Lesson 1:
Importance of Animal Nutrition to Agriculture

Agriculture is the largest industry in the United States. The total assets of agriculture exceed one trillion dollars, which is equal to approximately 70% of the capital assets of all U.S. manufacturing corporations. The production of livestock is an important part of the total agricultural industry. About one-half of farm cash receipts come from the sale of livestock and livestock products. The cost of feed represents from one-half to more than three-fourths of the total cost of raising livestock. Careful attention to animal nutrition can help reduce feed costs and thus increase the potential profit from livestock.

Careers in Animal Nutrition

More than 20% of the U.S. labor force works in an agriculture-related occupation. Approximately 540,000 are employed in the meat, poultry, and dairy production industry. Careers associated with nutrition are many, and may be directly or indirectly related to nutrition. Careers include: agricultural instructors, livestock producers/farmers, nutrition specialists, feedlot managers/employees, feed sales reps, horse trainers, feed store managers, veterinarians, and nutrition researchers.

Most occupations require a college degree or years of experience. More and more areas are requiring a Master's degree or other advanced degree. Today, most feed sales reps are required to have a college degree.

Nutrition Guidelines

The work of research scientists in agriculture has resulted in greatly improved methods of feeding livestock. Many U.S. Agriculture Experiment Stations conduct feeding trials. Results of these experiments relate to the value of feeds and rations under controlled feeding conditions.

The National Research Council of the National Academy of Sciences in Washington, D.C. develops the requirements for different livestock species. The respective sets of requirements are available in publications specific to each species, such as *Nutrient Requirements of Dairy Cattle.* Sub-committees on each species are formed to review the requirements that were set through years of experimentation. The National Research Council (NRC) revises and/or reviews its requirements every several years to keep up with new information discovered through continuing research.

Feed Tags

Before evaluating feed tags, remember one thing--feed tags do not tell the whole story. Investigate the reputation of the feed company before buying any of their products. Companies that have gained the trust of consumers and stood the test of time are good indications of a quality product. When crude protein percentages are given on a tag, a consumer has no idea what type of protein was used. (State regulations do not require this information.) These proteins could be rapidly soluble, slowly soluble, or bound. Find out as much as you can about a product before buying.

Individual states generally regulate the manufacturing and sale of feeds. However, regulations relating to feed additives are made by the federal government. The Association of the American Feed Control Officials has published the "Uniform State Feed Bill," which is followed by many states when preparing their regulations of feed manufacture and sale. This results in a fairly of uniform state regulations.

Major provisions of most state feed laws, rules and regulations include (1) registration of feed manufacturers; (2) labeling requirements; (3) prohibited acts; (4) definitions of misbranding and adulterations of feed; (5) a schedule of inspection fees and reports; (6) inspection, sampling and analysis procedures, and (7) penalties for violations.

The feed tag found on a bag of commercial feed is important to the livestock producer. It contains information about the content of the feed and its proper use. The format and content of the feed tag are regulated by state laws.

FIGURE 1.1 - Sample Feed Tag

NET WEIGHT 50 LBS.

SUPER COW
16% TEXTURED

GUARANTEED ANALYSIS

Crude Protein, not less than 16.0%
Crude Fat, not less than 3.0%
Crude Fiber, not more than 7.5%

INGREDIENTS

Grain Products, Processed Grain By-Products, Plant Protein Products, Animal Protein Products, Cane Molasses, Salt, Calcium Carbonate, Dicalcium Phosphate, Manganese Oxide, Ferrous Sulfate, Copper Sulfate, Magnesium Oxide, Potassium Chloride, Cobalt Carbonate, Zinc Oxide, Ethylenediamine Dihydriodide, Sodium Selenite, Lignin Sulfonate and Sodium Bentonite (pellet binders), Vitamin A Acetate, D-Activated Animal Sterol (source of Vitamin D-3), Vitamin E Supplement, Niacin Supplement, Dried Lactobacillus Acidophilus Fermentation Products, Zinc Methionine.

FEEDING DIRECTIONS

Feed Super Cow 16% Textured as a high-energy supplement to excellent legume hay or haylage or lush legume-grass pasture when used as the only source of roughage for the lactating cow. Feed 1 lb. of this feed for each 2-3 lbs. of milk produced.

Manufactured by
MFA INCORPORATED
Columbia, MO 65201

378X1F 1WR56244 5624

Generally, the tag contains the following information:

1. Net weight
2. Product name and brand name
3. Guaranteed analysis of the feed
   - Minimum percentage of crude protein
   - Maximum or minimum percentage of equivalent protein from nonprotein nitrogen
   - Minimum percentage of crude fat
   - Maximum percentage of crude fiber
   - Minimum and maximum percentages of calcium and salt
   - Minimum percentage of phosphorus
   - Other minerals
   - Vitamin content
4. When drugs are used as an additive:
   - The word "medicated" must be on the label.
   - The medication's purpose must be stated.
   - Directions for use and precautionary statements must be included.
   - A list of active drug ingredients must be given.

Certain exemptions on labeling are common.

1. No mineral guarantee is needed *if* no label claims concerning minerals are made, *and* the total mineral content is less than 6.5% of the total contents.
2. Vitamin information is exempted when the feed contains no claims concerning vitamins or is not being sold as a vitamin supplement.
3. Crude protein, crude fat and crude fiber guarantees are exempted if the feed is not intended to furnish these substances or if they are a minor part of the total ingredients, i.e., in drug premixes, mineral or vitamin supplements, and molasses.

This general description of feed tag labeling is not intended to be a specific guide for a given state. Instead, the Department of Agriculture in each state establishes committees to set state standards. The feed laws, rules and regulations of each state should be considered to determine specific requirements for that state.

Economic Importance of Understanding Nutrition

As was stated before, agriculture is big business in the United States. About one-half of farm cash receipts come from the sale of livestock and livestock products.

The cost of feed is 50-75% of the total cost of raising livestock. Careful attention to animal nutrition can help reduce feed costs and thus increase the potential profit from livestock. However, the lowest cost feed ration may not be the most profitable. Feeding efficiency and

nutrition value must also be considered when selecting rations.

It is estimated that 65-80 percent of the total cost of production in a swine operation is for feed. Poultry feed costs range from 55 percent (layers) to 65 percent (broilers and turkeys) of the total cost. Dairy feed costs range from 50-60 percent of the total cost of milk production. Feed costs for a cattle finishing operation are approximately 70 percent of the total cost of feeding cattle. Feeder lamb feed represents about 50 percent of the total cost of production.

General Functions of Nutrients

An animal uses feed for several purposes. Some are basic to all animals, and some are specific to the purpose of the animal. Basic uses include maintenance, growth, and reproduction. Uses reflecting the purpose of the animal include finishing, fitting for show, production, and work.

Maintenance - A maintenance ration is one that maintains basic life processes without any work or production being done. A maintenance ration must supply (1) heat to maintain body temperature; (2) energy for vital functions and a minimum amount of movement, and (3) small amounts of protein, minerals and vitamins.

Oxidation of food in the digestive tract and of nutrients in the muscles and other tissues produces heat. The rate of oxidation is relatively constant and occurs at a low temperature. An animal at rest must still maintain activity in such vital organs as the heart and lungs, as well as other internal organs. Animals that are standing require a higher rate of oxidation of nutrients than those lying down (because of the muscle tension needed to remain standing). Even more energy is needed when an animal moves around. Maintenance rations for mature animals, except swine and poultry, can be mostly roughages that yield enough heat but are relatively low in energy value.

An animal's maintenance requirement is relative to its body surface and its weight. Some protein is required in the maintenance ration because there is some breakdown of protein in body tissues each day. There is also daily loss of calcium and phosphorus from the body of an animal. For this reason, a small amount of protein in the maintenance ration replaces the loss. Salt and a small amount of vitamins A and D are also needed in maintenance rations for most species of livestock.

Growth (assimilation of tissue) - During the growth period, there is a substantial increase in the size of muscles, bones, internal organs, and other body parts. Animals need nutrients to grow properly so that they will be efficient producers when mature. The full genetic potential of an animal cannot be reached if it is not fed a well-balanced ration during the growing period.

Young, growing animals have more nutritional needs than do mature animals. A shortage of digestible nutrients or net energy during growth will result in slower growth or smaller size when animals mature.

Reproduction - If the livestock producer is to make a profit, animals must reproduce. Poor nutrition is a major contributing factor to reproductive failure. The production of sperm and the quality of semen is influenced by the ration's quality. Males that are too fat may become temporarily or permanently sterile. Rations balanced with the proper nutrients improve fertility.

Finishing - Animals such as beef, swine, lambs, and broilers that are fed for meat need nutrients above the maintenance requirements for fattening. Nutrients for fattening animals come mainly from carbohydrates and lipids in the ration. Unneeded protein may also be converted into body fat.

Fitting for show - Animals being fitted for show purposes are fed a liberal supply of carbohydrates and fats, usually through the addition of more grain in the ration. Mature animals being fitted for show need little additional protein, minerals, and vitamins above the maintenance requirements. However, young and growing animals must be fed more liberal amounts to reach the desired level of finish for show purposes.

Production - The production of milk requires a liberal supply of energy, protein, minerals, and vitamins in the ration. For milk production, the

quantity of milk and its fat content influence the amount of nutrients needed above the maintenance level. Wool and mohair have high protein content; therefore, rations for sheep and goats must contain an adequate protein level to meet this production need.

Work - The production of work is limited mainly to horses. Riding and racing require additional nutrients for efficient production. As the amount of work increases, so does the animal's energy requirements. Animals require additional nutrients in relation to the kind of terrain they are on, and whether or not they are in confinement feeding. Also, when animals are on pastures, the distance to feed and water influences the amount of nutrients needed.

Summary

Producers are rarely interested in just maintaining animals, yet the maintenance requirements must be met before animals will provide any productivity. Because of the great impact that nutrition has on the overall success of a livestock operation, it is important to have a basic understanding of animal nutrition.

Credits

Cullison, Arthur Edison. *Feeds and Feeding.* 4th ed. Reston, VA: Reston Publishing Co., 1987.

Gillespie, James R. *Animal Nutrition and Feeding.* 4th ed. Albany, NY: Delmar Publishers, Incorporated, 1987.

Lesson 2:
Livestock Digestive Systems

Livestock digestive systems fall into four basic types: ruminant, nonruminant, modified nonruminant, and avian. A ruminant animal has a four-compartment stomach that aids in digestion of roughages. The nonruminant digestive system is very similar to the human digestive system. It is considered a simple stomach system, which is unable to digest roughage effectively. A modified non-ruminant digestive system is also a simple stomach system, but it has an active cecum that helps digest roughages. The avian digestive system does not have a true stomach; it uses several organs to aid in concentrate digestion.

Digestive Parts and Functions of Ruminants, Nonruminants and Modified Nonruminants

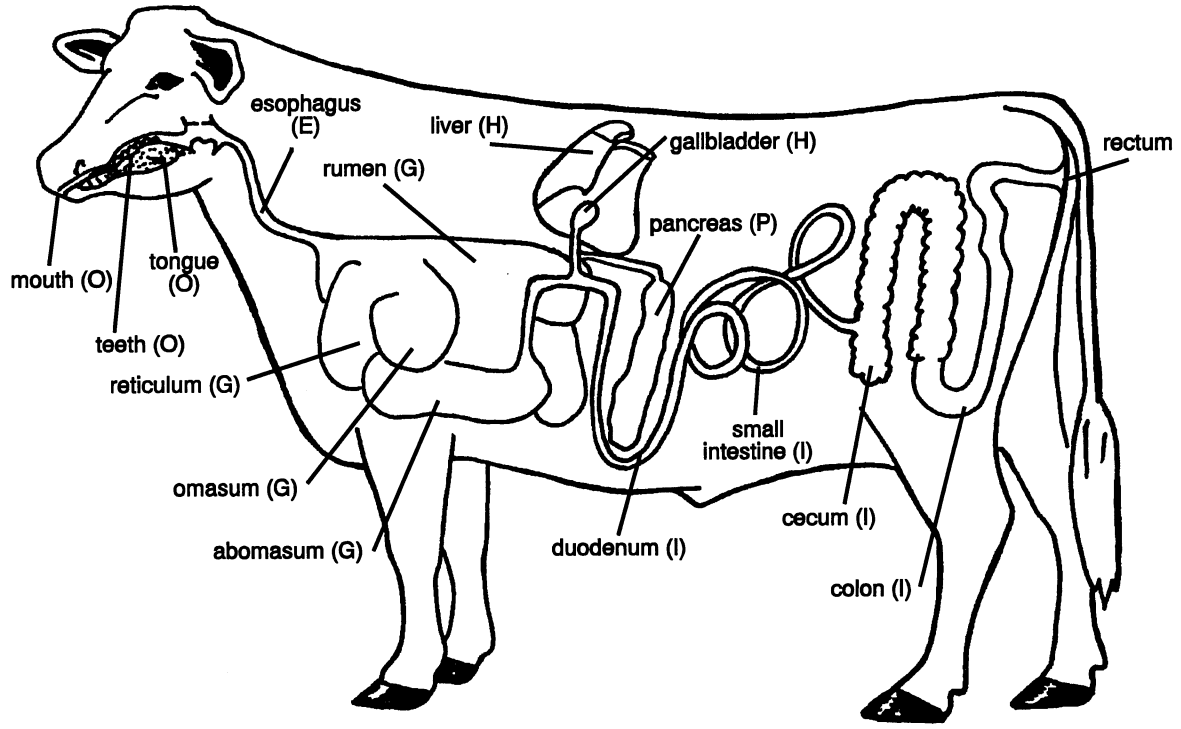
Oral region - The oral region includes the mouth, teeth, and tongue. Three physical processes take place here. Prehension is the process of bringing food into the mouth, which can occur in several ways. Humans use their fore limbs to bring food into their mouth. Livestock take in feed through the mouth, tongue, lips, and teeth.

