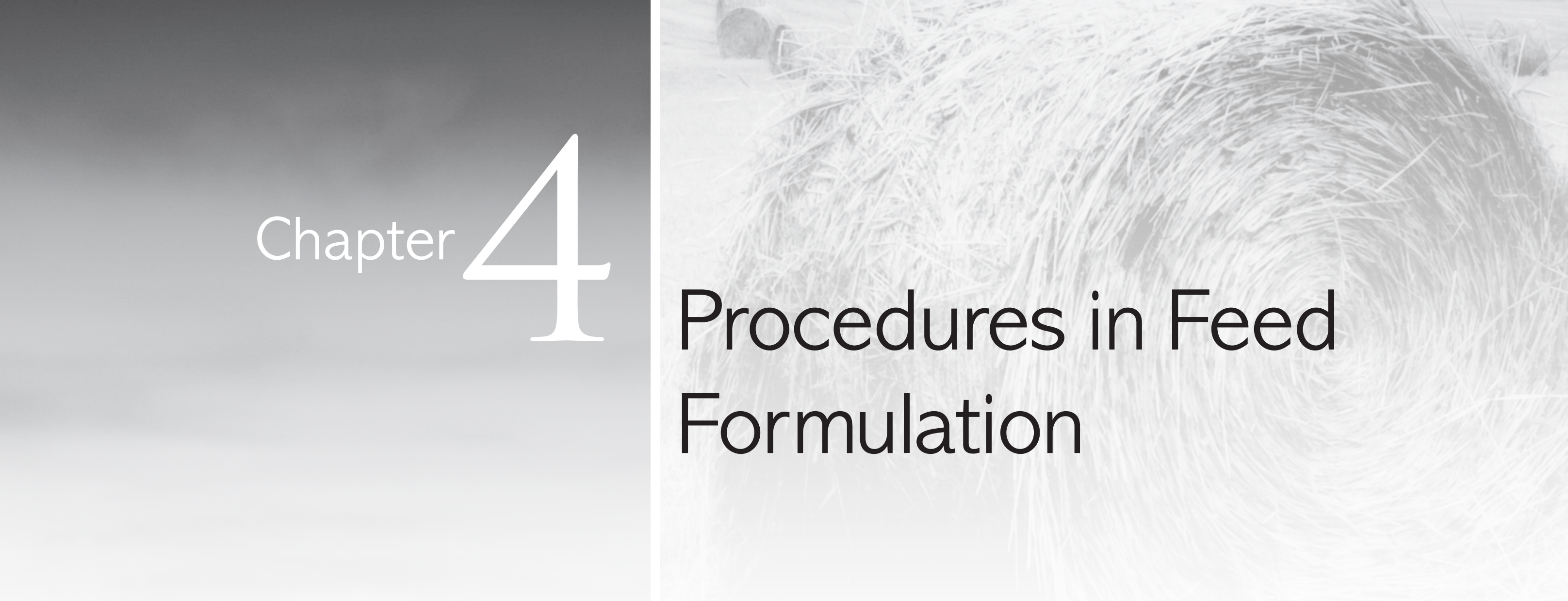

Chapter 4 Procedures in Feed Formulation

CHAPTER GOALS

- Examine feeding standard tables for various livestock.
- Describe and discuss mathematical solutions to animal diet formulation (algebra, Pearson square, substitution).
- Define the purpose of a premix and how these can be formulated to incorporate into animal diets.

I. Balancing Rations to Meet Daily Nutrient Requirements of Animals

A. *Materials Needed*

1. Nutrient requirement data from available sources
   a. National Research Council (NRC) requirement tables. These are available by species.
   b. University research and extension publications.
2. Feed analysis data from available sources
   a. National Research Council.
   b. University research and extension publications.
   c. Commercial publications (several firms publish feed analysis tables).
   d. Online databases from commercial laboratories that perform feed analysis.

B. *Procedural Outline to Follow*

1. Consult any available texts or guides for developing rations and feeding programs for the animals involved. Must know species, productive function (lactating, pregnant, etc.), age, and body weight.
2. Prepare a listing of the requirements of all nutrients to be considered.
3. Determine the feedstuffs available for the program and consult available material about the use of these feeds in the program planned. Remember that different feeds may have different feed value for different classes of animals.
4. Prepare a listing of the nutrient composition of the feeds to be used. You may need to consult several sources to cover all nutrients of interest.
5. Proceed to balance the ration, using guides for dry matter, crude or digestible protein and energy (TDN or other). Use the upper limit of the suggested dry matter intake as a general guide for estimated total dry feed allowance.
6. Check ration for other nutrients such as calcium, phosphorus and vitamins. You may need to add concentrated sources of vitamins and minerals to complete the requirement.

7. If the ration is complete ask the following questions
   a. Have all deficiencies been corrected?
   b. Are excesses present?
   c. Is the ration palatable and physically feasible to feed the animal?
   d. Does this appear to be the most economical combination of feeds?
   e. What is the cost of the ration per pound or ton, or what does it cost to feed this animal daily?
   f. What will be needed in addition? (free-choice salt, mineral, etc.)

II. Simple Techniques in Ration Formulation

The techniques presented here will allow formulation of simple mixtures on the basis of a single nutrient (protein). These techniques can also be used with other procedures to accomplish more complex formulations of complete rations. Our approach shall be to first learn the techniques as applied to simple formulations and then apply variations that will allow their application to more complex formulations.

