7 Feedstuffs Classification

Learning Objectives

After you have studied this chapter, you should be able to:

- Describe feedstuff classification and identify feedstuff categories and characteristics.
- Identify the nutritive characteristics in various feedstuff categories.

Key Terms

Anaerobic
Energy feed
Ensiling
Feed
First-limiting amino acid
Forage
Green forage
Lignin
Mineral supplement
National Research Council
Nonnutritive additive
Nutritive value
Pasture
Protein quality
Protein supplement
Range plants
Roughage
Silage
Vitamin supplement
Weathering

INTRODUCTION

Feeds of many origins, qualities, and availabilities are used in animal diets in the United States and around the world. The nutritive content varies tremendously among them. Making sense of it all can be a daunting task. The National Research Council, a branch of the National Academy of Science, publishes a series of reports entitled *Nutrient Requirements of Domestic Animals*. Those publications use eight categories to group feedstuffs with others that have common characteristics. Feedstuffs within a group generally have similar nutritive values as well as other common characteristics. These categories help us organize types of feeds and give us a way to think about how we go about balancing a ration. In practical terms, most rations are balanced with the use of computers and databases that have information on every available feedstuff programmed into them. The category a feed falls into is not important to the computer. However, with the limits of the human mind, it is still useful to be able to put feeds into these categories: (1) dry forages and roughages; (2) pasture, range plants, and green forages; (3) silages; (4) energy feeds; (5) protein supplements; (6) mineral supplements; (7) vitamin supplements; and (8) nonnutritive additives.

FEEDSTUFF CATEGORIES

Dry Forages and Roughages

Feeds placed in this category contain at least 18% crude fiber, with values ranging up to 50% crude fiber. Dry **forages** and **roughages** are high in cellulose, hemicellulose, and possibly lignin and low in readily digested carbohydrates such as starch and sugars. Consequently, they generally have a lower digestibility and therefore lower energy values than do concentrates. The protein content varies from nearly 30% for alfalfa to 2–3% for some straws. Because ruminants and cecal fermenters generally use these feeds, the quality of the protein is not usually a concern. It is hard to make general statements about the mineral and vitamin contents of these feeds because they vary so widely. Examples of feeds in this category are legume hay, grass hays, wheat straw, cornstalks, corncobs, cottonseed hulls, peanut hulls, and rice hulls (Figures 7–1, 7–2, and 7–3).

Forage Fiber-containing feeds, such as grass or hay. Contain at least 18% fiber but have high digestible energy (more than 70%).

Roughage A bulky feedstuff with low weight per unit volume. Contains at least 18% fiber but can range up to 50%. Less digestible than forages.

Pasture, Range Plants, and Green Forages

Examples of feeds in this category are Bermuda grass pasture, sorghum-sudan grass, tall-grass prairie species, and wheat pasture (Figure 7–4). Many of these feeds could be harvested as dry feeds that would be classed in the previous category. The moisture

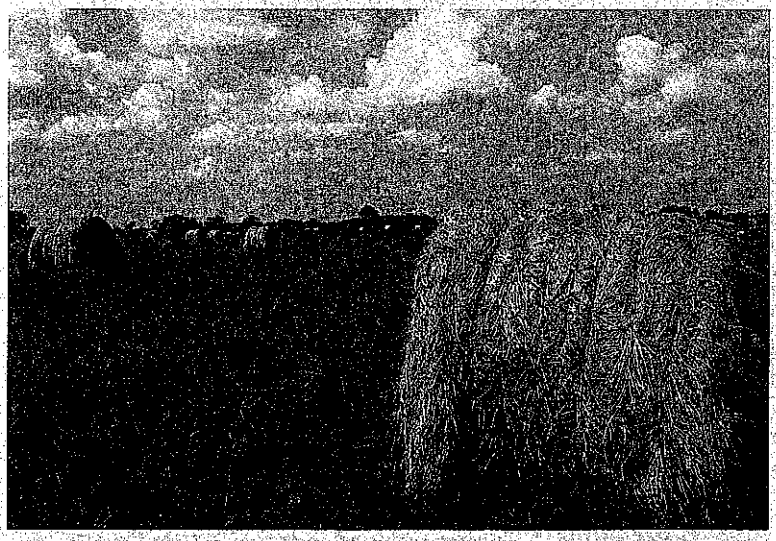


Figure 7–1
Hay is an example of a dry forage and roughage.
(Photo by Norm Klopfenstein. Courtesy USDA–Natural Resources Conservation Service.)

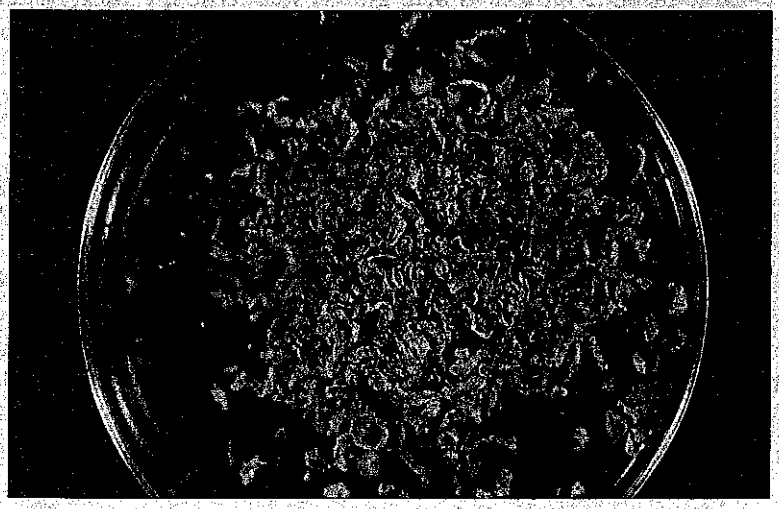


Figure 7–2
Beet pulp is a by-product of sugar production. It is often used in dairy rations and feeds for show cattle.

Figure 7–3
Cottonseed hulls are a by-product of the cotton industry and an excellent fiber source.