The second process is mastication--the chewing of food once it enters the mouth. Mastication begins by physically tearing and grinding the food into smaller particles. Saliva is also added to food during mastication.

The third process is called deglutition, or swallowing the food, which occurs after saliva is mixed and chewing has taken place. These three physical processes occur in all digestive systems, except the avian's.

Esophageal region - This region includes the esophagus, pharynx, and the larynx. The esophageal region applies to all classes of livestock. At the top of the esophagus is the pharynx, which controls the passage of food, water, and air. When deglutition occurs, the

FIGURE 2.1 - Digestive System Parts of a Ruminant
NOTE: Drawing does not show exact anatomical placement.



larynx closes. This allows the feed to go into the esophagus--not into the respiratory tract. The muscular tube that extends from the mouth to the stomach is called the esophagus.

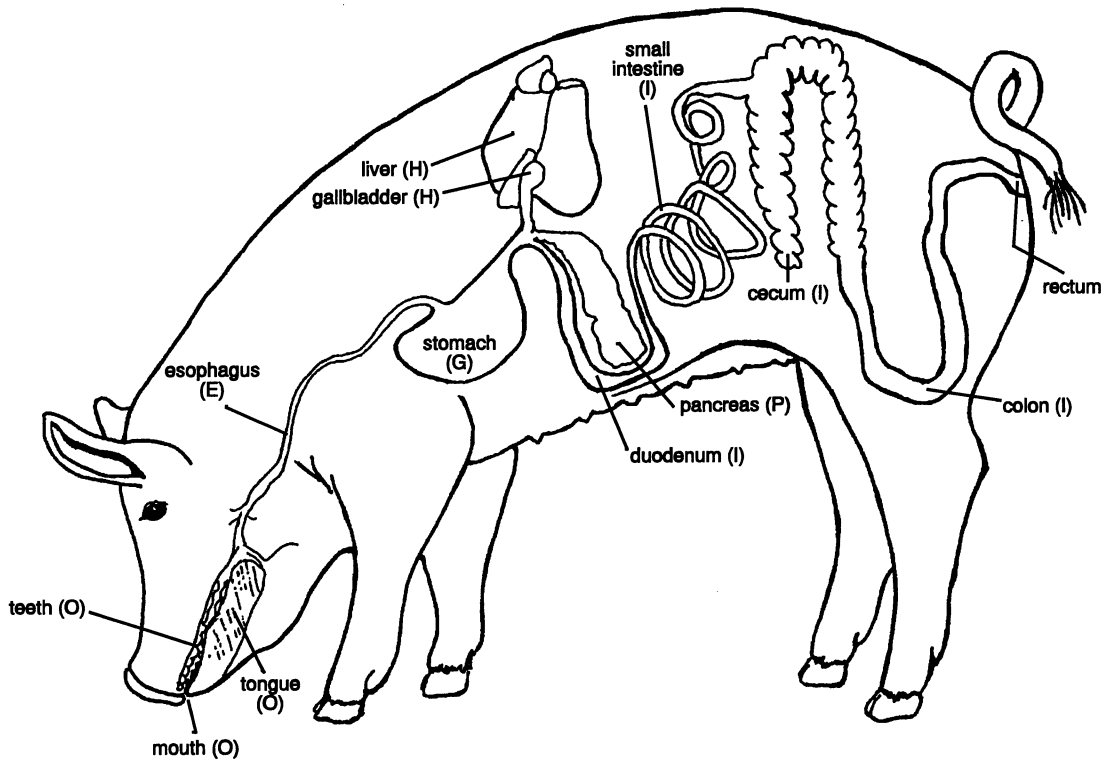
Peristalsis is the coordinated contraction and relaxation of smooth muscles. This process creates a unidirectional movement, which pushes food through the digestive system. For further digestion of food, peristalsis is reversed in ruminants through belching or vomiting. Reverse peristalsis is considered an abnormal function in other digestive systems.

Gastric region - The gastric region in ruminant animals consists of four compartments: the rumen, reticulum, omasum, and abomasum. In the rumen and reticulum area, bacteria and protozoa are present to aid in digestion. These microorganisms digest carbohydrates, and produce carbon dioxide and volatile fatty acids. The fatty acids are then absorbed as a source of energy. Carbon dioxide is released through belching. Once food enters the gastric region, the food is mixed and stirred with water through muscular action in the rumen. Vitamins K, C, and B complex are synthesized in the rumen. Since the vitamins are synthesized, there is no need to supplement these vitamins in the diet if quality feedstuffs are provided in the diet.

The major function of the omasum is to grind the partially digested food further. The omasum also absorbs a small percentage of water from the partially digested food. Finally, the omasum absorbs some of the volatile fatty acids as food passes through the digestive tract.

The abomasum is considered the "true stomach" of the ruminant animal. In the abomasum, digestive juices are added, which contain acids and enzymes that increase the moisture content of the feed. This mixture becomes acidic in nature because of the added acids. This also occurs in nonruminant and modified nonruminant

FIGURE 2.2 - Digestive System Parts of a Nonruminant



animals. Protein is digested here and in the small intestine.

The gastric region for nonruminant and modified nonruminant animals is based on a simple stomach system. With the enzymes and acids present in the stomach, digestion begins on proteins. Fats are partially broken down in the stomach. Carbohydrates move the fastest through the stomach, because digestion occurs in the small intestine.

Pancreatic region - The pancreatic region consists of one organ: the pancreas. It is made up of two glands, the endocrine and exocrine glands. The endocrine gland secretes the hormones insulin and glucagon. These hormones are necessary for digestion in the small intestine. The exocrine gland secretes trypsinogen, which is an enzyme necessary for digestion. Trypsinogen is produced in an inactive form, and then activated in the small intestine. The pancreas serves the same function in all four classes of livestock.

Hepatic region - In this region are two organs: the liver and the gallbladder. The liver is the largest gland in an animal's body. It serves the same purpose in ruminants, nonruminants, and modified nonruminants. The liver is one of the most important digestive organs for all animals, including humans.

The liver provides many physiological functions. It produces bile, which is an essential fluid for lipid (fat) absorption. The liver is used in detoxification of harmful compounds. It also acts as a storage facility for vitamins and carbohydrates. The liver aids in metabolism of proteins, carbohydrates, and lipids. The liver destroys red blood cells so more blood cells can be made. It is used in the plasma proteins and urea formation in all livestock except avians. Polypeptide hormones are deactivated in the liver, as well.

The only function of the gallbladder is to store bile produced by the liver. Gallbladders serve the same purpose in ruminants, nonruminants, and poultry. Some animals do not have a gallbladder (horses, rats, gophers, doves, pigeons, elephants, moose, elk, deer, camels, and giraffes).

Intestinal region - The intestinal region consists of four organs: the duodenum, colon, cecum, and the small intestine. Fats are emulsified in the duodenum. When fats are mixed with bile in the duodenum, they become soluble in water. This process is called emulsification. Once fats are emulsified, they are absorbed into the bloodstream in the small intestine.

Proteins and carbohydrates are broken down further in the duodenum, where the food mixture becomes neutral when alkaline enzymes are added. Bile and pancreatic fluids are added to the partially digested food mixture in the duodenum. The duodenum functions similarly in ruminants, nonruminants, and modified non-ruminants. Avians do not have a duodenum.

Except for water and fiber, all nutrients are absorbed into the bloodstream in the small intestine. At this point in digestion, food is broken down enough to be absorbed into the bloodstream and used by the animal. Absorption takes place in the small intestine by hairlike projections called villi. Villi are used to increase the surface area in the small intestine so more nutrients can be absorbed.

Peristalsis occurs in the small intestine so undigested food can be pushed through the colon, cecum and finally through the rectum. The small intestine functions similarly in all classes of livestock, except the avian class.

The cecum functions similarly in all classes of livestock, except poultry. It has a very limited function in nonruminant animals--the storage of microorganisms. In ruminant animals, the cecum absorbs 5-15 percent of the fiber the animal eats. It also stores microorganisms needed for ruminant fiber digestion. The modified non-ruminant cecum is much larger than other classes of livestock. It is also very functional. Roughage is totally digested in the cecum in modified nonruminant animals.

The colon functions similarly in ruminant, non-ruminant, and modified nonruminant systems. Water is absorbed and fecal formation occurs in the colon. Mucus is added to the fecal matter to provide lubrication. The fecal mixture remains neutral during this process.

Parts and Functions of the Avian Digestive System

Oral region - Only two physical processes occur in this region. In prehension, the beak and tongue of the bird bring food into the mouth. Deglutition is the process of swallowing. In avians, food goes directly into the mouth and down the esophagus; mastication does not occur.

Esophageal region - This region includes the esophagus, pharynx, and larynx. At the top of the esophagus, the pharynx controls the passage of food, water, and air. When deglutition occurs, the larynx closes. This allows the feed to go into the esophagus--not into the respiratory tract.

The muscular tube that extends from the mouth to the crop is the esophagus. In peristalsis, the coordinated contraction and relaxation of smooth muscles creates a unidirectional movement. This movement pushes food through the digestive system. Reverse peristalsis is considered an abnormal function.

Gastric region - In avians, the gastric region uses both chemical and mechanical processes to aid digestion. Three organs make up the gastric region: the crop, proventriculus, and gizzard. The crop stores food after it enters the body. Mucus is secreted in the crop and added to the food to softens and lubricates it. The food then moves from the crop to the proventriculus, where it secretes gastric fluids and adds these fluids to the slightly digested food. The food then continues on to the gizzard, a muscular organ that mechanically mixes and grinds food. The gizzard acts as mixing machine for gastric fluids and food. Grit, which accumulates in the gizzard, is sometimes added to the diet to aid in digestion. Grit, plus the mixing motion, replace teeth for the grinding and tearing of food.

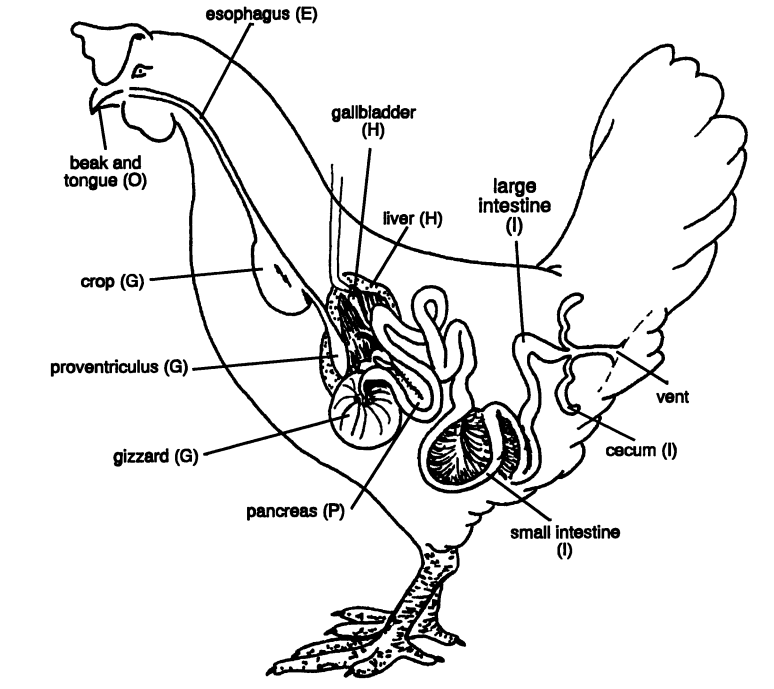
Pancreatic region - This region consists of one organ: the pancreas. The pancreas is made up of two glands: the endocrine and exocrine glands. The endocrine gland secretes the hormones insulin and glucagon, which are necessary for digestion in the small intestine. The exocrine gland secretes trypsinogen, an enzyme necessary for digestion. Trypsinogen is is produced in an inactive form and then activated in the small intestine by pH changes.