A. *Using Two Feed Sources*

Formulate 100 lbs. of a complete swine diet containing 16% crude protein (CP). The feeds to be used are corn (8.9% CP) and a commercial supplement containing 36% CP.

1. Algebraic equations—a system of two equations in two unknowns
   a. Mathematical procedure

$$
\begin{array}{lrcl}
 & X & = & \text{lbs. corn} \\
 & Y & = & \text{lbs. supplement} \\
\text{equation (1)} & X + Y & = & 100 \text{ lbs. diet} \\
\text{equation (2)} & 0.089X + 0.360Y & = & 16.0 \text{ lbs. protein (16\% of 100 lbs.)}
\end{array}
$$

A third equation is developed to subtract from equation (2) in order to cancel either X or Y; equation (3) is developed by multiplying everything in equation (1) by a factor of 0.089, thus

$$
\begin{array}{lrcrcr}
\text{equation (2)} & 0.089X & + & 0.360Y & = & 16.0 \\
\text{(subtract) equation (3)} & \underline{-0.089X} & - & \underline{0.089Y} & = & \underline{-8.9} \\
 & 0 & & 0.271Y & = & 7.1
\end{array}
$$

$$Y = \frac{7.1}{0.271} = 26.2 \text{ (lbs. supplement)}$$

Replace Y with 26.2 in equation 1: $X = 100 - 26.2 = 73.8$ (lbs. corn)

   b. Check

$$
\begin{array}{lcl}
73.8 \text{ lbs. corn} \times 8.9\% \text{ CP} & = & 6.57 \text{ lbs. CP} \\
\underline{26.2} \text{ lbs. supplement} \times 36.0\% \text{ CP} & = & \underline{9.43} \text{ lbs. CP} \\
100.0 \text{ lbs. diet} & & 16.00 \text{ lbs. CP}
\end{array}
$$

2. Pearson square—another technique to accomplish the same objective
   a. Place the percent protein desired in the combination of the two feeds in the center of a square and the percent protein content of each feed at the left corners.

Corn	8.9%		20.0 parts corn
		16%	
Supplement	36.0%		7.1 parts supplement
			27.1 total parts

b. Subtract diagonally across the square, the smaller number from the larger without regard to sign and record the difference at the right corners.

c. The parts of each feed can be expressed as a percent of the total, and these percentages can be applied to any quantity.

$$\frac{20.0 \text{ parts corn}}{27.1 \text{ total parts}}(100) = 73.8\% \text{ corn and}$$

$$\frac{7.1 \text{ part supplement}}{27.1 \text{ total parts}}(100) = 26.2\% \text{ supplement}$$

73.8% × 100 lbs. = 73.8 lbs. corn
26.2% × 100 lbs. = 26.2 lbs. supplement

d. Check

73.8 lbs. corn	× 8.9% CP =	6.57 lbs. CP
26.2 lbs. supplement	× 36.0% CP =	9.43 lbs. CP
100.0 lbs. diet		16.00 lbs. CP

e. Precautions about using the Pearson square

(1) It can only be used for two feed materials; however, either or both of these can be mixtures as long as the percentage of the nutrient of interest has been determined for the mix.

(2) The number in the center of the square must be intermediate to the two numbers at the left corners. For example, any combination of a 8.9% protein corn and a 36% protein supplement would have to have a protein content between 8.9% and 36%. Always check this because the Pearson square will give an answer if the number in the center is not intermediate to the other two even though such an answer is incorrect. This precaution also applies to algebraic equations.

(3) The requirement must be expressed as a percent or proportion and can be used for any nutrient or expression of energy, e.g., percent protein, percent Ca, percent TDN, Mcal/lb., etc.

B. *Using Three or More Feed Sources*

Prepare 100 lbs. of diet containing 12% protein from a mixture of soybean meal (SBM) and tankage (3 parts SBM and 1 part tankage) with corn. Assume corn to contain 9.0% protein, SBM to contain 44% protein and tankage to contain 60% protein.

1. First, we must arrive at a weighted average protein percent for those ingredients that are most similar in protein content. In this case, the 3:1 mixture of SBM and tankage.

3 parts SBM	× 44% prot. =	1.32 parts protein
1 part tankage	× 60% prot. =	0.60 parts protein
4 parts mix		1.92 parts protein

$$\frac{1.92 \text{ parts protein}}{4 \text{ parts mix}}(100) = 48\% \text{ protein}$$

2. Now, the Pearson square can be used as before

Corn	9.0%		36.0	$\frac{36}{39}(100) = 92.31\%$ corn
		12.0%		
Mix	48.0%		3.0	$\frac{3}{39}(100) = 7.69\%$ mix
			39.0	

a. In 100 lbs. this means

92.31% × 100 lbs. = 92.31 lbs. corn
7.69% × 100 lbs. = 7.69 lbs. mix

b. The 7.69 lbs. mix must be divided into ¾ (75%) SBM and ¼ (25%) tankage, which complies with the initial proportions of each feed. Thus

c. Check

92.31 lbs. corn	× 0.09 =	8.31	lbs. protein
5.77 lbs. SBM	× 0.44 =	2.54	lbs. protein
1.92 lbs. tankage	× 0.60 =	1.15	lbs. protein
100.00 lbs. diet		12.00	lbs. protein