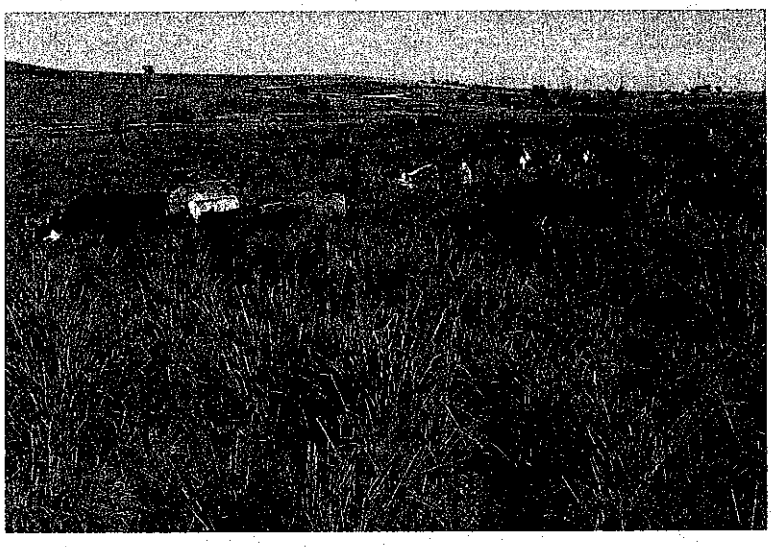


Figure 7–4
Grazing is the world's most common use of growing forage. These cattle are grazing native switchgrass pasture, which offers pasture for cattle in midsummer, when the cool-season species are less productive.
(Photo by Lynn Betts. Courtesy USDA–Natural Resources Conservation Service.)

content of these feeds is usually between 50–85% but can be quite variable. Winter range pasture in the range states may contain as little as 15–30% moisture, whereas wheat pasture can be as high as 90% moisture. The dry-matter nutritive content tends to be quite variable as well. Young, well-fertilized wheat pasture can have very high crude protein and can be very digestible, whereas late season prairie hay is the opposite.

Silages

Ensiling The process of producing silage from forage.

Anaerobic Conditions that lack molecular oxygen.

The process of **ensiling** plant material under **anaerobic** conditions produces silage (Figure 7–5). This is a common storage method for livestock feed. The plant material undergoes a controlled fermentation that produces acids. The acids then kill off the bacteria, molds, and other destructive organisms. As long as the silage is left undisturbed, it will keep for years. Many different materials can be ensiled. Corn silage is produced by chopping and ensiling the whole corn plant after the ears have formed. Other grain-producing species also produce good-quality silage, as do legume forage species, cannery waste, and roots and tubers. One common misconception is that ensiling improves the nutritive content of a feed. The opposite is actually true. The fermentation process uses nutrients and thus reduces the nutritive content of the material.

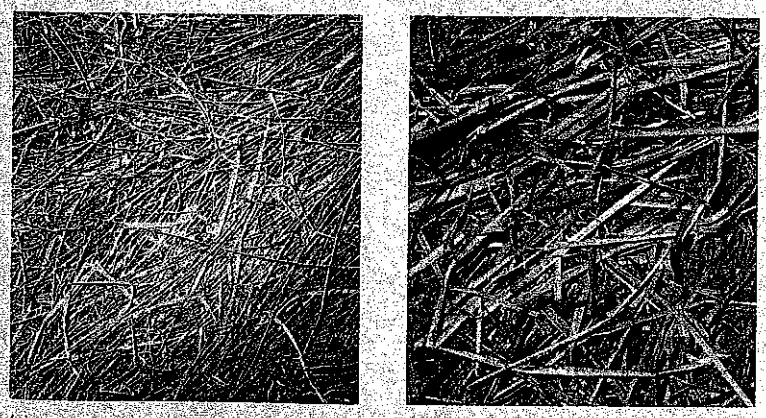
Figure 7–5
Silage is plant material allowed to ferment under anaerobic conditions in a silo such as the bunker silo pictured here. Samples are taken to be analyzed for nutritive value and moisture content. (Photo by Stephen Ausmus. Courtesy USDA–Agricultural Research Service.)

This category of feedstuff also causes some confusion because the ensiling process can be used to preserve other products such as high-moisture corn. However, these other products are not automatically classified as silage just because they are ensiled.

Characteristics

The three categories previously discussed in this section have much in common in terms of the plants found in each category, and thus their nutritive values are similar. Most of the feeds from these three categories are commonly referred to as either roughages or forages without further classification. A forage is generally considered to be of higher quality than a roughage (Figure 7–6). Feeds in these categories provide the bulk of the diets of the herbivorous species (ruminants and cecal fermenters) and as such are the major feeds available for animal use in the United States and the rest of the world. For these reasons, a general discussion of them seems in order before discussing the remaining categories.

The characteristics of good-quality forage generally include being relatively immature when harvested by animals or by mechanical means; being green and leafy; having soft, pliable stems; being free from mold or mustiness; being palatable; and being free from foreign material. The further a feed gets from this ideal, the poorer the quality and the more likely it will be thought of more as a roughage than a forage. For example, under most range conditions an excess of high-quality forage is available during the growing season. However, animals need feed all year long. Thus, a



(a) (b)

Figure 7–6
The hay (a) is a fine-stemmed forage of high nutritive value. The wheat straw (b) is a roughage of low nutritional value.

part of the growth must be retained to provide feed during the nongrowing months of the year. This feed is consumed as a mature, weathered, low-quality feed during the winter months and thought of as roughage.

It is common to divide forages and roughages into legumes (e.g., alfalfa, lespedeza, soybeans, and clovers) and grasses (e.g., prairie grasses, timothy, Bermuda grass, and wheat). Legumes are generally better quality feed than grasses because the former have a lower stem and a higher leaf content. Of course, there are exceptions. Although wheat pasture is a grass, it may contain from 20–34% crude protein when it is in a young vegetative state. This protein level is higher than that of most legumes. For some nutrient parameters, there is actually little difference between legumes and grasses of equal maturity, but for other parameters, legumes are much higher in nutrient value. As a general rule of thumb, legumes and grasses have about the same energy content, but legumes have much higher protein, calcium, and carotene contents.

Many variables affect the nutritive content of forages and roughages. These include maturity at the time of harvesting, weather damage, soil fertility, plant species, and harvesting method. Maturity at the time of harvesting is perhaps the most important factor because all nutrients, except fiber, decrease in number with advancing maturity. Fiber increases with maturity. Young plants may contain only 20% crude fiber, but mature plants may have 40% or more. **Lignin** also increases as fiber increases.

Lignin Polymers of phenolic acids found in plants as part of the structural components of the plant.

The digestibility and palatability of a forage decrease with advancing maturity and increasing fiber level (Figures 7–7, 7–8). The rate of change is much greater for some plants than for others. For example, timothy, brome grass, and buffalo grass retain good palatability over a wide range of maturities. Orchard grass and lovegrass are very palatable and digestible when young, but they lose these characteristics quickly as they mature. The effects of maturity are more pronounced for grasses than for legumes. Nutrient changes with advancing maturity and **weathering** are illustrated in Table 7–1. Table 7–2 gives the nutrient content of some representative forages and roughages.

Weathering Loss in nutritive value through exposure to the elements.