Hepatic region - The hepatic region consists of two organs: the liver and the gallbladder. The liver is a very important digestive organ and is the largest gland in an animal's body. It serves the same purpose in all classes of livestock. The liver aids in digestion for all animals--including humans.

The liver provides many physiological functions; it produces bile, an essential fluid for lipid absorption. It detoxifies harmful compounds and stores vitamins and carbohydrates. Metabolism of carbohydrates, proteins, and lipids is aided by the liver. It also destroys red blood cells so more blood cells can be made. The liver is needed to form plasma proteins and to deactivate polypeptide hormones.

The only function of the gallbladder is storage of the bile produced by the liver.

FIGURE 2.3 - Digestive System Parts of an Avian



Intestinal region - Three physical movements occur in the small intestine which aid in the movement of digested food through the intestinal region: pendular motion, segmentation contractions, and peristalsis. Pendular motion mixes food by shortening and lengthening the intestine. Segmentation contractions are ringlike contractions that mix food at regular intervals. The last movement is peristalsis, the coordinated contraction and relaxation of smooth muscles. The small intestine is the primary organ in digestion and absorption in the avian class. Special enzymes in the small intestine provide an effective and efficient manner of breaking down proteins, lipids, and carbohydrates into particles that can be absorbed.

The ceca is a blind-ended tube found at the junction of the small intestine and the large intestine. Ceca (two or more) is the plural form of cecum. Poultry have two nonfunctioning cecum in their digestive systems.

The function of the large intestine, or colon, is to remove water from digested food for fecal formation. Urinary and fecal materials are mixed in the cloaca before they leave the body through the vent.

Summary

All of these digestive systems use chemical and mechanical processes to help in digestion and absorption.

Credits

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Ensminger, M. E., and C. G. Olentine, Jr. *Feeds and Nutrition.* 2nd ed. CA: The Ensminger Publishing Company, 1990.

Largen, Velda L. *Guide to Good Food.* South Holland, IL: Goodheart-Willcox Company, Inc., 1988.

Lesson 3:
Energy's Role in Livestock Nutrition

Two sources of energy are carbohydrates and fats. As in humans, excess energy consumption in livestock results in fat storage in the body (excess body weight). For the producer, the right balance of carbohydrates and fats in a ration can also mean lower production costs.

Basic Functions of Energy

Maintenance of life - Nutrients providing energy are needed for maintenance. Work done by the animal's vital functions is called its basal metabolism. The basal metabolism of an animal is the animal's heat production while it is at rest and not digesting food. Vital life processes, such as the beating of the heart, maintenance of blood pressure, nerve impulse transmission, breathing, and the work of other internal organs depends upon a supply of nutrients.

Energy nutrients are oxidized in the muscles to keep them in a state of tension. An animal requires more energy standing than lying down, and even more energy to move about or do work.

Energy supplies the fuel that maintains the body temperature of the animal. There are several sources of heat to maintain body temperature. These include the work of the vital organs, normal activity of the animal, work done by the animal, and shivering.

Growth and production - It is only after all the maintenance needs of the animal are met that energy nutrients can be used for growth and production. Some energy is also lost through the feces, urine, and gases produced by the body.

Fattening livestock requires a large amount of energy nutrients. Energy is used in the secretion of milk and the production of eggs and wool. The energy not used for other needs becomes fat within the body tissues. Fat deposits in the tissues makes the meat tender, juicy, and gives it a better flavor.

The energy requirements of lactating animals are almost twice as high as for those not producing milk. This energy must also be in the form of net energy. A shortage of energy in the ration will limit milk production, although the animal will use some body fat for milk production if the ration is energy deficient.

Energy is used for the development of the fetus in pregnant animals. It is important that rations during the gestation period have sufficient energy to maintain the animal in a healthy condition without its getting too fat.

When feeding working horses, energy above the needs for maintenance must be provided for work. Several factors affect the amount of energy needed, including the intensity and duration of the work, the condition and training of the horse, the ability and weight of the rider or driver, the horse's degree of fatigue, and environmental conditions under which the horse is performing work.

Carbohydrates and Fats (Lipids)

Carbohydrates and lipids are the major sources of energy in livestock rations. Some energy also comes from protein in the ration. Of these sources, carbohydrates are the most readily available, are easily digested in greatest quantities in most feeds, and are generally lower in cost. Lipids (fats and oils) are the second most important source of energy for livestock. However, during warm weather, it is difficult to store feeds that are high in fat content because they tend to become rancid (bad odor and flavor). This makes the feed unpalatable, and animals are reluctant to eat it. Sometimes, rancid feed may cause digestive disturbances, making the animal sick. Proteins are seldom fed for their energy content because of the higher cost.

Carbohydrates - Carbohydrates make up almost 75 percent of a ration. Carbohydrates are organic compounds that contain three major elements: carbon, hydrogen and oxygen. Growing plants produce carbohydrates by photosynthesis (6 CO_2 + 6 H_2O + energy from the sun = $C_6H_{12}O_6$ [glucose] + 6 O_2). Carbohydrate compounds found in plants include starch, sugars, hemicellulose, cellulose, pectins, gums, and lignins. Most carbohydrates are combinations of sugars. One way carbohydrates are classified is by the number of sugar

molecules they contain. For example, monosaccharides contain one sugar molecule.

The simplest carbohydrates are sugars. Sugars are the most easily digested, while cellulose and lignin are more difficult to digest. Sugars provide the energy requirements necessary for various body functions.

Carbohydrates make up about 75 percent of all dry matter in plants. The more easily digested forms of carbohydrates are generally found in the seeds, roots, and tubers of the plants. Most carbohydrates are combinations of saccharides or sugars. One way carbohydrates are classified is by the number of molecules of sugars they contain. For example, monosaccharides contain only one sugar molecule.

The plant's fiber cells contain hemicellulose and cellulose, which are harder to digest. As a result of digestion, some of the hemicellulose and cellulose are converted to glucose. Because digestion of these forms is more difficult, they are less efficient sources of energy for the animal.

Carbohydrates fall into two groups--fiber and nitrogen-free extract (NFE). Fiber contains hemicellulose, cellulose, and lignin. The NFE group includes sugar, starch, some hemicellulose, and the more soluble parts of cellulose.

Starch is made up of many molecules of glucose. Plants store energy as starch in grain. Grains have a high feeding value because the starch digests easily.

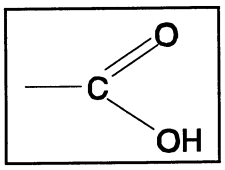
An animal's ability to use fibrous sources of carbohydrates is related to the bacteria in the digestive system. Ruminants, which have a high bacteria population in the rumen, also make use of energy from the ration's fiber portion. Bacterial action breaks down the fiber into volatile fatty acids, which are absorbed through the rumen wall. Roughage in a ruminant's ration can provide much of the maintenance energy needed by the animal. On the other hand, avians and animals with one stomach are less able to use energy from fiber.

To prevent excessive weight gains, increase the level of fiber in the ration for mature breeding animals. Fiber helps keep an animal's waste elimination "regular." Fiber is also an important part of the ration, keeping the monogastric (single-stomached) animal's digestive system regular, and giving the feed bulk.

Lipids (fats and oils) - Chemically, lipids are made up of carbon, hydrogen, and oxygen. There is more carbon and hydrogen and less oxygen in a fat molecule than in a carbohydrate molecule. Therefore, lipids supply approximately 2.25 times as much as energy as an equal weight of carbohydrates.

At body temperature, fats are solids and oils are liquids. In animal nutrition, both are generally called fats.

FIGURE 3.1 - Carboxyl Group



Fat composition - Fats are composed of two units--fatty acids and glycerol. Fatty acids consist of a carbon chain, 2-20 carbons in length, which contains a carboxyl group (COOH). Saturated fatty acids contain carbons attached with all single bonds. Unsaturated fatty acids contain carbons attached by double bonds. These double bond sites are chemically reactive; as a result, they are less stable than saturated. As the number of double bonds increases, the melting point of fat is lowered and the fats become softer (oils).

Glycerol is the second constituent of fat. Fats are formed when one glycerol combines with three fatty acids to form a triglyceride.

Rancidity - Bad odors and flavors may be a problem with both saturated and unsaturated fats. Oxidative rancidity occurs only in unsaturated fats. The presence of oxygen is needed, and rancidity is favored by moist conditions. Rancid foods have a changed flavor, odor, and nutritional value because essential fatty acids are destroyed. Rancidity is part of hyperoxide formation, which promotes aging and destroys the immune system. It can be prevented with antioxidants (Vitamin E) and by storing fats in a cool environment.

Three fatty acids (linoleic, linolenic, and arachidonic acids) are considered dietary

essential nutrients since they are not synthesized by nonruminants. However, these fatty acids *are* synthesized by microorganisms in the rumen.

Fat storage - The animal body stores fat as marbling in the muscle tissue or in adipose (fatty) tissue. Adipose tissue contains reserve energy, which an animal could use to help sustain life if feed supplies were cut off.

Fats can raise the energy level of the diet and/or the flavor, texture, and palatability of the feed. Added fat will reduce the dustiness of the feed. Show animals are sometimes fed rations high in fat to improve the glossiness of the hair coat.

Rations for adult animals should contain no more than 3-5 percent fat for ruminants and 15-20 percent fat for non-ruminants. Because fats carry fat-soluble vitamins, some fat in the ration is desirable. Too much fat in the diet will reduce feed intake and increase the chances of scouring (diarrhea).

Absorption of Carbohydrates and Lipids

Carbohydrates - Most carbohydrate absorption occurs in the small intestine; a small amount is absorbed in the large intestine. Starches and sugars are converted to glucose, fructose, and galactose. Crude fiber converted to short, chained fatty acids or glucose by digestion. By osmosis, nutrients pass into the blood capillaries through semipermeable membranes of the digestive tract, then through the liver and into the bloodstream for circulation throughout the body.

Lipids - The digestion process separates fatty acid from the glycerol molecule. Fatty acid is absorbed into lacteals (lymphatic vessels) and then into the bloodstream, where it moves to various parts of the body and is recombined with glycerol to form fat.

Sources of Energy for Animals

Primary sources of energy nutrients are grain and grain by-products. Feeds are energy concentrates when their crude protein content is less than 18 percent.

Shelled corn - The highest energy feed available for livestock rations is shelled corn. It is the most widely grown and used feed grain crop. Corn produces more pounds of total digestible nutrients (TDN) per acre than any other feed grain. It is an economical and superior source of energy for livestock.

Oats - Oats have about 85 percent of the energy of shelled corn. They are higher in crude protein than shelled corn and add fiber and bulk to the ration. When fed to ruminants, oats help to maintain the rumen function. Oats are not a good fattening feed, but they are used extensively for horses, young growing stock, show stock, and breeding animals. Oats are generally rolled, crimped or ground for feeding.

Barley - Barley is almost equal to corn in energy value, but it lies between corn and oats in fiber content. It is used in the ration similarly to oats. Barley can replace up to 50 percent of corn in fattening animal rations. To improve taste, barley is usually steam rolled, crimped or coarsely ground. Barley is sometimes cooked to improve its taste when used for beef show animals.

Grain sorghum - There are many varieties of grain sorghum, including milo, kafir, and various hybrids. Most grain sorghum is grown in the western part of the U.S. in semi-arid regions where corn does not grow well. Grain sorghum is similar to shelled corn in composition and can replace up to 100 percent of the corn in a feedlot ration. It is usually rolled or crimped when included in livestock rations.

Forages (roughages) can supply some energy needs in the livestock ration, although they are not as concentrated an energy source as grains. The value of forages for livestock feed is highly dependent on the time of harvesting. As forage plants mature, the crude fiber content increases, which lowers the digestibility of the feed.

Corn silage - Corn silage, which contains almost 50 percent grain, is an excellent energy source for certain classes of livestock, such as cattle.

Hay - Good quality hay, especially legumes, can provide almost all of the energy needs of a ruminant animal. The quality is greatly dependent upon the time of harvesting.

Pastures - Properly managed pastures can be a good source of nutrients for livestock. Rotate and fertilize pastures to get the best yield and nutritional value.

Fat - Feed-grade animal fat is a byproduct of packing, poultry processing, and animal rendering plants. Animal fat is an economical source of energy used in the manufacturing of commercial mixed feeds. Commercial feed mixes contain 1-7 percent animal fat, depending on the type of feed. Animal fat in the feed reduces the dustiness of the feed, improves its color, texture and palatability, reduces wear on feed mixing equipment, and improves pelleting characteristics.