3. Algebraic equations could also be used to solve this problem

X = lbs. corn
Y = lbs. mix (3:1 mixture of SBM:tankage)

$$\begin{aligned} &1)\quad X + Y = 100.0 \\ &2)\quad 0.09X + 0.48Y = 12.0 \\ &3)\quad -0.09X - 0.09Y = -9.0 \\ &\qquad\quad 0 \quad\; 0.39Y = 3.0 \end{aligned}$$

$$Y = \frac{3.0}{0.39} = 7.69 \text{ lbs. mix}$$

$$X = 100 - 7.69 = 92.31 \text{ lbs. corn}$$

C. *Using Fixed Ingredients*

Prepare 1000 lbs. of diet from corn (8.9% CP), SBM (46% CP) and fixed ingredients totaling 10% of the diet (e.g., salt, limestone, dicalcium phosphate, trace mineral premix, vitamin premix, etc.). The final diet should contain 14% CP. Assume no protein content in the fixed ingredients.

1. Use of Pearson square

a. Find percent protein to use in center of square

(1) The nonfixed portion (corn-SBM combination) is 900 lbs. (1000 lbs. × 90%) and will have to supply all the protein (1000 × 14% = 140 lbs. protein).

(2) To do this by the Pearson square method, it is first necessary to calculate what percent protein will be needed in the corn-SBM combination to provide 140 lbs. of protein per 900 lbs., as follows

$$\frac{140}{900}(100) = 15.56\% \text{ CP}$$

b. This figure (15.56%) is then used in conjunction with the Pearson square as follows

Corn	8.9%		30.44 parts corn	$\frac{30.44}{37.10}(100) = 82.05\%$
		15.56%		
SBM	46.0%		$\frac{6.66}{37.10}$ parts SBM	$\frac{6.66}{37.10}(100) = 17.95\%$

900 lbs. × 82.05% = 738.45 lbs. corn
900 lbs. × 17.95% = 161.55 lbs. SBM

c. Check

738.45 lbs. corn	×	8.9%	=	65.72 lbs. protein
161.55 lbs. SBM	×	46.0%	=	74.31 lbs. protein
100.00 lbs. fixed	×	0	=	0
1000.00 lbs. ration			=	140.03 lbs. protein

2. Use of algebraic equations for the same problem

$$X = \text{lbs. corn}$$
$$Y = \text{lbs. SBM}$$

$$\begin{array}{lrcrcl} 1) & X & + & Y & = & 900.0 \text{ lbs. corn-SBM} \\ 2) & 0.089X & + & 0.460Y & = & 140.0 \text{ lbs. CP} \\ 3) & -0.089X & - & 0.089Y & = & -80.1 \\ \hline & 0 & & 0.371Y & = & 59.9 \end{array}$$

$$Y = \frac{59.9}{0.371} = 161.5 \text{ lbs. SBM}$$

$$X = 900 - 161.5 = 738.5 \text{ lbs. corn}$$

3. If any of the fixed ingredients contain protein, the amount contributed to the diet is calculated and then subtracted from total quantity needed before formulation by either Pearson square or algebra. Assume the following example. Formulate 1 ton (2000 lbs.) of broiler diet to contain 20.0% crude protein using the following ingredients

Feedstuff	**Amount, lbs.**
Ground corn (9.0% CP)	?
SBM (44% CP)	?
Meat and bone meal (50% CP)	100.0
Fish meal (65% CP)	40.0
Alfalfa meal, dehydrated (17.5% CP)	40.0
Mineral premix (0% CP)	30.0
Vitamin premix (0% CP)	20.0
TOTAL	2000.0

a. Determine the total amount of crude protein needed in the formulation.

2000 lbs. diet × 0.20 = 400 lbs. CP needed

b. Determine the amount of ingredients fixed and the amount of crude protein they contribute.

Fixed ingredients				
Meat and bone meal	100.0 lbs.	× 0.50	=	50.0 lbs. CP fixed
Fish meal	40.0 lbs.	× 0.65	=	26.0 lbs. CP fixed
Alfalfa meal, dehydrated	40.0 lbs.	× 0.175	=	7.0 lbs. CP fixed
Mineral premix	30.0 lbs.	× 0	=	0
Vitamin premix	20.0 lbs.	× 0	=	0
	230.0 lbs. feed			83.0 lbs. CP

Thus, 2000.0 lbs. − 230.0 lbs. fixed = 1770.0 lbs. nonfixed (corn-SBM).
400.0 lbs. − 83.0 lbs. fixed = 317.0 lbs. CP needed from nonfixed.

c. Solve by algebra.

$$
\begin{array}{rrcl}
 & X & = & \text{lbs. corn} \\
 & Y & = & \text{lbs. SBM} \\
1) & X + \quad Y & = & 1770.0 \text{ lbs. corn-SBM} \\
2) & 0.09X + 0.44Y & = & 317.0 \text{ lbs. CP} \\
3) & \underline{-0.09X} - \underline{0.09Y} & = & \underline{-159.3} \\
 & 0 \qquad 0.35Y & = & 157.7
\end{array}
$$

$$Y = \frac{157.7}{0.35} = 450.6 \text{ lbs. SBM}$$

$$X = 1770.0 - 450.6 = 1319.4 \text{ lbs. corn}$$

d. Solve by Pearson square.