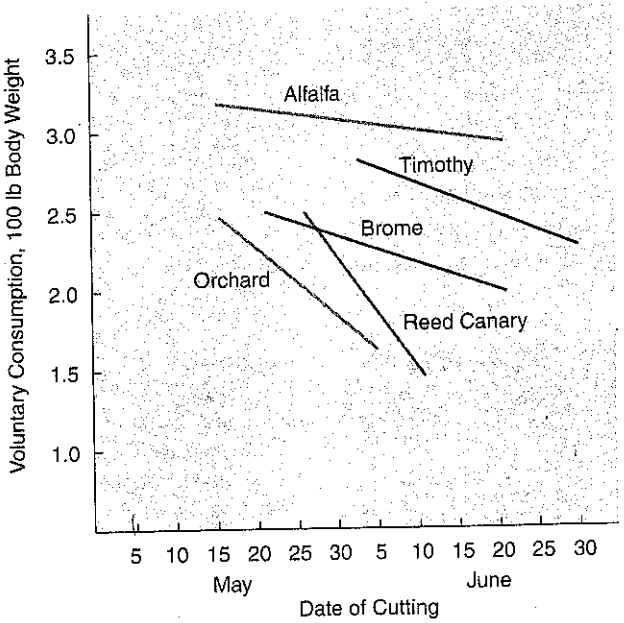


Figure 7–7
Effect of maturity on voluntary intake of first cutting forages by sheep. The later in the season the hay harvested, the less of it animals will willingly eat.
(Source: Wagner, 1988, p. 50.)

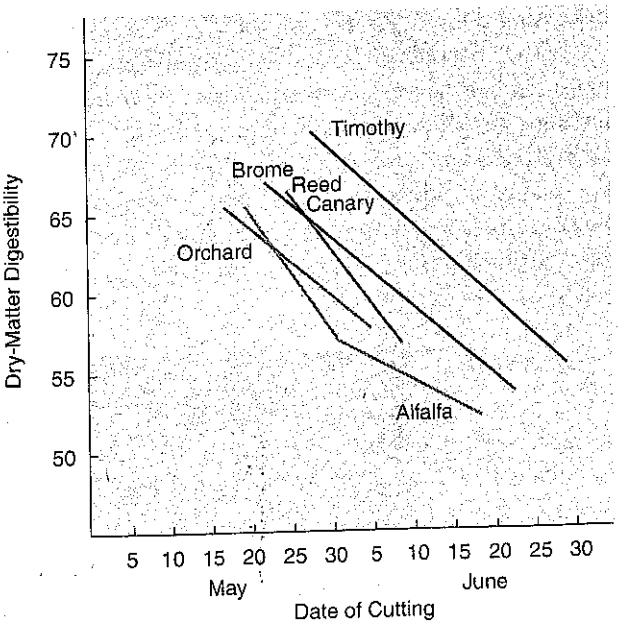


Figure 7–8
Effect of maturity on dry-matter digestibility of first cutting forages. As forages mature, the dry-matter digestibility declines. (Source: Wagner, 1988, p. 51.)

Table 7–1
AVERAGE CHEMICAL COMPOSITION OF FOUR NATIVE GRASSES DURING DIFFERENT MONTHS OF THE YEAR[1,2]

Month	Dry Matter (%)	Crude Protein (% on DM basis)	Crude Fiber (% on DM basis)	Calcium (% on DM basis)	Phosphorous (% on DM basis)	Carotene (mg/kg)
May	44.0	10.01	30.69	0.30	0.13	174.8
June	45.5	7.84	32.23	0.30	0.99	195.6
July	48.3	6.04	33.11	0.35	0.09	145.2
August	56.5	4.92	34.83	0.31	0.08	81.4
September	60.8	3.99	35.51	0.28	0.07	40.4
October	66.5	3.79	35.80	0.32	0.06	20.2
November	81.4	2.55	38.56	0.25	0.03	3.6
December	94.4	2.63	38.07	0.30	0.04	0.9
January	93.4	2.49	38.45	0.34	0.09	0.4
February	93.6	2.52	37.21	0.29	0.04	0.3
March	96.0	1.95	43.19	0.21	0.03	0.0
April	92.6	2.91	39.97	0.29	0.04	0.6

[1]Data taken from *Chemical Composition of Native Grasses in Central Oklahoma from 1947 to 1962* by Waller, Morrison, and Nelson, Bulletin B-697, January 1972.
[2]Values represent averages for 15 years.
Source: Wagner, 1988, p. 47.

Energy Feeds

Energy feeds primarily include the cereal grains, by-product feeds made from cereal grains (e.g., corn hominy feed, wheat bran), and fruits and nuts. All are low in protein.

Feeds placed in this category contain less than 18% crude fiber or less than 35% cell wall and have a protein content of less than 20% (Figure 7–9). They are usually high in starch and NFE and are thus high in energy content. Protein supplements, which are discussed next, may have similar energy content but have greater than 20% crude protein. The cereal grains are very low in crude fiber, with the range being about 2–10%. Corn (Figure 7–10), sorghum (Figure 7–11), and wheat contain about 2%, barley about 6%, and oats 10–12%. Seeds that have a fibrous outer hull are higher in crude fiber. The lower the fiber levels, the higher the energy content tends to be because more readily digested carbohydrates such as starch and sugars will be present. The energy value of grains is high, with the TDN as high as 90%

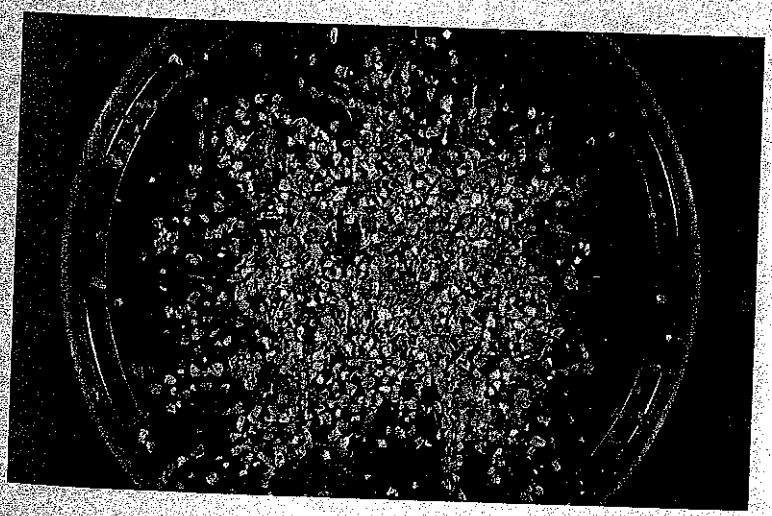


Figure 7–9
Energy feeds, generally the cereal grains or their by-products, contain less than 18% crude fiber (35% cell wall) and have a protein content of less than 20%. They are usually high in starch and NFE and are thus energy dense. Ground wheat is pictured here.