Deficiency and Toxicity Symptoms

Deficiency - Too little energy in the ration causes several problems for all classes of livestock. Typical of these are:

1. Slower growth in the young
2. Delay in the onset of puberty
3. Decrease in milk yield in lactating females
4. Shortened lactation period
5. Loss in body weight
6. Several kinds of reproductive problems, including reduced fertility and delayed estrus
7. In sheep, a reduction in wool quantity and quality
8. Higher mortality rate
9. Lowered resistance to disease and parasites
10. Weakness, generally poor condition, and an unthrifty appearance
11. Loss of subcutaneous fat
12. Reduction in levels of blood glucose, calcium, and sodium.

Toxic effects - Feeding too much energy results in ketosis or obesity. Animals that are too fat can be less fertile, conceive less, and have delayed estrus.

Ketosis occurs when an animal has a higher energy demand (such as lactating dairy cattle) and a low supply of carbohydrates. To meet the energy demand, the animal increases the metabolism of fats. The increased fat metabolism rate overloads the liver with ketone acids. Ketone acids can provide energy for muscles but **cannot** provide energy for the brain.

If the situation is not corrected, glucose blood levels drop so low that the animal collapses, goes into a coma, and dies. This often happens to the best milk cows because of high energy requirements.

Summary

Fuel is supplied to the body by energy nutrients. The major sources of energy in livestock rations are carbohydrates and fats. Energy is used for digestion; absorption of nutrients; breathing; heart action; movement of muscles; production of milk, eggs, wool, and mohair; waste formation and excretion; and to supply heat to maintain body temperature. Some feed energy is lost through the feces, urine, and gases produced in the body. Excess energy not used to sustain life is stored as body fat.

Credits

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Lesson 4:
Protein's Role in Animal Nutrition

Every nutrient plays an important role in animal nutrition. Protein plays an integral part in several body functions in animals and humans. Protein deficiencies in humans appear as stunted growth, discolored skin, and body sores. Protein deficiencies are rare in humans because there is a great emphasis on proper diets. But there is an increasing problem with excess amounts of proteins in human diets. Unused, excess protein in a diet turns into body fat. Research has shown excess body fat leads to many health problems in humans. Good sources of protein for humans are poultry, fish, dairy products, and dried peas and beans.

Functions of Protein

Protein plays similar roles in livestock nutrition as it does in human nutrition. The word "protein" originates from the Greeks. It means "of primary importance." Proteins are the lumberyards that supply the materials necessary for building and maintaining the body. Proteins consist of carbon, hydrogen, nitrogen, and oxygen compounds.

Uses of protein include building, repairing, and maintaining body parts such as muscles, skin, body tissues, hair or feathers, and hooves. Protein also produces body regulators, such as enzymes and hormones. These body regulators aid in the reproduction, digestion, and health maintenance of an animal.

Protein is a good source in the production of blood glucose, which is an important function of proteins. Proteins can be modified for use in genetic compounds, such as DNA, RNA, and ATP. Proteins can also be used as energy when excess amounts are fed, but they are *only* used as energy after the body's needs are met. Proteins also function as precursors to some B-complex vitamins.

Loss of weight, rough hair coats, poor appetites, low digestive efficiencies, and lower reproduction rates are symptoms of animal protein deficiencies. If these deficiencies are not corrected, an animal may die and the investment will be lost. Death usually occurs because of a lack of amino acids, which are produced by proteins. Functions of protein and deficiency symptoms apply to each class of livestock.

The Role of Amino Acids in Protein Synthesis

During digestion, amino acids synthesize food proteins to be used for a specific physiological function. Genetic compounds, such as DNA and RNA, determine which proteins are needed by the body. This information is sent to the amino acids, which synthesize the proper protein for the situation. These proteins can be used for skin, hair, hoof, or muscle development. Amino acids are nitrogen compounds that originate from proteins fed to the animal. A good description of amino acids is "the bricks and mortar of which muscles, body tissues, skin, and hair are built."

Amino acids are separated into two groups: essential and nonessential. Essential amino acids must be provided in non-ruminant diets. Nonessential amino acids can usually be synthesized by the animal. There are 23 amino acids--10 essential ones and 13 nonessential ones. All classes of livestock require both essential and nonessential amino acids.

Classes of livestock synthesize amino acids differently. Ruminants can synthesize their own amino acids as long as enough nitrogen and protein are fed in the diet. Non-ruminants can produce some nonessential amino acids, but they cannot produce any essential amino acids. These must be provided in their diet. DNA serves as the information center that links amino acids together to form a specific protein. The role of amino acids is to link together to form a specific protein for a particular physiological function.

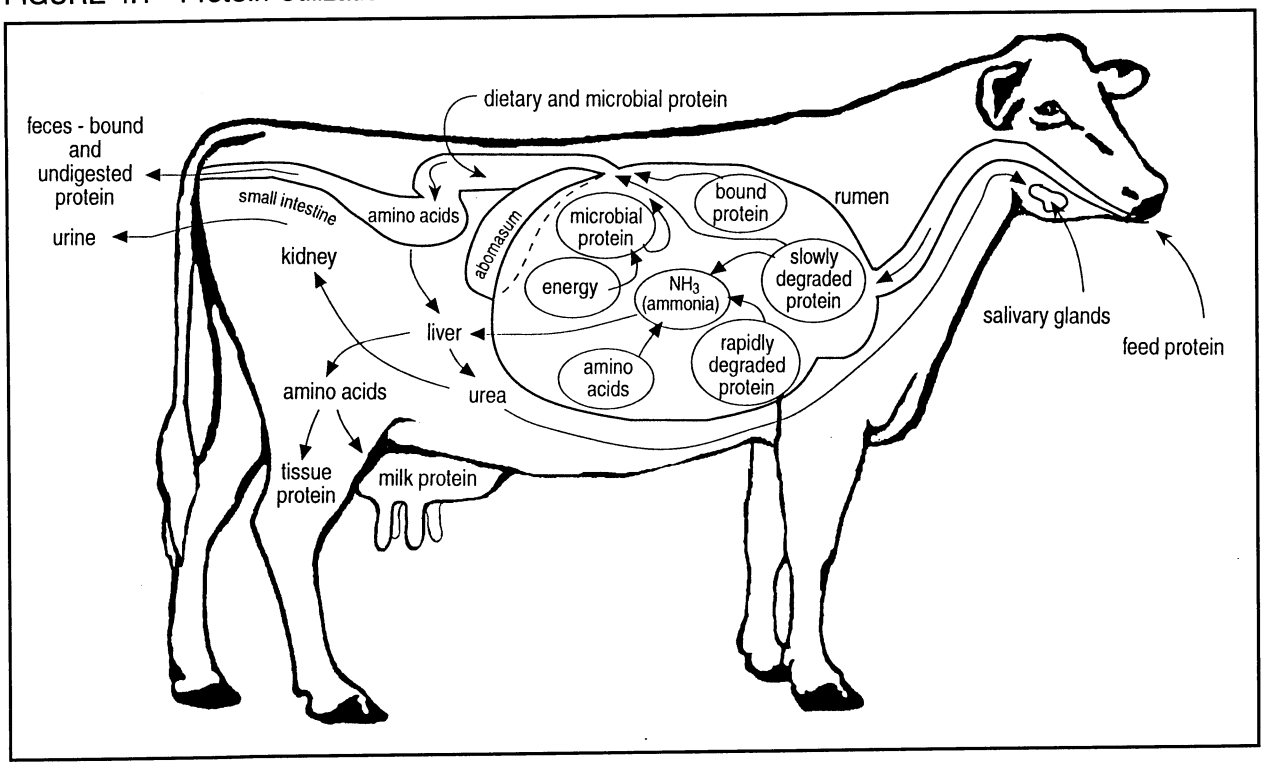
Essential Amino Acids

The 10 essential amino acids are:

Phenylalanine	Histidine
Valine	Arginine
Threonine	Lysine
Tryptophan	Leucine
Isoleucine	
Methionine	

There are 13 nonessential amino acids, as well.

FIGURE 4.1 - Protein Utilization in the Ruminant



Symptoms of Protein Deficiency

Symptoms of amino acid/protein deficiency are lack of growth, poor hair coat, lack of muscling, and lack of energy. Dietary proteins are necessary for amino acids, and amino acids are needed for making specific proteins for usage by the body. If a food is lacking in an essential amino acid and the animal cannot synthesize it, the amino acid must be supplied in the diet. For example, corn is deficient in lysine, which is an essential amino acid. Therefore, for certain proteins to be synthesized, lysine must be supplied from another feedstuff.

Sources of Protein

Strong sources of protein are very important as livestock feed. Protein sources are divided into three groups: animal, plant, and synthetic. Rations are figured by the percentage of crude protein (CP) supplied by a source. Therefore, all sources of protein are listed by percentage of crude protein. Following are some good sources of plant and animal protein sources. (Note: These are book value ranges. Home-raised protein sources should be tested for CP values.)

Animal protein sources
Feather meal, 87 percent CP
Blood meal, 80 percent CP
Fish meal, 60 percent CP
Poultry by-product meal, 55 percent CP
Meat scrap, 55 percent CP
Meat and bone meal, 50 percent CP
Dried skim milk, 34 percent CP
Dried whole milk, 25 percent CP

Plant protein sources
Sunflower meal, 47 percent CP
Soybean meal, 44 percent CP
Cottonseed meal, 41 percent CP
Rapeseed meal, 37 percent CP
Dehydrated alfalfa meal, 18 percent CP
Alfalfa hay, 15 percent CP
Red clover hay, 13 percent CP
Wheat grain, 12 percent CP
Oat grain, 12 percent CP
Corn grain, 9 percent CP

Synthetic protein sources - The most commonly used synthetic protein is urea. Urea can only be fed to ruminants because microbes present in these animals feed on the urea. It should be fed only to ruminants on high energy diets, such as

fat cattle on the dry lot. Urea consists of 45 percent nitrogen and is a good source for amino acids. Toxicity (poisoning) can occur if excess amounts are fed to ruminants. If the microbes cannot digest all of the urea, an ammonia byproduct is produced, which is damaging to the urinary tract.

Determining Which Proteins Should be Used

Ruminants - The first step in deciding which proteins to feed ruminants is to determine which proteins will feed the microorganisms or "bugs" in the rumen. These **microbes** can synthesize amino acids from nonprotein nitrogen that non-ruminants cannot.

A producer can choose true proteins, such as soybean meal or cottonseed meal. The other option is to feed a nonprotein nitrogen (NPN) feedstuff, such as urea or anhydrous ammonia. These two types of proteins supply nitrogen used by the microbes for protein synthesis.

When using true proteins such as plant protein or animal protein, crude protein does not determine digestibility (amount of protein available to the animal). Crude protein is the total amount of protein available in the feedstuff, but an animal cannot digest all the protein available. Digestible protein best describes the amount of protein used by the animal. Price, of course, is another influencing factor.

The next consideration is the **amount** of protein digested by the rumen. Most nonprotein nitrogen feedstuffs are digested and utilized by microbes in the rumen.

In Figure 4.1, nonprotein feedstuffs are considered rapidly degraded proteins. Excess amounts of nonprotein nitrogen can result in higher levels of ammonia in the rumen. Excess rumen ammonia is absorbed into the bloodstream and converted to urea in the liver. The nonprotein nitrogen (rapidly degraded protein) is converted into NH_3 (ammonia), and the excess enters the bloodstream, is transformed into urea in the liver, and leaves the body through the urine. Excess nonprotein nitrogen can result in ammonia toxicity due to high levels of blood ammonia. Only limited amounts of NPN can be used. (Four pounds of urea per cow per day is a safe maximum.)