(1) The nonfixed portion (corn-SBM combination) is 1770.0 lbs. and will have to supply the remaining 317.0 lbs. CP not contributed by the fixed ingredients (400.0 − 83.0 = 317.0)

(2) To do this by the Pearson square, it is first necessary to calculate what percent CP will be needed in the corn-SBM combination to provide the 317.0 lbs. of protein per 1770.0 lbs., as follows

$$\frac{317.0}{1770.0}(100) = 17.91\% \text{ CP}$$

(3) This figure (17.91% CP) is then used in conjunction with the Pearson square as follows

Corn	9.0%		26.09 parts corn	$\frac{26.09}{35.00}(100) = 74.54\%$
		17.91%		
SBM	44.0%		$\frac{8.91}{35.00}$ parts SBM	$\frac{8.91}{35.00}(100) = 25.46\%$

1770.0 × 74.54% = 1319.4 lbs. corn
1770.0 × 25.46% = 450.6 lbs. SBM

(4) Check

1319.4 lbs. corn × 9.0% CP	=	118.75
450.6 lbs. SBM × 44.0% CP	=	198.26
230.0 lbs. fixed ingredients	=	83.00
2000.0 lbs. diet		400.01 lbs. CP

D. *Substitution Method*

A process of substituting amount of one ingredient for that amount of another or of substituting in a new ingredient.

1. Example of an original formulation

Ingredient	**Amount, lbs.**	**% CP**	**CP, lbs.**
Smooth brome hay	60.0	6.0	3.60
Ground corn	33.0	9.0	2.97
SBM	7.0	46.0	3.22
	100.0	Total	9.79

2. Assume you want to increase the crude protein content to 13% by substituting SBM for corn. Rather than using a trial-and-error approach, establish a one for one substitution

   Add in 1 lb. SBM = +0.46 lbs. CP
   Remove 1 lb. corn = −0.09 lbs. CP
   Net change in protein = +0.37 lbs. CP

3. Since you want to increase from 9.79–13% CP, you will need 3.21 lbs. (13.0 − 9.79) additional protein in each 100-lb. mixture.
4. Thus, if each one for one substitution increases CP by 0.37 lbs., then

   $\frac{3.21}{0.37}$ = 8.68 lbs. SBM needed to substitute for 8.68 lbs. corn

5. The revised formulation follows

Ingredient	**Amount, lbs.**	**% CP**	**CP, lbs.**
Smooth brome hay	60.00	6.0	3.60
Ground corn	24.32	9.0	2.19
SBM	15.68	46.0	7.21
	100.00	Total	13.00

6. Another possible substitution would be to replace some of the low protein containing brome hay (6% CP) with a high protein content alfalfa hay (16% CP). This substitution would cause a less drastic change in the energy value of the formulation.
   a. Add in 1 lb. alfalfa hay = 10.16 lbs. CP
      Remove 1 lb. brome hay = −0.06 lbs. CP
      Net change in protein = +0.10 lbs. CP
   b. Thus, if each one for one substitution increases CP by 0.10 lbs., then

      $\frac{3.21}{0.10}$ = 32.1 lbs. alfalfa hay to substitute for 32.1 brome hay

   c. This revised formulation follows

Ingredient	**Amount, lbs.**	**% CP**	**CP, lbs.**
Smooth brome hay	27.9	6.0	1.67
Alfalfa hay	32.1	16.0	5.14
Ground corn	33.0	9.0	2.97
SBM	7.0	46.0	3.22
	100.0	Total	13.00

E. *Simultaneous Algebraic Equations*

Useful in calculating what combination of two feeds (or two feed groups) will provide the required amount of each of two different nutrients.

1. Assume you want to determine the amounts of corn and SBM needed to meet the daily requirements of CP and metabolizable energy (ME) for a 27.3-kg (60-lb.) pig.
2. Requirements and feed composition

	CP	**ME**
27.3 kg pig daily requirement	0.272 kg	5390 kcal
Corn	9.0%	3275 kcal/kg
SBM	46.0%	2825 kcal/kg

3. Mathematical procedure

   X = kg corn
   Y = kg SBM

   Protein equation (1) $0.09X + 0.46Y = 0.272$ kg CP
   Energy equation (2) $3275X + 2825Y = 5390$ kcal ME

   As discussed previously, a third equation is developed to subtract from equation (2) to cancel either X or Y; equation (3) is developed by multiplying everything in equation (1) by a factor of 36,388.89 (3275 = 0.09), thus

$$
\begin{array}{lrcrcr}
\text{equation (2)} & 3275X & + & 2825Y & = & 5390 \\
\text{(subtract) equation (3)} & \underline{-3275X} & - & \underline{16{,}739Y} & = & \underline{-9898} \\
 & 0 & - & 13{,}914Y & = & -4508
\end{array}
$$

$$Y = \frac{-4508}{-13{,}914} = 0.324 \text{ (kg SBM)}$$

   Then solve for X

$$
\begin{array}{ll}
\text{equation (1)} & 0.09X + 0.46Y = 0.272 \\
 & 0.09X + (0.46)(0.324) = 0.272 \\
 & 0.09X + 0.149 = 0.272 \\
 & 0.09X = 0.123 \\
 & X = \dfrac{0.123}{0.09} = 1.367 \text{ (kg corn)}
\end{array}
$$