Table 7–2
SELECTED NUTRIENT ANALYSIS OF SOME FORAGES AND ROUGHAGES

Feedstuff	As Fed (% DM)	TDN (%)	NE_m (Mcal/lb)	NE_g (Mcal/lb)	CP (%)	EE (%)	CF (%)	ADF (%)	Ash (%)	Ca (%)	P (%)	K (%)	Mg (%)
Alfalfa, hay	90.6	60.0	1.31	0.74	18.6	2.39	26.1	33.8	8.57	1.4	0.28	2.43	0.28
Bermuda grass, fresh	30.3	64.0	1.44	0.86	12.6	3.70	28.4	36.8	8.1	0.49	0.27	1.7	0.17
Citrus pulp, silage	21.0	78.0	0.86	0.57	7.3	9.7	15.6	25	5.5	2.04	0.15	0.62	0.16
Corncobs, ground	90.0	50.0	0.44	0.19	3.2	0.7	36.2	35	1.7	0.12	0.04	0.87	0.07
Orchard grass, fresh, early bloom	23.5	68.0	1.57	0.97	12.8	3.70	32.0	30.7	8.1	0.25	0.39	3.38	0.31
Potato silage	25.0	82.0	0.91	0.61	7.6	0.4	4.0	5	5.5	0.04	0.23	2.13	0.14
Rice hulls	92.0	12.0	0.00	0.00	3.3	0.8	42.9	72	20.6	0.10	0.08	0.57	0.83
Sorghum silage, 30% DM	30.0	60.0	0.60	0.34	7.5	3.0	27.9	38	8.7	0.35	0.21	1.37	0.29
Wheat straw	89.0	44.0	0.34	0.10	3.6	1.8	41.6	54	7.8	0.18	0.05	1.42	0.12

Source: Bath et al., 1997; NRC, 1996
TDN = total digestible nutrients
NE_m = net energy for maintenance
NE_g = net energy for gain
CP = crude protein
EE = ether extract
CF = crude fiber
ADF = acid detergent fiber
Ca = calcium
P = phosphorous
K = potassium
Mg = magnesium

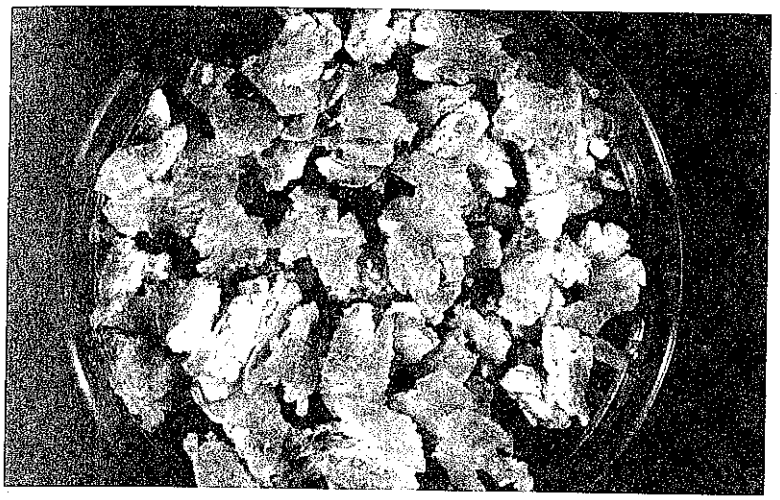


Figure 7–10
Corn is the most common feed grain in the United States. This corn has been steam flaked.

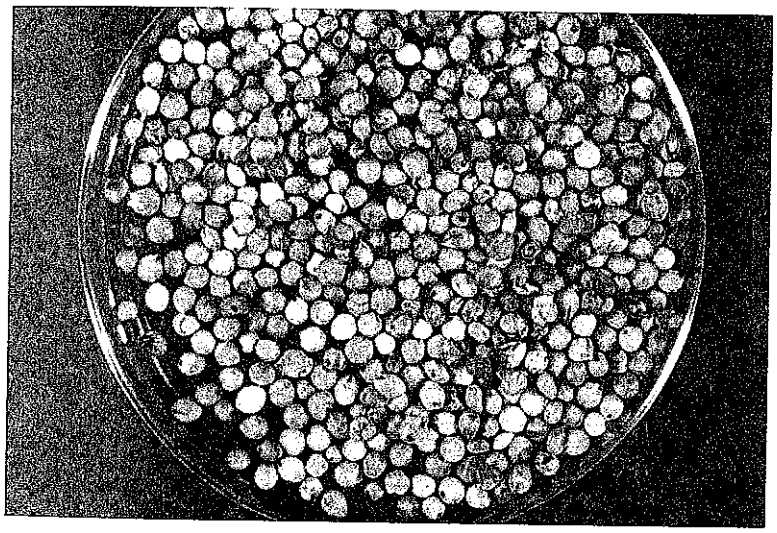


Figure 7–11
Grain sorghum is an excellent energy feed grown in drier parts of the United States.

on a dry-matter basis. These values are because of the high starch content (as high or higher than 70%), low fiber content, and high digestibility. The by-product feeds in this category usually have somewhat lower energy content because they contain more fiber and less starch as a result of processing (Figure 7–12). These feeds are fed to

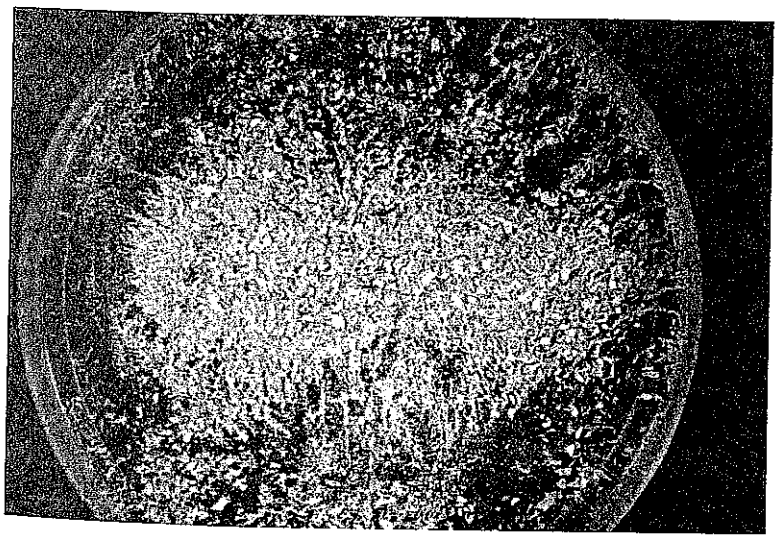


Figure 7–12
Wheat shorts are an energy feed that is also a by-product feed. By-product feeds usually have lower energy values and higher fiber levels than the original grain before processing.