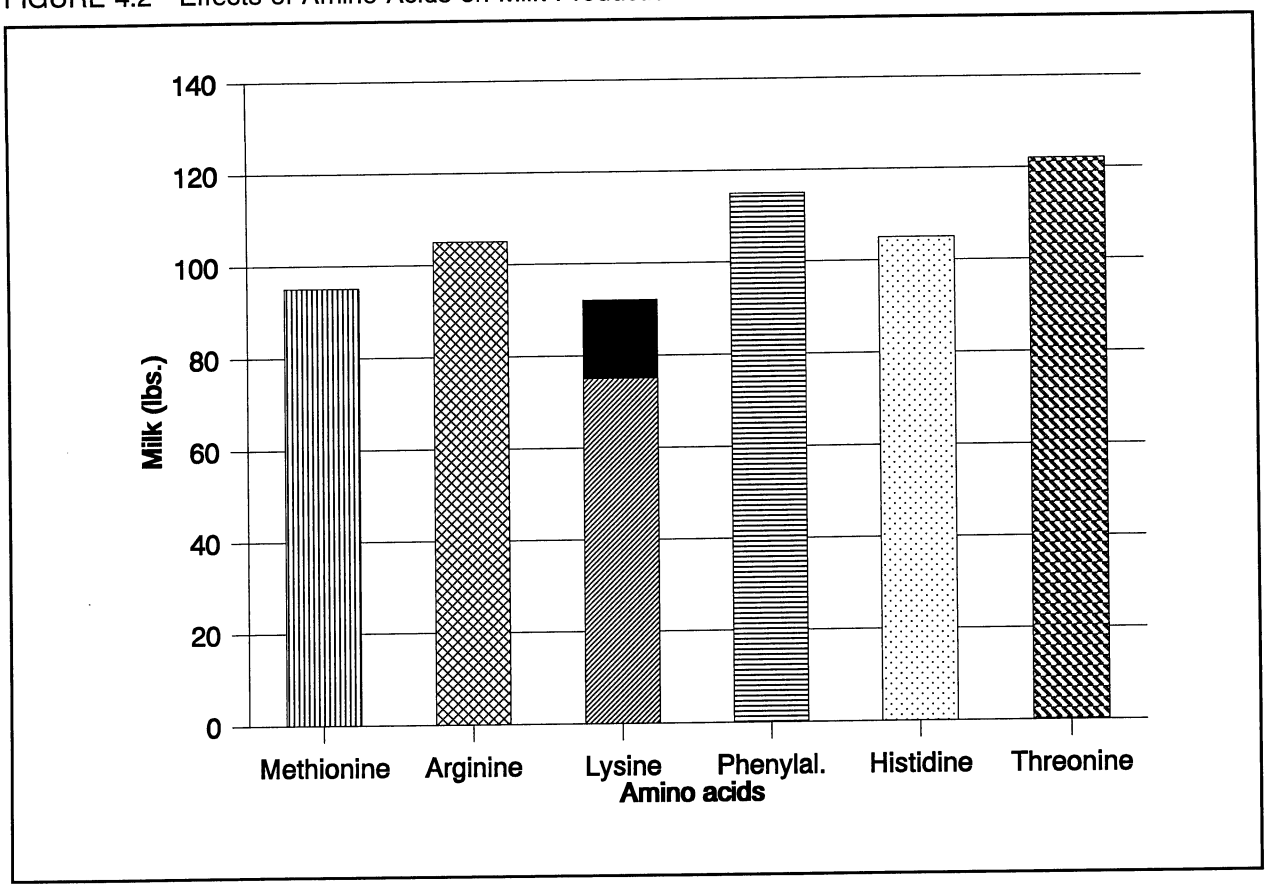
In Figure 4.1, bound proteins are the undigestible portions of true proteins. These proteins cannot be digested by the rumen or the small intestine. These proteins are the difference between crude protein and digestible protein. Bound proteins

TABLE 4.1 - Digestibility in Swine Feedstuffs

Source	*Crude Protein*		*Isoleucine*		*Leucine*		*Lysine*		*Meth. & Cystine*		*Threonine*		*Tryptophan*	
	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%	Tot.%	Total Dig.%
Blood meal	86	78	1.13	.75	11	9.24	7.85	6.51	1.91	1.45	3.57	2.9	1.08	.85
Meat and bone	61	44	1.66	1.11	3.7	2.63	3.1	2.29	1.9	1.33	1.86	1.2	.37	.23
Soybean meal	47.6	38.5	2.2	1.83	3.66	3.07	3.01	2.55	1.3	1.05	1.88	1.48	.57	.46
Raw soybeans	38	21	1.7	.88	3	1.56	2.5	1.52	1.2	1.0	1.6	.9	.46	.26
Heated soybeans	39	28	1.8	1.3	3.2	2.37	2.5	1.97	1.1	.83	1.6	1.15	.54	.38
Feather meal	83	59	3.69	2.9	6.63	5.1	1.59	.81	4.24	3.0	3.49	2.58	.42	.25
Corn	8	6	.32	.25	1.11	.95	.27	.18	.37	.11	.32	.07	.08	.004
100 lb. pig needs per day (4.1 lbs. feed total)	16			.019		.025		.031		.017		.02		.005

Source: "Apparent Ileal Digestibility of Crude Protein and Essential Amino Acids in Feedstuffs for Swine - 1992." Chicago, IL: Heartland Lysine, Inc., 1992.

FIGURE 4.2 - Effects of Amino Acids on Milk Production



enter and leave the body virtually undigested. There are also true proteins that are considered rapidly degraded proteins. A large part of these proteins are used by microbes in the rumen.

The last form of protein is slowly degraded protein. Part of these true proteins are digested in the rumen. Microbes in the rumen use some of them, and the remaining portions escape into the small intestine, where it is digested along with microbial protein and then used for muscle formation and milk production.

The last step in classifying feedstuffs is based on **rumen digestion.**

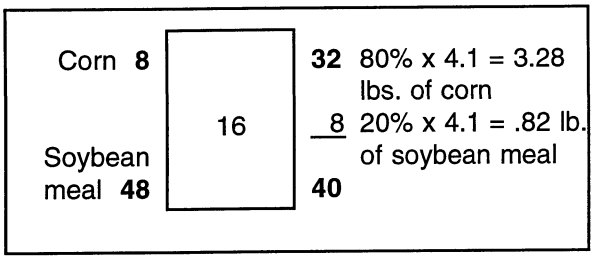
1. Soluble proteins disappear or are digested in two hours or less after entering the rumen. These proteins are classified as "rapidly degraded protein" in Figure 4.1. Example sources are urea, alfalfa silage, and anhydrous ammonia. Most of these proteins are used by microbial cells ("bugs").

2. Degradable proteins are broken down at a measurable rate over time. The amount of protein digested in the rumen depends on the rate and amount of time spent there. These proteins are classified as "rapidly and slowly degraded proteins" in Figure 4.1. These proteins are used by microbial cells and the small intestine. Examples are soybean meal and cottonseed meal.

3. Escape or bypass proteins bypass rumen digestion. Most of them are digested and absorbed in the small intestine. These proteins are classified as "slowly degraded proteins" in Figure 4.1. Examples are fish meal, blood meal, meat and bone meal, and corn gluten meal.

4. Nonprotein feedstuffs cannot supply all the protein necessary in the diet, but true proteins can. Nonprotein feedstuffs must be supplemented with true proteins.

FIGURE 4.3 - Balancing a Ration

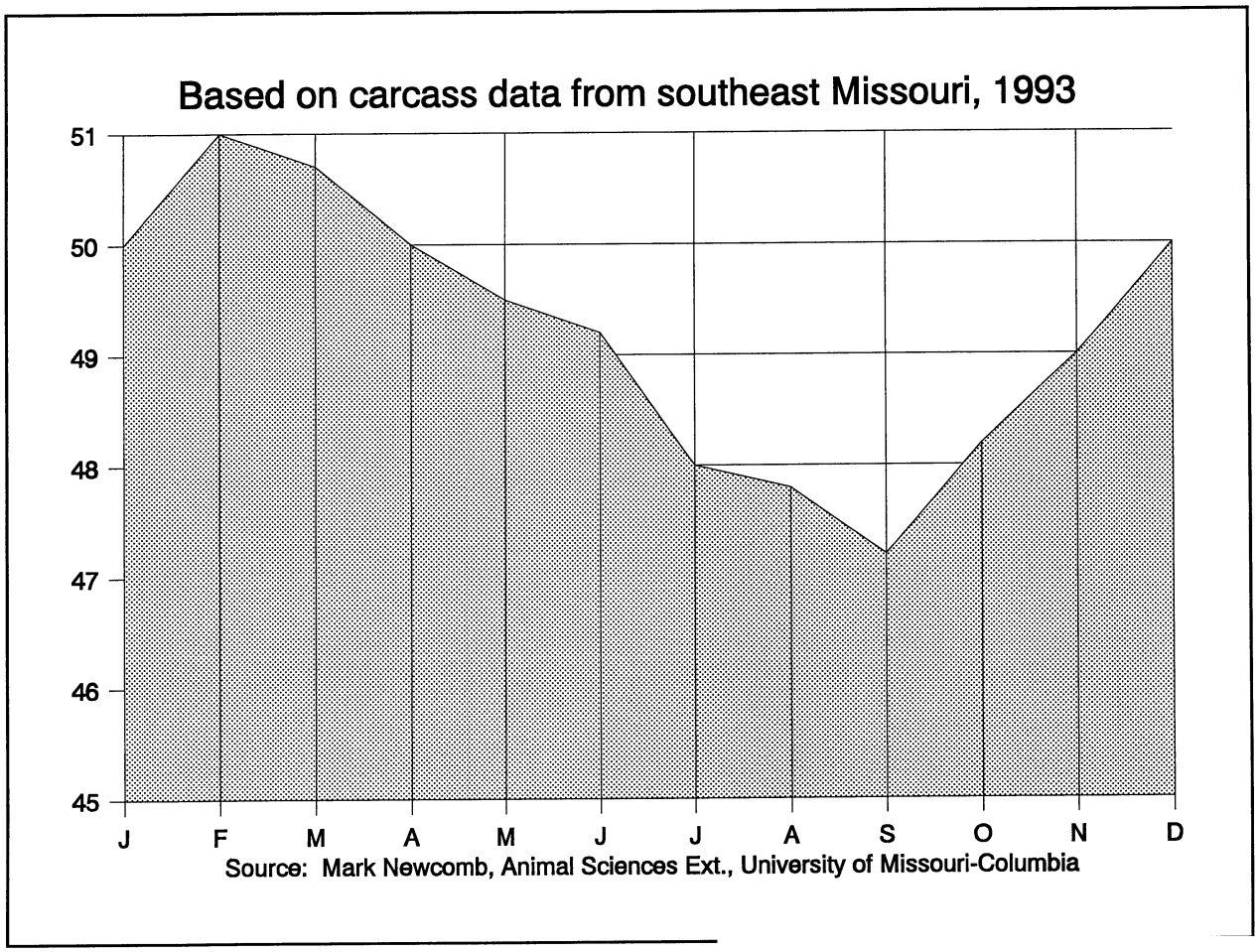


5. Figure 4.2 shows the effects of amino acids on milk production. Milk production in dairy cattle is limited by the lowest limiting amino acid (here, lysine). In Figure 4.2, this animal would only produce 75 lbs. of milk daily because the lysine becomes limiting at this level of milk production.

   Figure 4.2 also shows what would happen if the diet was supplemented with a bypass protein high in lysine. When this occurs, lysine is no longer the limiting amino acid; methionine now becomes the limiting amino acid. This change results in increased milk production (75 lbs. to 92 lbs. daily). Paying close attention to ration balancing can mean a much more profitable operation. This concept of limiting amino acids also applies to nonruminants.

Nonruminants - Protein digestibility is easier to understand in nonruminants because there are no microbial cells to feed and no predigestion before entering the stomach. Table 4.1 shows the requirements for a growing 100 lb. market hog, as well as the crude protein, digestible protein, and amount of amino acids present in different feedstuffs. A 100 lb. market hog requires a 16 percent crude protein diet. The average 100 lb. hog consumes 4.1 lbs. of feed daily. Of that, 16 percent needs to be crude

FIGURE 4.4 - Swine Percentage Lean Over Time



protein, which is .66 lb. of crude protein. (Remember, this is an estimate.)

To further understand the hog's requirement, look at the bottom line of Table 4.1. It shows that the amino acid requirement for the 100 lb. hog is .019 lb. of isoleucine, .025 lb. of leucine, .031 lb. of lysine, .017 lb. of methionine and cystine, .02 lb. of threonine, and .005 lb. of tryptophan.

Blood meal, for example, has a crude protein percentage of 86 percent, of which 70 percent can be digested. Of 100 lbs. of blood meal, 86 lbs. are crude protein, while 70 lbs. are usable (digestible) protein. Of the 100 lbs. of blood meal, the total amount of isoleucine is 1.13 lbs. There is .75 lb. of usable (digestible) isoleucine available in 100 lbs. of blood meal. To find out the digestible amount of isoleucine available in 50 lbs. of blood meal, multiply 50 lbs. of blood meal by .0075 digestible isoleucine. (50 x .0075 = .375 lb. of digestible isoleucine)

To find the available digestible leucine in 50 lbs. of blood meal, multiply 50 lbs. of blood meal by .0924. (50 x .0924 = 4.62 lbs.) Let's use this information in a real-life ration. On the average, a 100 lb. hog eats 4.1 lbs. a day. To find out if the ration below meets the amino acid requirements of this hog, find out the total amount of each feedstuff.