4. Check

$$
\begin{array}{l}
1.367 \text{ kg corn} \times 9\% \text{ CP} = 0.123 \text{ kg CP} \\
0.324 \text{ kg SBM} \times 46\% \text{ CP} = \underline{0.149} \text{ kg CP} \\
\qquad\qquad\qquad\qquad 0.272 \text{ kg CP}
\end{array}
$$

$$
\begin{array}{lr}
1.367 \text{ kg corn} \times 3275 \text{ kcal/kg} = & 4477 \\
0.324 \text{ kg SBM} \times 2825 \text{ kcal/kg} = & \underline{915} \\
 & 5392 \text{ kcal ME}
\end{array}
$$

5. The above amounts of corn and SBM could then be used as the basis for formulating a dietary mixture for 27.3-kg (60-lb.) pigs

	Daily kg	**% of Diet**	**lbs. per Ton**
Corn	1.367	80.84	1616.8
SBM	0.324	19.16	383.2
Total	1.691	100.00	2000.0

6. To produce a properly balanced mixture, this diet should be supplemented with a vitamin–mineral supplement.

III. Formulating Vitamin Premixes

A. *Premixes are mixtures of microingredients and some type of carrier material*
They are added to feeds at the time of mixing to ensure uniform distribution of these ingredients in mixed feeds.

B. *Commonly used carriers*

1. Soybean meal.
2. Ground grain.
3. Corn gluten meal.
4. Wheat middlings.
5. Several other mill feeds.

C. *A vitamin A and D premix could have these ingredients*

1. Carrier.
2. Vitamin A concentrate.
3. Vitamin D concentrate.

D. *Development of a vitamin A premix for beef cattle*

Objective: Prepare 100 lbs. of a vitamin A premix to be used at a rate of 20 lbs./ton of beef cattle supplement that is to contain 10,000 IU of vitamin A per pound. The vitamin A concentrate selected contains 2 million IU/gram. Soybean (SBM) will be used as a carrier.

1. Sufficient premix is being prepared to mix 5 tons of supplement; thus

   5×2000 lbs. $=$ 10,000 lbs. of finished supplement.

2. The supplement is to contain 10,000 IU/lb. then

   10,000 IU $\times$ 10,000 lbs. $=$ 100,000,000 IU required in total.

3. The amount of vitamin A concentrate required is

   $$\frac{100{,}000{,}000 \text{ IU}}{2{,}000{,}000 \text{ IU/g}} = 50 \text{ g}$$

4. 50 g = 0.11 lbs. of vitamin A concentrate $\left(\frac{50}{454} = 0.11\right)$

5. The final premix formula is

Vitamin A concentrate (50 g)	0.11 lbs.
Carrier (SBM)	99.89 lbs.
Total	100.00 lbs.

6. The premix may now be packaged in 20-lb. bags and one used for each ton of finished supplement prepared.

E. *Development of a B-vitamin–antibiotic premix for a swine diet*

Objective: Prepare a premix to be added at a rate of 10 lbs./ton of growing-finishing swine diet.

Nutrients or Medicants to Be Added	Concentration of Source	Level/lbs. of Diet to Be Supplied by Premix	Total Nutrient Required per Ton of Diet	Quantity of Source
Riboflavin	Pure	1.5 mg	3.0 g	3.0 g
Pantothenic acid	Pure	2.5 mg	5.0 g	5.0 g
Niacin	Pure	6.0 mg	12.0 g	12.0 g
B_{12}	20 mg/lb.	0.005 mg	10.0 mg	227.0 g
Antibiotic	Pure	10.0 mg	20.0 g	20.0 g

Final premix formula:

Riboflavin	3.0 g	
Pantothenic acid	5.0 g	
Niacin	12.0 g	267 g or 0.59 lbs.
B_{12} premix	227.0 g	
Antibiotic	20.0 g	
Carrier (SBM)		9.41 lbs.
Total		10.00 lbs.

If it is desired to prepare this in large quantities, the above formula can be used by multiplying values by the factor desired.

IV. Formulating Trace Minerals Premixes

A. *In formulating trace mineral premixes, the compounds selected as sources of certain elements will contain other elements as well.*

Atomic weights and formula weights of compounds will permit determination of the concentration of the element in the source material if the formula is known. Generally, the supplier furnishes a guaranteed analysis of the mineral content and this is then used in the formulation.

B. *Mineral compounds may also be variable with respect to water of hydration.*

This must be known to arrive at the correct formula weight. For example, iron sulfate might be one of the following forms

	Molecular Wt	Percent Iron
$FeSO_4.H_2O$	169.92	32.87
$FeSO_4.4H_2O$	223.96	24.94
$FeSO_4.7H_2O$	278.01	20.09

(% calculations based on atomic wt of 55.85 for Fe)

C. *Development of a Trace Mineral Premix*

Objective: Prepare a trace mineral premix to be used at the rate of 10 lbs./ton of beef cattle supplement. Ground limestone is to be used as a carrier.