Table 7–3
SELECTED NUTRIENT ANALYSIS OF SOME COMMON ENERGY FEEDS

Feedstuff[1]	Dry Matter (%)	Crude Protein (%)	Ruminant TDN (%)	Poultry ME (kcal/kg)	ME (kcal/kg)	Swine TDN (%)	ME (kcal/kg)
Bakery products, dried	91	10.0	82	1,650	3,630	1,635	3,600
Barley, grain	89	11.5	74	1,250	2,750	1,305	2,870
Corn, yellow, grain	86	7.9	80	1,540	3,390	1,520	3,350
Hominy feed, corn expeller	89	11.5	86	1,390	3,060	1,530	3,365
Molasses, cane, dried	91	7.0	80	1,080	2,375	1,165	2,560
Oats, grain	90	11.0	68	1,160	2,550	1,215	2,670
Oat groats (dehulled oats)	92	16.0	90	1,500	3,300	1,545	3,400
Sorghum, milo, grain	89	11.0	71	1,505	3,310	1,470	3,230
Wheat, hard, grain	88	13.5	76	1,440	3,170	1,465	3,220
Wheat, soft, grain	86	10.8	79	1,460	3,210	1,550	3,415
Wheat bran	89	14.8	62	590	1,300	1,055	2,320

[1]All table data are "as fed."
Source: Dale, 1997. Used with permission.

ruminants and cecal fermenters to increase the energy density of their rations, and to monogastrics as the primary source of energy for their diets.

Energy feeds are by definition below 20% in crude protein content. The cereal grains range between 8% and 12%. Some of the by-product feeds are higher. The protein digestibility ranges from 50–80% but the protein quality is generally poor. This is because the essential amino acid content is usually poor for grains. Lysine, methionine, and tryptophan are frequently the **first-limiting amino acids** in these feeds. If not first, they tend to be second or third limiting.

First-limiting amino acid The first amino acid whose lack of availability restricts the performance of the animal.

In general, cereal grains are invariably very low in calcium (Ca), modest in phosphorus (P), and low in most trace minerals. Grains are very low in both vitamin D and carotene, which is a precursor for vitamin A. However, they are generally a good source of vitamin E and do contain some B vitamins. Table 7–3 shows the nutrient content of some representative energy feeds.

Protein Supplements

Protein supplements include feeds from three major sources. They are either of plant origin (e.g., soybean meal, cottonseed meal, and corn gluten meal), animal origin (e.g., fish meal, dried skim milk, and tankage), or nonprotein nitrogen (NPN) sources (e.g., urea, purified amino acids, and ammonium salts). Protein supplements are generally expensive feeds. Although balanced rations require less total protein than energy sources, the protein sources are expensive and represent the second largest source of expense in the ration. In some management and feeding situations, protein supplements are the largest out-of-pocket expense in the entire program.

Feeds placed in this category contain more than 20% crude protein. Some have high-energy contents as well. However, economics dictates that they be used to satisfy the protein needs of the animal. Because ruminants can convert the poorer quality proteins to higher quality microbial protein, an effective cost-reduction strategy is to feed the NPN sources to ruminants and avoid the higher quality, and thus more expensive, of these. Very-high-quality, and thus very expensive, feeds must be used for some rations (e.g., baby pig rations, milk replacers).

Feedstuff[1]	Swine TDN (%)	Carotene (mg/kg)	Vitamin A (IU/g)	Vitamin E (mg/kg)	Calcium (%)	Total Phosophorus (%)	Ash (%)
Bakery products, dried	79	5	3.9	25	0.1	0.35	8.0
Barley, grain	70	—	—	36	0.08	0.42	2.5
Corn, yellow, grain	80	2	1.7	22	0.01	0.25	1.1
Hominy feed, corn expeller	82	9	15.3	—	0.05	0.5	3.0
Molasses, cane, dried	65	—	—	5.4	1.18	0.9	8.0
Oats, grain	65	—	—	20	0.3	0.35	4.0
Oat groats (dehulled oats)	84	—	—	15	0.07	0.45	2.2
Sorghum, milo, grain	78	—	—	12.2	0.04	0.29	1.7
Wheat, hard, grain	79	—	—	15.5	0.05	0.41	2.0
Wheat, soft, grain	83	—	—	15.5	0.05	0.3	2.0
Wheat bran	57	—	—	10.8	0.14	1.17	6.4

The protein feeds of plant origin are primarily derived as products of the extraction of the oil from a group of seeds referred to as *oilseeds* because of their high fat content (Figure 7–13). These protein sources are thus referred to as *oilseed meals.* The most important of these sources are soybeans and cottonseed (Figure 7–14). However, significant amounts of flax, peanut, sunflower, sesame, and others are also available. The protein content is generally at least 40% and is highly digestible. The **protein quality** varies but is generally good. Lysine, cystine, and methionine levels are commonly low. Soybean meal is different in that its lysine level is usually higher. As you recall, the essential amino acid content is usually poor for grains with lysine, methionine, and tryptophan frequently being the first-, second-, and third-limiting amino acids in these feeds. These amino acids may need to be provided as purified amino acids, or animal-based protein supplements can be added to make up the deficiencies. The energy content varies depending on how much of the oil was removed in the extraction process. In general, oilseeds are low in calcium and high in phosphorus. Caution must be used when balancing rations for monogastrics because half

Protein quality A measure of the presence and digestibility of the essential amino acids in a feedstuff.

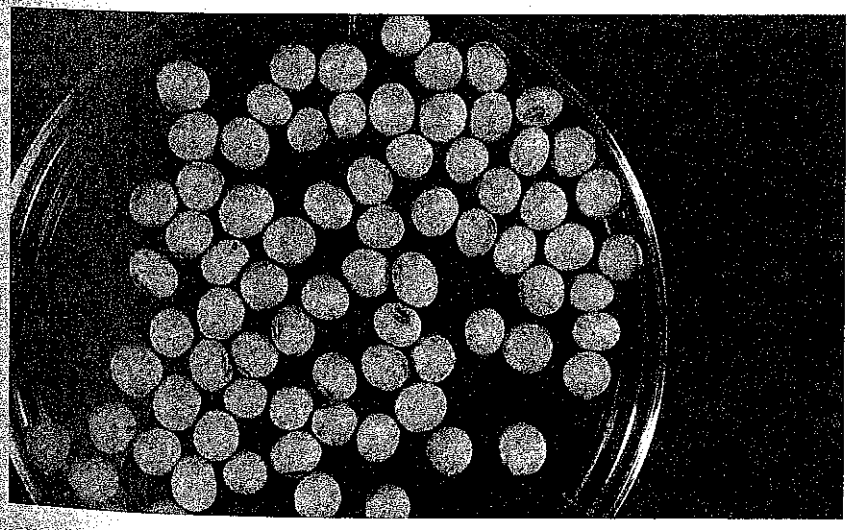


Figure 7–13
Whole soybeans can be used as livestock feed. However, they are usually processed to remove their oil content for human consumption. The remaining soybean meal is a high-quality protein supplement.