In the following ration, 3.28 lbs. of the 4.1 lbs. eaten is corn, and .82 lb. is soybean meal. Usually, lysine is the limiting amino acid in most hog rations. Soybean meal will supply .021 lb. of lysine (.82 lb. x .0255 = .021). The corn supplies .006 lb. of lysine (3.28 x .0018 = .006). The hog requires .031 lb. of lysine; these feedstuffs supply .027 lb. of lysine (.021 + .006). This ration, therefore, is lacking lysine. Remember that all hog rations need vitamins and minerals, which have not been figured in yet. In real life, this ration would be balanced for lysine (not protein) to prevent this deficiency from occurring. (See Figure 4.3.)

Remember that the 4.1 lbs. eaten daily is an average. In the winter, hogs will eat more than in the summer. To the average producer, using the above ration in the winter wastes money because it includes more amino acids than the hog needs. In the summer, the hog's appetite decreases and its needs are not met because it eats less than 4.1 lbs. a day. Figure 4.4 shows this difference in eating habits.

If using the above ration, packers receive leaner hogs in the winter because hogs are eating more, so their amino acid needs are met, resulting in more muscle. In the summer, when hogs eat less, their amino acid needs are not met and fat is produced instead of muscle.

The processing of feedstuffs improves protein digestibility. Compare raw soybeans to heated soybeans on Table 4.1. Crude protein remains about the same, but the digestibility of heated soybeans jumps up 7 percent. This concept also applies to digestibility of amino acids. (See Table 4.1.)

Summary

Understanding protein's role in nutrition is economically important because protein is one of the more expensive components in ration development.

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Lesson 5:
Minerals' Role in Animal Nutrition

General Functions of Required Minerals

When an organic material such as feed is burned, the leftover ash is the material's mineral content. Minerals are inorganic substances needed by animals for production and maintenance; they are needed in very small amounts in the ration. If a particular mineral is needed, it must be provided in the diet in a form that can be digested, absorbed, and used in metabolism. Rations must be formulated so that a mineral imbalance does not occur.

At least 19 mineral elements are needed by various animal species. These minerals are divided into two groups based on the quantities needed. Those needed in larger amounts are called macro-minerals, and those needed in small amounts are called trace or micro-minerals.

Macro-minerals include calcium (Ca), sodium (Na), phosphorus (P), magnesium (Mg), potassium (K), and chlorine (Cl). Trace or micro-minerals needed include sulfur (S), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), and zinc (Zn).

Although the mineral content of an animal's body is small (2-5 percent, depending on the species), minerals perform many essential functions. Minerals provide material for the growth of bones, teeth, and soft tissues. Minerals fill in soft bone and teeth cells to make the cells hard and rigid. Minerals regulate many vital chemical processes. They also aid in muscular stimulation and activity, reproduction, digestion of feed, repair of body tissue, formation of new tissue, and release of body heat for energy.

Minerals are an essential part of the blood, body fluids, and some secretions in the body. They help regulate the acid-base balance to maintain body fluids at a pH of about 7.0. Other functions of minerals include cell structure and integrity; part of organic compounds such as proteins, amino acids, carbohydrates, and fats; control the location of body water through osmotic pressure; coenzymes that activate enzymes; necessary components of hormones; and egg production.

Toxic minerals - Some minerals, such as arsenic, cadmium, mercury, and lead, are toxic to animals. Selenium helps protect against arsenic, cadmium, and mercury poisoning.

Arsenic is found in some herbicides, insecticides, and defoliants. Crops do not grow well on soils contaminated with arsenic. Crops recently sprayed with a material containing arsenic can cause arsenic poisoning if livestock graze on the foliage.

Cadmium is normally not found in soils in excessive amounts; however, contamination from industrial plants or sewage from cities causes a buildup of cadmium in the soil.

Mercury can be discharged into air and water by industrial plants, and is used in herbicides and fungicides for seed treatment.

The major danger from lead is contamination of plants from lead in the air. The most common source of lead toxicity is lead-based paint from discarded paint cans or peeling buildings.

Macro-Minerals: Functions, Deficiencies, Interactions, Sources

Calcium (Ca)

Major functions - An animal's bones and teeth contain 99 percent of the calcium found in its body. Calcium is also an important part of milk and eggs, so it is essential in the diets of lactating animals and laying hens. Calcium is also important for proper nerve and muscle functioning, for maintaining the acid-base balance of the body fluids, and for blood coagulation.

Deficiencies - A deficiency of calcium will result in abnormal bone growth and weak bones in all classes of livestock. Young animals that are deficient in calcium can develop rickets, where the normal amount of calcium is not deposited in the growing bones. The joints then become enlarged and bones become weak, soft, deformed, and fragile. The calcium in the spongy part of the bones is withdrawn first to meet the needs of the animal. If the deficiency continues, the calcium is withdrawn from the shafts and

other structural parts of the bone. Bones then become porous, weak, and fragile. Older animals with a calcium deficiency can develop osteoporosis.

Calcium-deficient poultry have thin-shelled eggs, reduced egg production, and lowered hatchability. Milk fever can occur when cattle are deficient in calcium shortly before or after calving.

Interrelationships - The ratio of calcium to phosphorus, magnesium, and zinc must be correct for the proper utilization of these minerals. The calcium-to-phosphorus (Ca:P) ratio should be 1:1 to 2:1. Excessive calcium in the ratio will result in poor utilization of these other minerals. An excess of magnesium decreases the absorption of calcium, replaces calcium in the bone with magnesium, and causes an increase in the excretion of calcium from the body. The vitamin D level is critical because a deficiency of vitamin D in the ration prevents the proper utilization of calcium. Also, an excess amount of calcium reduces the absorption and utilization of zinc.

Sources - Legume forages and animal-origin protein supplements are the highest in calcium content, ranging from one to two percent on a dry weight basis. Plants grown on well-fertilized soils are higher in calcium content than those grown on poorer soils. Other good feed sources of calcium include milk, bonemeal, and citrus pulp. Rations that are high in grain need more calcium supplements, while legume forage rations need little or no added calcium.

Calcium supplements come from various materials. Typical sources are ground limestone, oyster shell flour, and marble dust. Supplements can be fed free choice in a mineral mix or added to the ration at the proper level.

Grains, straw, dried mature grasses, and protein supplements from plant sources contain the least amount of calcium, ranging from 0.01 to 0.15 percent. Grass forages generally contain 0.35-0.75 percent calcium. In the end, only about 20-30 percent of calcium in the average ration is absorbed from the intestinal tract and taken into the bloodstream.

Salt (NaCl)

Major functions - Salt contains the mineral elements sodium (Na) and chlorine (Cl), which are needed by all classes of livestock. Cattle, sheep, and horses usually require more salt supplements than swine or poultry because of the higher levels of forages in their diets. Most grains and forages produced on nonirrigated soils are low in sodium and chlorine content. Sodium and chlorine are important for maintaining osmotic pressure in the body cells. The assimilation of nutrients and removal of waste from cells depend on maintenance of the proper osmotic pressure. Sodium is the major mineral responsible for maintaining a neutral pH level in the body tissues. Chlorine is essential for the formation of bile and hydrochloric acid in the digestive juices. Both sodium and chlorine affect muscle and nerve activity.

The requirements for salt in the diet vary with the specie, type of feed fed, activity of the animal, air temperature, water salinity, and production. Milk is especially rich in salt; therefore, lactating animals have a higher salt requirement. Heavy sweating causes a rapid loss of salt from the body, increasing the animal's salt requirement.

Deficiencies - Animals that are temporarily deprived of salt can develop an abnormal appetite for dirt, manure or urine. Symptoms of salt deficiency are slow to develop because the salt in the body is recycled when the intake is low. However, some symptoms which may occur include reduced growth and efficiency of feed utilization in growing animals, and lowered reproduction, reduced milk production, and weight loss in adult animals. In laying hens, lowered production, loss of weight, and cannibalism may result from a salt deficiency.

Ration requirements - Salt can be mixed in the ration at 0.25-0.50 percent of the ration and/or fed free choice. During the lactation period of cattle, sheep, and horses, include salt at about one percent of the ration. Generally, include about 0.50 percent salt in a ration for swine. Including salt in the ration helps to ensure that all animals get an adequate amount; it also improves palatability.

Sources - Supplemental salt can be added in block form, as loose salt or in the mineral mix.

The price and availability of the various sources are the main considerations when deciding which to use. In a ration, it is a common practice to add salt (0.25-0.50 percent) as the carrier for trace minerals because of the improved palatability of the mix. Salt fed to cattle on pasture often has organic iodine added to prevent foot rot and magnesium oxide added to help prevent grass tetany. Block salt is easy to use, does not need protection from wet weather and stimulates salivation. There is little danger of the animal overeating salt. However, some animals might not get enough salt or might develop sore tongues if available only in the block form.

Loose salt can be plain or have trace minerals added. It is easy for the animal to consume but needs protection from rain or snow. Another disadvantage is that animals starved for salt might eat too much of the loose form. When salt is fed loose, make sure there is an adequate water supply to prevent toxic reactions from overeating. Salt fed loose should be protected by a mineral feeder.

Toxicity - Toxicity rarely develops from the consumption of salt, unless ruminants that overeat salt are restricted in their access to water. As much as 15 percent of the ration can be given to cattle on pasture to limit grain intake, with no toxicity resulting. However, salt toxicity can readily occur in nonruminants. It is characterized by a staggering gait, blindness, and other nervous disorders. Also, ruminant animals that have been salt starved can overeat if given unlimited access to salt, and overeating can cause digestive upset or death.

Phosphorus (P)

Major functions - Phosphorus is a vital element in many body functions, and is helps interrelationships with several other macro- and trace minerals. Approximately 80 percent of phosphorus in the body is found in the bones and teeth; therefore, it is a key element in their proper growth and development. Phosphorus is a component of phospholipids, which are important in lipid transport and metabolism, as well as cell-membrane structure. Phosphorus affects appetite, milk and egg production, energy metabolism, conversion of carotene into vitamin A, and utilization of vitamin D. Phosphorus is a component of RNA and DNA and is involved in other metabolic processes as a constituent of several enzyme systems.

Deficiencies - A deficiency can result in rickets or osteoporosis, as well as in poor appetite, slow gains, lower milk and egg production, reproductive problems, poor utilization of vitamin D, deficiency of vitamin A, and generally unthrifty appearance. While it is not a specific symptom of phosphorus deficiency, the deliberate eating of soil and chewing on other nonfeed objects can suggest a phosphorus deficiency in the diet.

Interrelationships - Excessive amounts of calcium and magnesium in the diet reduce phosphorus absorption. In ruminants, an excess of phosphorus can cause urinary calculi, lameness, spontaneous fracture of long bones, and a laxative effect. Phosphorus is more efficiently absorbed than calcium; about 70 percent of ingested phosphorus is absorbed. The Ca:P ratio in the diet should be 1:1 to 2:1.

Sources - Feeds that are good sources of phosphorus include wheat bran, cottonseed meal, and dried skim milk. Legume and grass pastures grown on fertile soils are fairly good sources, while mature, weathered grass forage is generally low in phosphorus. Cereal grains and grain products are fairly high in phosphorus, but much of it is not readily available to nonruminants. An adequate vitamin D level in the diet improves the assimilation of phosphorus. Ruminants are better served by plant sources of phosphorus, while poultry and swine need phosphorus from inorganic sources. Phosphorus supplements can be included in a mineral mix fed free choice and/or added to the ration at the proper level.

Magnesium (Mg)

Major functions - Magnesium helps activate several enzyme systems, relaxes nerve impulses, and is involved in protein digestion. It also serves as a ruminant alkalizer and buffer. Magnesium is a constituent of bones and teeth and is necessary for normal skeletal development. While magnesium is essential for life, it is present in only small amounts in the body.

Deficiencies - A low level of magnesium in the ration can cause decreased utilization of phos-

phorus and may cause hyperirritability in animals. Magnesium deficiency can cause vasodilation (dilation and relaxation of the blood vessels) which is evidenced by the flushing of the skin.

An acute magnesium deficiency can result in grass tetany. Older, lactating animals are generally affected, but younger animals can develop grass tetany, as well. Grass tetany is likely to develop when levels of magnesium drop below 0.001 percent in the blood serum. Tetany is more likely to develop in cattle and sheep grazing on grass pastures, small grains, highly fertilized fescue in late winter or early spring or grass hay diets. The affected animals become nervous, stagger, and then fall down. Other characteristics of grass tetany include loss of appetite and convulsions. Unless they are quickly treated by an injection of magnesium, they often die.

Interrelationships - Adding magnesium to the ration can cause a zinc deficiency if the ration is not properly supplemented with zinc. Too much magnesium in the ration can interfere with the metabolism of phosphorus and calcium.