Source	Atomic Wt	Formula Wt	% Element
$MnSO_4$	54.94 (Mn)	151.00	36.38 Mn
$CuSO_4$	63.54 (Cu)	159.60	39.81 Cu
$CoSO_4.H_20$	58.93 (Co)	172.99	34.01 Co
$FeSO_4.7H_2O$	55.85 (Fe)	278.01	20.10 Fe
$ZnSO_4$	65.37 (Zn)	161.43	40.49 Zn

Level to Be Added per lbs. of Supplement		Total Nutrient Needed per Ton (grams)		Quantity of Source (grams)
Mn	15.0 mg	30 g		82.46
Cu	5.0 mg	10 g		25.12
Co	0.5 mg	1 g		2.93
Fe	15.0 mg	30 g		149.25
Zn	5.0 mg	10 g		24.70
			Total	284.46 g (0.63 lbs.)

Final premix

Trace mineral sources	284.46 g or		0.63 lbs.
Ground limestone carrier			9.37 lbs.
		Total	10.00 lbs.

This premix would be used to mix 1 ton of supplement. If it is desired to prepare enough premix for several tons of supplement, the above values can be increased as appropriate. Note that the use of ground limestone as the carrier will increase the calcium content of the ton of supplement approximately 0.15%.

V. Formulating a Complete Supplement

A. A *procedure outlined for formulating a complete ration (II, previously) can be used for this purpose.*

B. *Example Procedure*

1. Establish the feed to be supplemented with the formula to be prepared. Assume the animal in this case is a 1000- to 1100-lb. beef cow (dry) being wintered on weathered bluestem grass.

2. Estimate intake of the feed to be supplemented. The following intake estimates for beef cows are usually made

Type of Roughage	Estimated Dry Matter Intake (% of Body Wt)
Low-grade (dry grass, straw, etc.)	1.5
Average-grade (nonlegume hay)	2.0
High-grade (legume hays, green pasture, etc.)	2.5

3. Determine nutrient deficiencies that must be met by determining the amount of nutrients supplied by estimated intake of the feed to be supplemented.

	CP lbs.	TDN lbs.	Ca lbs.	P lbs.	Vitamin A IU
Requirement, 1100-lb. cow (dry)	0.97	8.4	0.026	0.026	20,000
Nutrients supplied by 16.5 lbs. of dry bluestem pasture	0.74	10.2	0.066	0.018	0
Deficiency	0.23	—	—	0.008	20,000

4. Establish the specification for the supplement from the deficiencies above.

	Daily Deficiency	Amount Needed per lb. of Supplement	Specifications for Supplement
Crude protein	0.23 lbs.	0.23 lbs.[1]	23%
Phosphorus	0.008 lbs.	0.008 lbs.	0.8%
Vitamin A	20,000 IU	20,000 IU	20,000 IU/lb.

5. Using the above specifications in formulating the supplement

Example: Assume the supplement will contain 5.0% dehydrated alfalfa meal and 5.0% liquid molasses and that the following ingredients will be used to complete the formula.

Milo grain, ground

SBM (50% CP)

Dicalcium phosphate (27% calcium, 19% phosphorus)

Vitamin A concentrate (40,000 IU per g)

The "fixed portion" of the formula, and the amount of protein furnished by it, is

Ingredient	% in Formula	Crude Protein: % in Ingredient	Crude Protein: % Furnished
Alfalfa meal	5.0	17.0	0.85 (17.0% × 5.0)
Molasses	5.0	4.3	0.21 (4.3% × 5.0)
	10.0		1.06

Thus:

23.0% − 1.06 = 21.94 protein to be furnished by 90.0% of the formula (100.0% − 10.0%).

The combination of soybean meal and milo must contain 24.4% protein. (21.94 ÷ 90.0%).

[1] Missing nutrients to be supplied by 1 lb. of mixed supplement daily.

The "square" procedure can be used to calculate the proportions of SBM and milo needed

			Parts	%
SBM	50% CP		15.4	37.5
		24.4%		
Milo	9% CP		25.6	62.5
			41.0	100.0

The square is set up by placing the percent protein of the two feeds at the two left corners and the percent protein needed in the mixture of the two feeds in the center. Solve by subtracting diagonally. The resulting figures show that 15.4 parts SBM with 25.6 parts milo will provide a mixture containing 24.4% protein. Convert proportions to percentages (25.6 ÷ 41.0 = 62.5%; 15.4 ÷ 41.0 = 37.5%) and multiply the answers by 90.0 to find percent SBM meal and percent milo needed in the formula:

62.5% × 90.0 = 56.3% milo

37.5% × 90.0 = 33.7% SBM

The tentative supplement, and its content of protein and phosphorus is

		Crude Protein		**Phosphorus**	
Ingredient	**% in Formula**	**% in Ingredient**	**% Furnished**	**% in Ingredient**	**% Furnished**
Alfalfa meal	5.0	17.0	0.85	0.26	0.013
Molasses	5.0	4.3	0.21	0.08	0.004
SBM	33.7	50.0	16.85	0.63	0.212
Milo	56.3	9.0	5.07	0.28	0.158
	100.0		22.98 or 23.0		0.387

The supplement furnishes 0.39% phosphorus, while 0.8% is needed. The difference, 0.8 − 0.39 = 0.41%, can be provided by dicalcium phosphate. To calculate the necessary amount of dicalcium phosphate, divide 0.41% (amount needed) by 0.19% (% phosphorus in dical), which equals 2.2%. Next, include the dicalcium phosphate in the fixed portion and recalculate the needed amounts of SBM and milo as before.