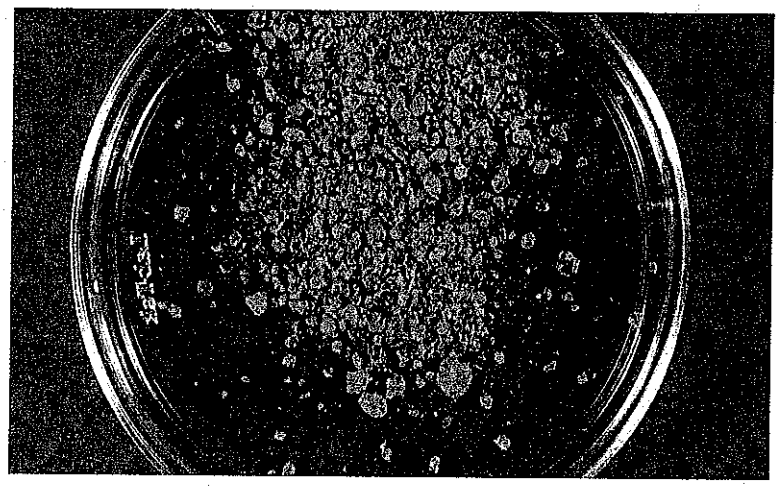


Figure 7–14
Cottonseed is a by-product of cotton production. After the oil is extracted from the seeds for human use, cottonseed meal, a high-quality protein supplement, remains.

or more of the phosphorus can be tied up as phytic-bound forms and is unavailable to the animals. The trace mineral content is variable but is generally considered to be low. Oilseeds are low in carotene, which is a precursor for vitamins A and E. They are low-to-moderate sources of B vitamins.

The protein feeds of animal origin are primarily derived as end products of the meat packing, dairy processing, and marine industries. The most important of these are meat meal, bonemeal, blood meal (Figure 7–15), feather meal, dried milk, and fish meal. The milk products are the highest quality of the end products and generally the most expensive. Good fish meals can rival milk products in quality. In addition, they generally contain much higher quantities of total protein. The lysine content of fish meal is considerably higher than that of other commonly available protein sources. Fish meals are usually good mineral and B vitamin sources. Milk and fish products are usually used for monogastric and young ruminant rations because of their high quality and subsequent cost. The quality of the protein in the meat products is usually lower than that of the milk and fish products. However,

Table 7–4
CRUDE PROTEIN AND AMINO ACID CONTENT OF SOME PROTEIN SUPPLEMENTS[1]

Ingredients	Dry Matter (%)	Crude Protein (%)	Methionine (%)	Cystine (%)	Lysine (%)	Tryptophan (%)	Threonine (%)
Blood meal, animal	89	80.0	1.0(91)	1.4(76)	6.9(86)	1.0	3.8(87)
Brewers dried grain	93	27.9	0.6	0.4	0.9	0.4	1.0
Brewers dried yeast	93	45.0	1.0	0.50	3.4	0.8	2.5
Canola meal	91	38.0	0.7(90)	0.47(75)	2.3(80)	0.44	1.71(78)
Casein, dried	90	80.0	2.7(99)	0.3(84)	7.0(97)	1.0	3.8(98)
Cottonseed meal, 41%, direct solvent	90	41.0	0.51	0.62	1.76	0.52	1.35
Feather meal, poultry	93	85.0	0.55(76)	3.0(59)	1.05(66)	0.4	2.8(73)
Fish meal, herring, Atlantic	93	72.0	2.2	0.72	5.7	0.8	2.88
Meat and bonemeal, 45%	92	45.0	0.53	0.26	2.2	0.18	1.8
Milk, whole dried, feed grade	96	25.5	0.62	0.4	2.26	0.41	1.03
Peanut meal, solvent	92	48.0	0.42	0.73	1.77	0.5	1.16
Soybean meal, solvent	90	44.0	0.65	0.67	2.9	0.60	1.7
Yeast, Torula, dried	93	48.5	0.80	0.6	3.8	0.5	2.6

[1]Numbers in parentheses represent percentage availability.
Source: Dale, 1997. Used with permission.

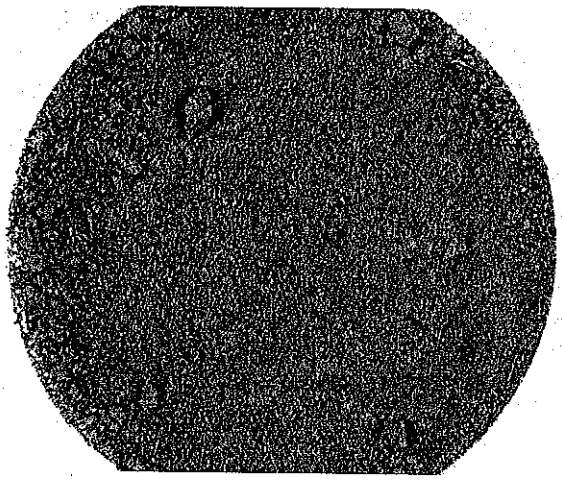


Figure 7–15
Blood meal is an example of a slaughter by-product used as a protein supplement.

the quality is still good and their use is usually restricted to monogastrics. Some of the meat products have high mineral contents, depending on the percentage of bone they contain. The vitamin content is highly variable but generally low because of the types of processing required to make these feeds usable. Feather meal is a low-quality protein supplement, but it is very high in total protein content (over 90%). It is best used in ruminant rations, although it can be used as a part of monogastric rations.

The NPN sources technically include such a wide range of material that generalizations are impossible. Purified amino acids are technically NPN. However, because of the costs of such feeds, the practical use of the term NPN is for urea (Figure 7–16) and other similar products. Urea and similar products must be used with functional ruminants only—and then, very carefully. The ruminant microbes are able to use substantial amounts of NPN and, because they are frequently of lower cost than proteins, they are often used to cheapen a ration. They are not a significant source of other nutrients as a rule. Table 7–4 shows the crude protein and amino acid contents of some commonly used protein supplements.