Sources - If the diet is low in magnesium, the animal will draw upon the magnesium reserve in its bones. While most rations contain enough magnesium, it might be necessary to supplement the ration, especially under conditions described above that can result in grass tetany. A little more than one ounce of magnesium per head per day for cattle is enough, with a proportionately smaller amount for sheep. Magnesium sulphate or magnesium oxide can be mixed with salt, supplement or fed free choice in areas where grass tetany is a risk.

Potassium (K)

Major functions - Potassium is a major cation (positively charged ion) which affects the osmotic pressure and acid-base balance of the body fluids. It is also involved in controlling muscle activity and the metabolism of carbohydrates and protein synthesis. Potassium is also related to the relaxation of the heart muscle and the secretion of insulin.

Deficiencies - Potassium deficiency may result in reduced growth, general muscle weakness, diarrhea, and an unsteady gait. It may also cause the enlargement of the heart and kidneys, followed by death. Potassium deficiency most often occurs in dry lot finishing cattle or sheep on a high-concentrate ration.

Interrelationships/toxicities - Too much potassium in the diet can result in poor assimilation of calcium and magnesium. The resulting magnesium deficiency leads to poor retention of potassium, and a potassium deficiency results. A high potassium intake causes increased urine output as the animal tries to excrete the excess amount. A toxic level of potassium results in diarrhea, tremors, and heart failure. Excessive salt intake depletes the body's potassium.

Sources - While potassium is essential for life, it is usually adequate most animal rations. Forages are especially high in potassium, containing 3-4 percent on a dry weight basis in the early growth stage. Grains and concentrates contain 0.3-0.7 percent potassium. Animals generally need less than one percent potassium in the ration on a dry weight basis.

Micro-Minerals: Functions, Deficiencies, Interactions, Sources

Sulphur (S)

Major functions - Sulphur is an essential part of the amino acids cystine and methionine and is important in the metabolism of lipids, carbohydrates, and energy. It is also a component of hair, wool, and feathers.

Deficiencies - A deficiency of sulphur in the ration will appear as a protein deficiency. Slow growth and a general unthrifty condition are symptoms of a possible sulphur deficiency. Sheep that are fed nonprotein nitrogen without sulfur supplements show reduced wool growth. (Wool contains about four percent sulfur.)

Ration requirements - Ruminant rations that are high in nonprotein nitrogen (NPN) can be sulphur deficient. A nitrogen-to-sulphur ratio of 15:1 is more desirable as this improves the utilization of NPN in the ration. Nonruminants should be provided sulfur-containing proteins, as well.

Sources - Forages, especially legumes which are harvested in the earlier growth stages, should contain enough sulphur for ruminants. For

forages harvested in more mature stages, sulphur supplements might be needed to improve nitrogen utilization. Water supplies in some areas have a high sulphur content. This should be checked to learn the amount of sulphur being included in the diet through the drinking water.

Chromium (Cr)

Major functions - Chromium is believed to be related to glucose metabolism. It is also an activator of certain enzymes and a stabilizer of nucleic acids. Chromium is necessary for the stimulation of the synthesis of fatty acids and cholesterol in the liver.

Deficiencies - A deficiency of chromium is shown by impaired glucose tolerance and a disturbance of lipid and protein metabolism. Supplementation is not generally needed for chromium because such small amounts are required.

Cobalt (Co)

Major functions - Cobalt is used by rumen and cecal bacteria in the growth of rumen bacteria and is essential in the synthesis of vitamin B_{12}.

Deficiencies/toxicities - Cobalt deficiency symptoms are similar to vitamin B_{12} deficiency symptoms. These include poor appetite and general malnutrition, weakness, slow growth, decreased fertility, lower milk and wool production, emaciation, anemia, and eventually death. Toxicity is not likely.

Sources - Good sources of cobalt are usually commercial minerals, poultry by-products, soybean meal and molasses.

Copper (Cu)

Major functions - Along with iron and B_{12}, copper helps in hemoglobin formation. It is essential in some enzyme system activation, hair development and pigmentation, wool growth, bone development, reproduction, and lactation.

Deficiencies - Symptoms of copper deficiency include severe diarrhea, slow growth caused by anemia, swelling of joints, swayback in newborn lambs, difficulty in breathing, loss of hair color in cattle, and abnormal wool growth in sheep. Milk is low in copper; therefore, young animals raised solely on milk may develop anemia.

Interrelationships - Only small amounts of copper are needed by the animal; however, the level required is influenced by the amounts of iron, manganese, zinc, lead, nitrate, and molybdenum in the ration.

Toxicity - Copper levels above 250 ppm are toxic with death resulting. Levels above 50 ppm are considered potentially dangerous to animal health. Excessive amounts of copper accumulate in the liver and may result in death. Other toxicity symptoms include anemia and jaundice.

Sources - Most livestock feeds have 3-4 times the amount of copper needed by animals. Also, a variable store of copper is located in the liver and spleen. If needed, use commercial minerals or trace-mineralized salt containing copper sulfate. Commercial minerals fed to sheep should not contain copper because it may be lethal. Copper accumulates in bodies and does not metabolize.

Fluorine (F)

Major functions - Fluorine helps prevent cavities in teeth and possibly slows osteoporosis in older animals.

Deficiencies - Fluorine deficiency in the diet is rare, and supplements are not recommended. However, large amounts of calcium, aluminum or fat will lower the absorption of fluorine. Drinking water and forages usually contain enough fluorine to meet livestock needs.

Interrelationship - High dietary calcium depresses fluorine uptake in bone.

Toxicity - In excessive amounts, fluorine is toxic. The symptoms of too much fluorine in the diet develop slowly over time because fluorine is a cumulative poison. High levels will result in enlarged bones; softening, mottling and irregular wear of the teeth; a roughened hair coat; delayed maturity; and less efficient utilization of feed.

Iodine (I)

Major functions - Iodine is necessary for the production of the hormone thyroxine in the thyroid gland. This hormone controls the rate of oxidation of nutrients in the cells, and thus controls heat production in the animal's body.

Deficiencies - A deficiency in iodine reduces the production of thyroxine and leads to goiter (the enlargement of the thyroid gland). Enlargement of the thyroid gland is nature's way of trying to make enough thyroxin when there is insufficient iodine in the diet. There is no satisfactory treatment for animals that have developed pronounced iodine deficiency symptoms. Other deficiency symptoms include stillbirths and weak young; hairless pigs and wool-less lambs at birth.

Toxicity - Long-term chronic intake of large amounts of iodine reduces the thyroid uptake of iodine.

Sources - Good sources of iodine include iodized salt, calcium iodate, whey, and molasses.

Iron (Fe)

Major functions - Iron is necessary for hemoglobin formation and is also involved in oxidation of nutrients in the cells. (Hemoglobin is the part of the blood that transports oxygen to the cells in the body.) Other minerals needed for hemoglobin formation are copper and cobalt.

Ration requirements and deficiencies - The amount of iron required in the diet is believed to be as little as 80 mg per kg of diet for most animals. Livestock feeds generally contain enough iron to meet the needs of older animals.

Milk is low in iron; therefore, iron deficiency occurs with young, nursing animals. Iron deficiency occurs more frequently with nursing pigs raised in confinement than with other species. Other young appear to have sufficient reserves of iron in the liver and spleen to carry them through the nursing period. Oral doses or injections of iron for young pigs are necessary to prevent anemia, which is the most common symptom of iron deficiency.

Symptoms of anemia in young pigs include labored breathing; listlessness; pale eyelids, ears, and nose; and flabby, wrinkled skin. A concentrated ferrous sulphate or other iron solution can be given to young pigs orally. An iron dextran injection of 150-200 mg at three days of age can be used instead of oral administration.

Interrelationships - Too much iron in the diet will interfere with the assimilation of phosphorus because of the formation of insoluble iron phosphates. Copper is required for proper iron metabolism to occur.

Sources - Legumes and leafy plants contain enough iron to meet the needs of older animals. Trace-mineralized salt containing iron should be fed to all livestock to prevent iron deficiency.

Manganese (Mn)

Major functions - Manganese is essential for normal bone formation and growth of other connective tissue. It is also involved in enzyme systems that influence estrus, ovulation, fetal development, milk production, and growth. Manganese also functions in the synthesis of fatty acids, amino acid and cholesterol metabolism, and in blood clotting.

Deficiencies - A ration is manganese deficient when the level of manganese drops below 20 ppm. Indications of low manganese levels in the diet are: poor growth, abnormal bone development, sterility, delayed estrus, reduced ovulation, abortions, pinkeye, and slipped tendon in poultry. Swollen and stiff joints are evidenced by knuckling over (in calves) and crooked legs and enlarged hocks (in pigs).

Interrelationships - The normal range of manganese is 50-150 ppm. Levels in excess of 500 ppm will cause problems with phosphorus and iron utilization. Excess calcium and phosphorus decrease manganese absorption.

Sources - While the availability of manganese is not as good from manganese sulphate or manganese oxide, these inorganic sources can be used to add manganese to the ration. Most livestock rations have enough manganese, with roughages having higher levels than grain and corn being low. Beef cattle on all-concentrate diets based on corn and NPN supplements might need manganese supplements in the diet. Corn and soybean meal rations for swine can be improved with manganese supplements.

Molybdenum (Mo)

Major functions - Molybdenum is a component of an enzyme found in milk and in body tissues. It is also involved in stimulating rumen organisms.

Molybdenum is also part of three different enzyme systems involved in the metabolism of carbohydrates, fats, proteins, and iron.

Interrelationships/toxicities - Utilization of molybdenum is reduced by excess copper sulfate and tungsten. Molybdenum is related to uric formation in poultry and microbial action in ruminants. Toxic levels of molybdenum interfere with copper metabolism. Toxicity symptoms include severe scours and loss of condition.

Selenium (Se)

Major functions - Selenium is needed in small amounts because of its relationship with vitamin E absorption and utilization. Selenium prevents degeneration and fibrosis of the pancreas in chicks. Most importantly, it protects tissue against certain poisonous substances, such as arsenic, cadmium, and mercury.

Deficiencies - A deficiency of selenium causes nutritional muscular dystrophy (white muscle disease) in cattle, sheep, chickens, swine, and horses. It may also cause liver damage in swine.

Toxicity - Three types of selenium toxicity occur in livestock: acute, chronic blind staggers, and chronic alkali-disease. Symptoms include blind staggers, lameness, anemia, excess salivation, grinding of the teeth, and blindness. Excess selenium in poultry results in reduced egg production and deformities such as lack of eyes and deformed wings and feet.

Sources - Good sources of selenium include marine by-products, such as seaweed and kelp, cereal grains and wheat by-products.

Silicon (Si)

Major functions - Silicon is necessary for normal growth and skeletal development of chicks.

Deficiencies - A deficiency of silicon in a chick's diet results in slow growth and skeletal deformities, especially in the skull.

Sources - Silicon is present in large amounts in soil and plants. Also, on purified diets, the addition of silicon to the diet has increased the growth rate of chicks.

Zinc (Zn)

Major functions - Zinc is important for the normal development of skin, hair, wool, feathers, bones, and eyes; preventing parakeratosis; and healing wounds. Zinc is necessary in several enzyme systems, for protein synthesis and metabolism, and as an insulin component. Zinc also gives bloom to the hair coat.

Deficiencies - Symptoms of zinc deficiency in livestock include rough, thick skin in swine (commonly called parakeratosis); thickening of skin on the neck; loss of hair; wool slipping; poor feather development; slow wound healing; and poor appetite and growth.

Interrelationships - Excess calcium reduces the absorption and utilization of zinc. Animals are generally tolerant of excessive levels of zinc in the ration, although high levels will interfere with the utilization of copper and iron and might cause anemia. If the ration is high in zinc, additional copper and iron may be needed. Grains and forages seldom contain excessive levels of zinc, even if grown on soils with high levels of available zinc.

Sources - Zinc is often added in trace-mineralized salt for all livestock to ensure against a possible deficiency. Swine rations usually have zinc added to the ration. Other sources include fish meal, corn gluten feed, and meal and poultry by-products.

Absorption of Minerals in the Body

Dissolved minerals are absorbed into the bloodstream through villi in the small intestine. In the large intestine, nutrients are absorbed directly into the bloodstream through capillaries in the wall of the intestines.

Summary

At least 18 mineral elements are needed by animals. Those needed in large amounts are referred to as major or macro-minerals, while those needed in small amounts are called trace or micro-minerals. Minerals are required for the development of bones and teeth, as well as for many other functions in the body. Deficiencies cause lower production and poor gains, but rarely cause diseases or death. Commercial feeds and

mineral mixes are the most common sources of minerals in livestock rations. Minerals can be mixed in complete feeds or fed free choice.