		Crude Protein	
Ingredient	**% in Formula**	**% in Ingredient**	**% Furnished**
Alfalfa meal	5.0	17.0	0.85
Molasses	5.0	4.3	0.21
Dicalcium phosphate	2.2	0	0
	12.2		1.06

21.94 (i.e., 23.0 − 1.06) ÷ 87.8 (i.e., 100 − 12.2) = 25.0

			Parts	%
SBM	50%		16.0	39.0
		25.0%		
Milo	9%		25.0	61.0
			41.0	100.0

39.0% × 87.8 = 34.2% SBM

61.0% × 87.8 = 53.5% milo

The final formula will be

		CP		Phosphorus	
Ingredient	% in Formula	% in Ingredient	% Furnished	% in Ingredient	% Furnished
Alfalfa meal	5.0	17.0	0.85	0.26	0.013
Molasses	5.0	4.3	0.21	0.08	0.004
Dicalcium phosphate	2.2	0	0	19.0	0.418
SBM	34.2	50.0	17.1	0.63	0.215
Milo	53.5	9.0	4.8	0.28	0.150
	99.9 or 100.0		22.96 or 23.0		0.800

The values for protein and phosphorus, which are close to the specifications, could be made more exact by minor ingredient adjustments if desired.

Finally, calculate the amount of vitamin A concentrate needed. Since 20,000 IU are needed per lb. of supplement, a total of 2,000,000 IU are needed for 100 lbs. (20,000 × 100). To calculate the amount of vitamin A concentrate needed for 100 lbs. of supplement, divide 2,000,000 by 40,000 (potency of vitamin A concentrate per g). The answer is 50 grams. A total of 1000 g would be needed for a ton of the supplement (50 × 20). The formula can be converted to a ton basis for mixing purposes, and the estimated cost can be calculated, if desired, as illustrated by the following example

Ingredient	% in Formula	lbs. in Ton	Cost/lb. Ingredient ($)	Cost Ingredient
Alfalfa meal	5.0	100.0	0.075	7.50
Molasses	5.0	100.0	0.040	4.00
Dicalcium phosphate	2.2	44.0	0.100	4.40
SBM	34.2	684.0	0.110	75.24
Milo	53.5	1070.0	0.050	53.50
Vitamin A		2.2*	1.000	2.20
				$146.84†

*1000 g ÷ 454 (g/lb.) = 2.2 lbs.

†Does not include cost of mixing and pelleting.

VI. Additional Examples of Diet Formulation (shown at the End of Chapters 7, 8 and 9)

VII. Computer-Assisted Formulation

The acceptance of linear programming (LP) in the formulation of least-cost diets for livestock and poultry feeds is almost universal in its usage in the feed industry. The development of the microcomputer has placed the capabilities of least-cost programming within the range of small to medium-sized mills and individual producers who could not previously afford such a service. Recent additions of the NRC for many species contain software used to determine dietary requirements.

A. *Linear Programming Defined*

1. Linear programming is a mathematical technique for determining the optimum allocation of resources (different feedstuffs) to obtain a particular objective (meeting nutrient requirements, reducing costs, optimizing profits or exploring changes in nutrient specifications of the diet or in the nutrient content of feedstuffs).
2. Basically, LP is a system by which a number of linear equations are solved on a simultaneous basis. One must establish a series of equations that describe in mathematical terms the conditions or requirements of the formula. These requirements must be measurable in numerical terms.

B. *Equipment and Programs Needed*

1. Access to a computer. Most desktop computers are capable of running formulation software.
2. Many excellent programs are available. It is recommended that at least 640K total memory be available to provide for adequate matrix size.

C. *Information Needed*

In order to formulate a diet one must supply the following information to the computer.

1. A list of feed ingredients available for use in the diet and their present cost. Often the prices of feed ingredients fluctuate enough from week to week to greatly influence the ingredients selected by a computer in a least-cost formulation. These marked ration ingredient changes may affect animal performance. Most software allows the user to manually change prices of feedstuffs according to market fluctuations.

   Therefore, it should be pointed out that only ingredients known to be palatable and biologically available to the animal should be included.
2. The nutrient content of each ingredient. There are many sources of information on average nutrient content of ingredients, and these may serve as a starting point for establishing matrix values. However, it must be emphasized that these values usually represent an average nutrient content; one should always strive to have values that accurately reflect the composition of ingredients actually available for use.
3. The nutrient requirements of the animal in terms of minimum, maximum or exact quantities needed. There are several basic sources of information on nutrient requirements (NRC, university bulletins, feed company brochures, etc.). When using any of these recommendations, know that they represent average ingredient values and feeding standards for average or better growing conditions. Each user must make proper adjustments for local conditions and quality of management.