Ingredients	Isoleucine (%)	Histidine (%)	Valine (%)	Leucine (%)	Arginine (%)	Phenylalanine (%)
Blood meal, animal	0.8(78)	3.05(84)	5.2(87)	10.3(89)	2.35(87)	5.1(88)
Brewers dried grain	2.0	0.47	1.69	3.2	1.3	1.82
Brewers dried yeast	2.2	1.3	2.37	3.2	2.2	1.86
Canola meal	1.51(83)	1.10(85)	1.94(82)	2.6(87)	2.3(90)	1.5(87)
Casein, dried	5.7(98)	2.5(96)	6.8(98)	8.7(99)	3.4(97)	4.6(99)
Cottonseed meal, 41%, direct solvent	1.33	1.1	1.82	2.4	4.66	2.23
Feather meal, poultry	2.66(85)	0.28(72)	4.55(82)	7.8 (82)	3.92(83)	2.66(85)
Fish meal, herring, Atlantic	3.0	1.91	5.7	5.1	5.64	2.56
Meat and bonemeal, 45%	1.7	1.5	2.4	2.9	2.7	1.8
Milk, whole dried, feed grade	1.33	0.77	1.74	2.57	0.92	1.33
Peanut meal, solvent	1.76	0.95	1.88	3.70	4.55	2.04
Soybean meal, solvent	2.5	1.1	2.4	3.4	3.4	2.2
Yeast, Torula, dried	2.9	1.4	2.90	3.5	2.6	3.0

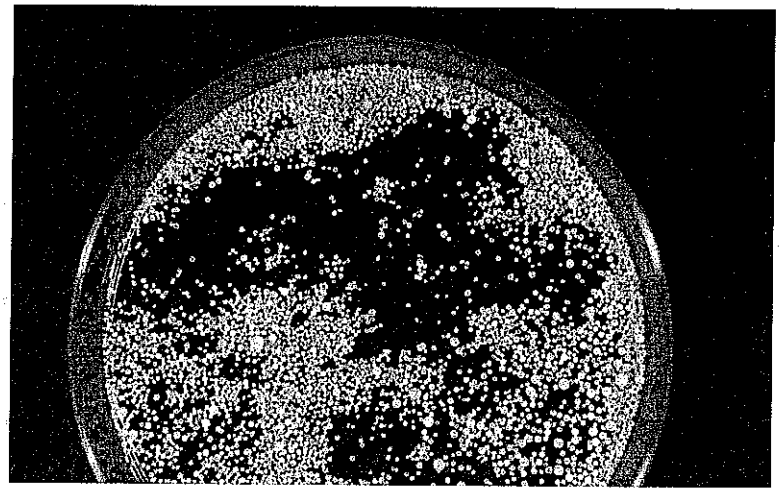


Figure 7–16
Feed-grade urea is used as a nonprotein nitrogen source in ruminant rations.

Mineral and Vitamin Supplements

Virtually all feeds contain at least some vitamins and minerals. Animals need these nutrients in much smaller amounts than they do the other nutrients. Nevertheless, dietary needs must be met in a satisfactory manner to achieve good animal performance and economical production. Depending on the feeds used to balance the ration for the other nutrients, concentrated sources of vitamins and/or minerals may be needed.

Mineral supplements in common use include salt (often trace mineralized) (Figure 7–17), bone meal, oyster shell (Figure 7–18), calcium carbonate, limestone, and fairly pure forms of other specific minerals such as selenium, cobalt, and others. In addition, a wide variety of premixed, complete, mineral supplements are generally available. The minerals of concern usually include sodium, calcium, phosphorus, magnesium, copper, iron, manganese, zinc, cobalt, and selenium. Table 7–5 shows the mineral content of some representative mineral supplements.

Vitamin supplements include such products as ensiled yeast, liver meal, fish oil, and wheat germ oil, as well as purified forms of individual vitamins. Although rations can be formulated and balanced for each individual vitamin easily with

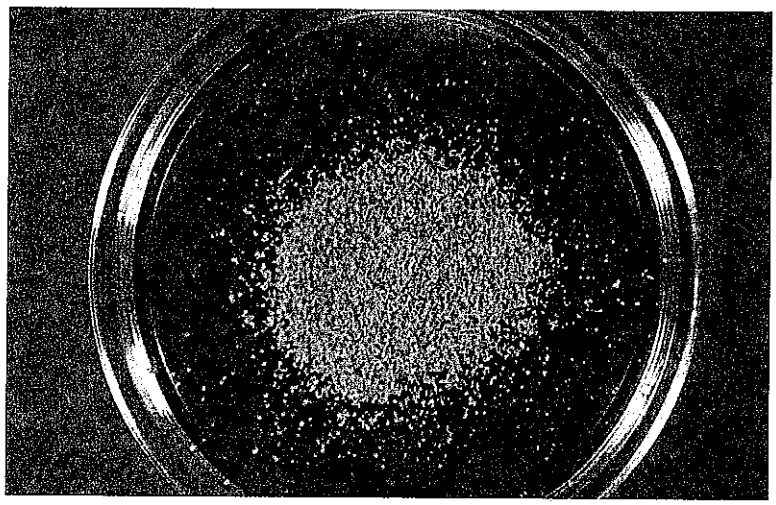


Figure 7–17
NaCl and a variety of trace minerals are collectively referred to as trace mineral salt. It is used in loose form such as this for mixing with other feeds, or it may be fed in blocks that animals lick when they crave salt.

Table 7–5
MINERAL CONTENT OF SOME REPRESENTATIVE MINERAL SUPPLEMENTS

	Calcium (%)	Total Phos. (%)	Ash (%)	Sodium (%)	Potassium (%)	Magnesium (%)	Fluorine (%)	Manganese (ppm)[1]	Iron (ppm)	Copper (ppm)	Zinc (ppm)	Selenium (ppm)
Bonemeal (steamed)	24.0	12.0	71.0	0.46	n/a[1]	0.64	n/a	30.4	840	16.3	424	n/a
Calcium carbonate	38.0	—[1]	95.8	0.06	0.06	0.5	n/a	279	336	24	n/a	0.07
Diammonium phosphate (N-18%)	0.5	20.0	34.5	0.04	—	0.45	0.2	500	15,000	80	300	n/a
Deflourinated phosphate	33.0	18.0	99.0	4.5	0.09	—	0.2	220	9,200	22	44	0.6
Dicalcium phosphate	20.0	18.5	85.6	0.08	0.07	0.6	0.18	300	10,000	80	220	0.6
Phosphoric acid, 75%	—	23.8	n/a	n/a	n/a	n/a	—	n/a	5	n/a	n/a	n/a

	Potassium (%)	Magnesium (%)	Iron (%)	Copper (%)	Manganese (%)	Zinc (%)	Cobalt (%)	Sulfur (%)	Selenium (%)	Sodium (%)
Copper sulfate ($CuSO_45H_2O$)	—	n/a	n/a	25.0	n/a	n/a	—	—	—	—
Ferrous sulfate ($FeSO_47H_2O$)	—	0.04	0.001	0.001	0.002	—	21.0	—	—	—
Manganese sulfate ($MnSO_4H_2O$)	—	0.05	21.0	0.01	0.12	0.01	—	11.0	—	—
Magnesium sulfate ($MgSO_4$)	—	0.03	0.04	—	25.0	—	—	19.0	—	—
Potassium sulfate (K_2SO_4)	—	20.0	n/a	n/a	n/a	n/a	n/a	26.6	—	—
Sodium selenite (Na_2SeO_3)	44.8	—	—	—	—	—	—	18.3	—	—
Zinc oxide (ZnO)	—	—	—	—	—	—	—	—	45.6	26.6
Copper sulfate ($CuSO_45H_2O$)	—	0.5	0.8	0.07	0.01	73.0	—	1.0	—	—

[1]ppm = parts per million; n/a = data not available; — indicates that the ingredient does not contain a significant amount of nutrient.
Source: Dale, 1997. Used with permission.