   There is often a tendency for persons starting to use LP to attempt to include specifications for nearly every known nutrient. For most situations it is not necessary to include more than a dozen or so in the requirements table. This number will depend a great deal upon the quality and variety of ingredients available, and through experience the nutritionist will learn which nutrients must have minimum values expressed in the computer.
4. Physical, nonnutritive or nutritive usage limitations on certain ingredients. Some examples may include
   a. Toxic properties in certain ingredients allow only limited usage in a diet.
   b. Limitation of feeds containing undesirable properties that may reduce palatability or impart undesirable odors to the carcass, milk or egg.
   c. Limitation on quantity available in inventory.
   d. Adverse effects on physical texture and storage ability. Ingredients such as fats or molasses may be good sources of energy, but if fed at excessive levels may cause problems with bridging of feed in bins, ability of the feed to flow and other such problems.
   e. Excessive levels of certain nutrients in the feed. In swine or poultry diets, ingredients such as dried bakery product containing large quantities of salt or dehydrated alfalfa meal's high fiber content may impair performance if fed at higher levels.
   f. Variation in nutrient content of certain ingredients. Limitations are often placed on the amount of some ingredients because of a high degree of variability. Animal byproducts are an example of this limitation.

D. The role of the nutritionist has changed markedly as a result of the increased speed and capacity of the computer. Where once the nutritionist spent many hours daily in the routine of formulating or revising feed mixes, this task can now be accomplished in a fraction of the time. This should allow the nutritionist to concentrate upon other aspects of feed formulation and manufacturing such as ingredient evaluation, establishing nutrient requirements and quality control.

Study Questions and Problems

1. If you are mixing soybean meal (SBM) (44% CP) and ground corn (9% CP) together to make 2000 lbs. of a 16% CP diet, the amount of soybean meal required will be about
   a. 200 lbs.
   b. 300 lbs.
   c. 400 lbs.
   d. 500 lbs.
   e. 600 lbs.
2. Assume you want to formulate 1 ton of a pig starter to contain 18% CP. How many lbs. of corn (9% CP) and soybean meal (44% CP) are needed in this mixture?
   a. 1440 lbs. corn; 560 lbs. SBM
   b. 1486 lbs. SBM; 514 lbs. corn
   c. 560 lbs. corn; 1440 lbs. SBM
   d. 1486 lbs. corn; 514 lbs. SBM
   e. 1391 lbs. corn; 609 lbs. SBM
3. Formulate 1000 kg of an 18% crude protein mix using ground milo (11% CP) and cottonseed meal (CSM) (41% CP).
4. Prepare 500 pounds of mineral mix to contain 27% Ca using ground limestone (36% Ca) and dicalcium phosphate (23% Ca, 18% P). What is the percent phosphorus in the final mix?
5. Formulate 1500 pounds of a 15% crude protein sow lactation diet using a mixture of 3 parts ground corn (9% CP) and 1 part oats (11% CP) in conjunction with soybean meal (46% CP).
6. Formulate 100 lbs. of mineral supplement to contain 7.0% phosphorus. Fix salt (0% P) at 40 lbs., limestone (0% P) at 20 lbs. and have dicalcium phosphate (22% P) and rock phosphate (15% P) make up the remainder of the supplement.

Ingredient	lbs.	lbs. P
Salt	40	0
Limestone	20	0
Dical	—	—
Rock phosphate	—	—
	100	7.0

7. A Brown Swiss dairy cow requires 6 lbs. of crude protein and 28 Mcal NE_L daily. She is receiving 2.25 lbs. protein and 12 Mcal NE_L from intake of forages. What combination of corn grain and cottonseed meal are needed in a concentrate mix to meet her requirements?

   __________________ lbs. corn (9% CP; 0.8 Mcal/lb.)

   __________________ lbs. CSM (40% CP; 0.7 Mcal/lb.)

   __________________ lbs. TOTAL

8. Formulate one ton (2000 lbs.) of a 15% protein swine diet containing milo (11% CP), soybean meal (48% CP) and the following fixed ingredients

   5% Alfalfa meal (20% CP)
   2% Dicalcium phosphate
   2% Trace mineralized salt
   1% Vitamin–antibiotic premix (50% CP)

   ______________ lbs. milo
   ______________ lbs. SBM
   ______________ lbs. alfalfa meal
   ______________ lbs. dicalcium phosphate
   ______________ lbs. TM salt
   ______________ lbs. vitamin−antibiotic premix
   ____2000____ lbs. TOTAL

9. Prepare 1000 kg of a 16% crude protein swine feed from the following feedstuffs
   a. grain source: a mixture of three parts corn (8.9% CP) and one part oats (12.1% CP)
   b. protein balancer: a 32% CP supplement
   c. 10 kg of trace mineral premix
   d. 5 kg of vitamin premix
   e. 5 kg of salt

   Assume that the premixes (items c and d) will add a total of 5.0 kg of protein to the 1000 kg formula. List the final ingredients on a 1000-kg basis in the spaces provided below.

   ______________ kg corn
   ______________ kg oats
   ______________ kg supplement
   ______________ kg trace mineral premix
   ______________ kg vitamin premix
   ______________ kg salt
   ____1000____ kg TOTAL

10. You have just begun working for the Super–Grow Feed Company. Your first assignment is to formulate a beef cattle supplement. Each pound of the supplement is to contain 30,000 IU vitamin A, 3000 IU vitamin D, 200 mg growth stimulant and 0.40 lbs. protein. Formulate 2000 lbs. of a supplement, and indicate the quantity of each of the following available ingredients

    ______________ lbs. soybean meal (48% CP)
    ______________ lbs. linseed meal (36% CP)
    ______________ lbs. vitamin A concentrate (50,000 IU/g)
    ______________ lbs. vitamin D concentrate (7000 IU/g)
    ______________ lbs. growth stimulant (50 g/lbs.)
    ____2000____ lbs. TOTAL

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