Figure 7–18
Oyster shell, a valuable source of calcium, is frequently used in laying-hen diets.

modern computer balancing programs, in practice, vitamin supplements are often added without regard for the amounts that may be found naturally in the feeds used in the ration. This is because of the highly variable availability of vitamins found in natural feedstuffs. Those vitamins usually supplemented in animal rations include vitamins A, D, and E for functional ruminants; and vitamin K, riboflavin, pantothenic acid, niacin, choline, folic acid, biotin, and cyanocobalamine for other species. Table 7–6 shows the vitamin content of a standard vitamin premix supplement (Figure 7–19).

Table 7–6
VITAMIN PREMIX FOR SWINE[1]

Vitamin	Amount/lb of Premix[1]	Suggested Source
Vitamin A	2,000,000 IU[2]	Vitamin A palmitate-gelatine coated
Vitamin D	200,000 IU	Vitamin D_3—stabilized
Vitamin E	10,000 IU	dl-Tocopherol acetate
Vitamin K (menadione equivalent)[2]	800 mg	Menadione sodium bisulfite
Riboflavin	1,200 mg	Riboflavin
Pantothenic acid	4,500 mg	Calcium pantothenate
Niacin	9,000 mg	Nicotinamide
Choline	20,000 mg	Choline chloride (60%)
Vitamin B_{12}	5 mg	Vitamin B_{12} in mannitol (.1%)
Folic acid	300 mg	Folic acid
Biotin	40 mg	D-biotin

[1]Premix is designed to be used at a rate of 5 lbs per ton of complete feed for sows and baby pigs, and 3 lbs per ton of complete feed for growing-finishing swine.
[2]A standard unit of potency. Defined by the International Conference for Unification of Formulae.
Source: Luce et al., 1998. Used with permission.

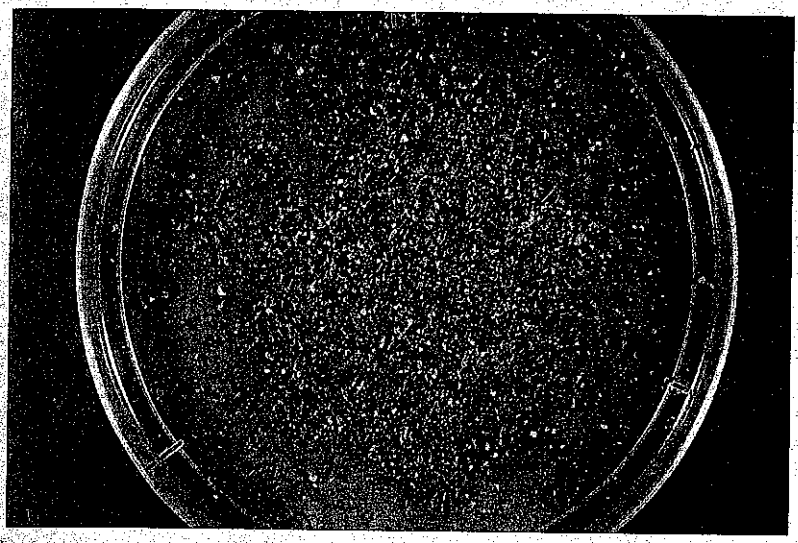


Figure 7–19
Vitamins are often mixed in appropriate individual quantities and blended with an inert carrier so they can be added to rations. Such vitamin supplements facilitate the balancing of rations and improve the accuracy of ration mixing.

Nonnutritive Additives

This is a catchall category for a large group of feed ingredients added to rations for some reason other than their nutritive value. They may be used to stimulate growth or some other type of production, improve feed efficiency, enhance health, or alter metabolism. Feedstuffs in this category include antibiotics, coloring agents, flavors, hormones, and medicants. Examples of substances in this category include monensen sodium (makes rumen fermentation more efficient), butylated hydroxytolulene (antioxidant), aluminum sulfate (used as an anti-gelling agent for molasses), monosodium glutamate (flavor enhancer used in pet foods), propylene glycol (emulsifying agent), and aluminum potassium sulfate (color additive). Not all additives are fed. Some can be given to the animal as an injection or implant.

The list of nonnutritive additives changes over time. Those additives classified as drugs must be approved by the Food and Drug Administration (FDA). A good reference to become familiar with is the *Feed Additive Compendium*. Updated yearly, this is an invaluable resource for nutritionists.

SUMMARY AND CONCLUSION

This chapter was designed to give you an overview of feeds and their general uses and nutritive values. The system of categorizing feedstuffs used in this chapter is the one found in the NRC publications, which is generally used and accepted. Although the chapter has provided generalities about the feeds classifications, exceptions are easy to find. Research is continually telling us more about feeds and their nutrient availabilities. Even identical species of plants can produce different nutrient levels in a feedstuff because of the many environmental factors that affect nutrient content. The by-product feeds tend to change because the processes that generate them change. Plant breeders are continually developing new and nutritionally different crops. With the advent of accelerating recombinant DNA technology, even more rapidly changing nutritive values can be expected. All of these changes tend to blur the lines between nutrient classes. It is important to keep up with changes in the values of the various feedstuffs. Consult current NRC publications and scientific journals. An additional important resource with high credibility with academics and industry leaders is the annual *Feedstuffs Reference Issue*.

STUDY QUESTIONS

1. What are the eight categories of feedstuffs as recognized by the NRC?
2. What are the similarities and differences in the first three categories described in this chapter?
3. What is the difference between a forage and a roughage? What are the characteristics of a good-quality forage?
4. What is the definition of an energy feed? What is the definition of a protein feed? What is the difference between an energy feed and a protein feed?
5. What are the differences and similarities of protein supplements from the three major sources of protein supplements?
6. What are the major similarities and differences in vitamin supplements and mineral supplements?
7. For what purposes are nonnutritive additives added to rations?
8. Why must one have a good, current source of nutrient composition for feedstuffs?

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