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Lesson 6:
Vitamins' Role in Animal Nutrition

Vitamins are organic compounds that are essential for normal growth and maintenance of animal life. Only small amounts of vitamins are needed because they function as catalysts (parts of enzymes or coenzymes) in metabolic processes. Vitamins are distinct from carbohydrates, fat, protein, minerals, and water.

Classification of Required Vitamins

In animal nutrition, 16 vitamins are essential. These vitamins are classified by their solubility (whether they dissolve in water or in fat).

Fat-soluble - These vitamins can be stored in the animal's fat tissue, reducing the need for a daily supply in the diet. This enables livestock to survive on vitamin-deficient diets for longer without deficiency symptoms. Included in this group are Vitamins A, D, E, and K.

Water-soluble - Water-soluble vitamins are generally stored in the animal's body for only 2-4 days. Therefore, these vitamins need to be supplied regularly in the diet. Water-soluble vitamins include inositol, niacin, vitamins C, B_1 (thiamin), B_2 (riboflavin), B_3 (pantothenic acid), B_6 (pyridoxine), B_{12}, biotin, choline, folic acid, and para-aminobenzoic acid (PABA).

Vitamins are available to animals in protein supplements, mineral and vitamin supplements, and commercially prepared complete feeds. Feed tags show guaranteed minimum and maximum percentages of calcium, minimum percentage of phosphorus, and minimum and maximum percentages of salt in the feed. Vitamins are usually added to mixed rations or provided free choice.

Fat-Soluble Vitamin Functions, Deficiencies and Sources

Vitamin A

Major functions - Functions include normal maintenance of the eyes and epithelium (membrane) tissue of the respiratory, digestive, urogenital systems, and the skin. Vitamin A is also needed for normal bone growth, body growth and normal tooth development.

Deficiencies - Night blindness (inability to see in dim light) is a symptom of severe vitamin A deficiency. Vitamin A is a part of the visual purple of the eye, which is depleted through the action of light. Visual purple is required for vision in dim light. Animals suffering from night blindness will recover when sufficient amounts of vitamin A are added to the diet. Animals can become permanently blind when vitamin A deficient.

Excessive watering of the eyes and development of cornea ulcerations are also indications of possible vitamin A deficiency. Other indications include nervous incoordination shown by a staggering gait, diarrhea, reduced appetite, poor growth and weight loss. Also, unsound teeth and rough, dry skin may be a sign of vitamin A deficiency. Paralysis of some parts can occur in some species. Young animals suffer from deficiency sooner because of their greater requirements and reduced storage ability.

Reproductive problems include poor conception rates, reduced fertility in males, shortened gestation periods, and increased retained placenta. In poultry, discharges from the eyes and nostrils can occur, as well as wobbly gait in chicks, reduced egg production and hatchability of eggs.

Sources - Vitamin A can be provided as a synthetic vitamin or as carotene. Vitamin A itself is only present in animals, but plants contain the precursor, carotene. Carotene is found in good quality, fresh, green forages in generally sufficient amounts. Excellent sources of carotene are green, leafy hays that have been in storage less than one year; dehydrated, pelleted legume hays; and good quality grass or legume silages. Other carotene sources include yellow corn, fish liver oil, dehydrated alfalfa meal and whole milk.

Storage in the body - Vitamin A is stored in the liver and fatty tissues of the body. The animal can use stored vitamin A when the diet is deficient in carotene.

Ration considerations - Conditions that might indicate a need for vitamin A supplements include (1) poor quality or low levels of forages,

(2) limited amounts of colostrum or whole milk in the diet, (3) diets of corn silage and low-carotene concentrates, (4) grazing during drought periods, and (5) rations made up mainly of cereal grains, except corn.

Additional comments - Vitamin A and carotene are readily destroyed by oxidation, thus resulting in considerable losses in processing and storing (such as in making and storing hay).

Vitamin D

Major functions - Vitamin D is important for calcium absorption and phosphorus metabolism in the body. Rickets is prevented by vitamin D, along with calcium and phosphorus. Vitamin D also promotes sound teeth.

Deficiencies - A shortage of vitamin D will result in rickets in young or osteoporosis in adults with insufficient calcification of the bones. However, less vitamin D is required when a good balance of phosphorus and calcium is present. Symptoms of vitamin D deficiency are decreased appetite, slower growth, digestive disturbances, stiffness in gait, and sometimes the development of tetany and convulsions. As the disease progresses, joints enlarge and become swollen and stiff. Pregnant animals might give birth to dead, weak or deformed young because of vitamin D deficiency. Chickens will show rickets, poor feathering and growth with a reduction of egg production, hatchability and poor eggshells in laying hens.

Sources - Diets that include sun-cured forages generally provide sufficient vitamin D. Animals regularly exposed to sunlight or ultraviolet light will not develop deficiency symptoms. Green forages, barn-cured hay, and silages have some vitamin D. Grain, grain by-products, and protein feeds have almost no vitamin D.

Additional comments - When animals are exposed to direct sunlight, the ultraviolet light in the sunlight penetrates the skin and produces vitamin D from traces of certain cholesterol in the tissues. However, tissue storage of vitamin D is very limited.

Vitamin E

Major functions - Vitamin E functions as an anti-oxidant, which helps in absorption and storage of vitamin A. As an antioxidant, it also acts in other metabolic functions in the cell. Vitamin E is essential for the integrity of red blood cells and in cellular respiration, primarily in heart and skeletal muscle tissues. It is also a regulator in the synthesis of DNA and vitamin C.

Deficiency symptoms - Vitamin E deficiency looks similar to selenium deficiency--white muscle disease or nutritional muscular dystrophy. Hatchability of eggs is reduced, although production does not appear to be affected. Extended vitamin E deficiency in poultry will cause permanent sterility in the male and reproductive failure in the female. The addition of selenium to the diet can prevent some symptoms of vitamin E deficiency.

Sources - Good dietary sources of vitamin E include whole cereal grains, the germ or germ oils of cereal grains, green forages, alfalfa meal, rice polishings, wheat germ meal, and good quality hay. After a long storage period, the vitamin E level in feeds declines. It is rapidly destroyed when near rancid fat. Vitamin E is seldom deficient in the diet unless feeds were produced on selenium-deficient soils. Vitamin E is produced commercially and can be added to the diet when needed by using a vitamin premix or injecting into the muscle.

Additional comments - Vitamin E is widely distributed in all natural feeds. Utilization of vitamin E depends on adequate selenium. There is some storage of vitamin E in the liver and other fatty tissues.

Vitamin K

Major function - Vitamin K is necessary for the formation of prothrombin in the blood, which helps blood clot.

Deficiencies - Vitamin deficiencies K rarely occur because it is synthesized in the rumen and in the intestinal tract of monogastric animals. Feeding moldy feeds with a high dicoumarol content, such as moldy sweet clover, might cause a vitamin K deficiency. This can lead to a bleeding syndrome called sweet clover poisoning or bleeding disease. Moldy feeds with a high dicoumarol

content fed to swine or poultry will also cause internal bleeding and death. Feeding vitamin K or water-soluble synthetic forms of the vitamin will counteract deficiency effects.

Sources - Dietary sources of vitamin K include green, leafy feeds (either fresh or dry); fish meal; liver; and soybeans. Vitamin K is usually widely available in normal farm rations, and is synthesized by all classes of farm animals. However, it is common to add vitamin K to swine diets and chick starter rations.

B Complex Vitamins: Functions, Deficiencies and Sources

Ruminants (cattle, sheep, goats) generally do not need vitamin B complex supplements. Microorganisms in the functioning rumen synthesize many of these vitamins, and feeds used in ruminant nutrition also supply many B complex vitamins.

However, the rumen does not function in young animals, so supplements are recommended if the young animal is not nursing. Mother's milk contains many B vitamins needed by the young.

Biotin

Major functions - Biotin is required in many reactions in the metabolism of carbohydrates, fats and proteins. Biotin serves as a coenzyme for transferring carbon dioxide from one compound to another. It is also a coenzyme for the production of energy.

Deficiencies - Deficiency symptoms include dermatitis, loss of hair, cracks in the feet, slow growth, hind leg spasticity in swine, and reduced hatchability of eggs.

Sources - Feed sources of biotin include most grains (except wheat and barley), soybean meal, green forages, alfalfa meal, synthetic biotin, and black strap molasses. Animals can readily synthesize biotin, and it is generally not deficient in normal rations. Biotin is available in commercial vitamin premixes.

Choline

Major functions - Choline is a structural component of fat and nerve tissue and is required in the diet at levels higher than other vitamins. It functions as a part of the cell structure, lipid transport, nerve impulse transmission, and fat metabolism in the liver.

Deficiencies - Choline deficiency symptoms include slow growth rate, unthriftiness, fatty livers, poor coordination, reproductive problems, lower milk production, and higher death rate in the young. It can also result in slipped tendons in chickens and turkeys. In swine, an abnormal gait and reproductive failure in adult females may develop. Deficiency symptoms are more visible as the protein content is lowered.

Sources - Good dietary sources of choline include meat scraps, canola meal, fish meal, soybean lecithin, and yeast. Some grains, forages, and dairy byproducts contain lesser amounts of choline. Most farm rations contain enough choline. It is synthesized in the body when there is sufficient protein and other vitamins, especially vitamin B_{12}.

Folic acid

Major functions - Folic acid is a part of the folate coenzymes; it is key to the normal function of body cells and essential amino acid formation. Folic acid is involved in the combining of single carbon units into larger molecules. It is closely related to vitamin B_{12} metabolism, and deficiencies of either one affect the function of the other.

Deficiencies - Shortages of folic acid result in weakness, slow growth, and anemia. Additional signs in young chicks include reduced growth, depigmentation of colored feathers, and poor feathering. In breeding hens, the result is lower egg production and hatchability.

Sources - Green pasture; green, leafy alfalfa hay; soybean meal; wheat germ; and cottonseed meal are good dietary sources of folic acid. Synthetic folacin is readily available when dietary supplements are needed, although for most animals, there is generally enough available through the diet and synthesis in the body.

Thiamine (B_1)

Major functions - Thiamine functions as a coenzyme in energy metabolism and is involved in peripheral nerve functioning. Thiamine helps

maintain a normal appetite, muscle tone and a healthy mental attitude.

Deficiencies - Utilization of thiamin is hindered by high fat diets. Indications of thiamine deficiency are anorexia, slow growth, weakness, increased irritability, lowered body temperatures, slower heartbeat, and enlargement of the heart. In laying hens, egg production is lowered.

Sources - Dietary sources of thiamine include cereal grains; grain byproducts; brans; green, leafy hay; green pastures; and milk. Infection of grains with certain kinds of mold can destroy the thiamine content. Thiamine is unstable when heated; therefore, drying grain or cooking soybeans reduces the amount of available thiamine in these feeds. Except for ruminants like cattle, sheep, and goats, all animals must have a dietary source of thiamine. It is also available in commercial vitamin premixes.

Riboflavin (B_2)

Major functions - Riboflavin promotes growth and functions as a constituent of several enzyme systems. It is also important in carbohydrate, fatty acid, and amino acid metabolism.

Deficiencies - Indications of riboflavin deficiency include slow growth in most species; poor reproduction and lower milk production in sows; anemia, diarrhea, vomiting, eye cataracts, stiffness of gait in young pigs; lesions around the mouth and loss of hair in calves; curled-toe paralysis in young chicks; and periodic moon blindness in horses.

Sources - Dietary sources of riboflavin include synthetic riboflavin; milk; green, leafy hay (especially alfalfa); green pastures; and grass silage. Riboflavin is commercially available in vitamin premixes. Ruminant rations may need riboflavin supplements, and swine and poultry rations generally have riboflavin added.

Additional comments - Grains are considered poor sources of riboflavin. Riboflavin is destroyed by light or heat.

Pantothenic acid (B_3)

Major functions - Pantothenic acid is a component of coenzyme A, which is important in energy metabolism and is required by the cells in the biosynthesis of fatty acids.

Deficiencies - In all species, deficiency symptoms include slow growth, loss of hair, and enteritis (inflammation of the intestine). In young pigs, it results in stiff legs, lack of coordination, and poor condition of the hair and skin. Young chicks will have extremely ragged feather development and lesions on the mouth. B_3 deficient calves show a rough coat, dermatitis, anorexia, and loss of hair around the eyes. (Mature ruminants synthesize vitamin B_3 in the rumen.)

Sources - Good feed sources of pantothenic acid include brewer's yeast, cane molasses, dried milk, alfalfa meal, and whey. Grains are deficient in this vitamin, and deficiencies are most likely to appear when confinement animals eat high grain diets. Mature ruminants synthesize pantothenic acid. However, pantothenic acid is commonly added to commercial swine and poultry rations.

Pyridoxine (B_6)

Major functions - Pyridoxine is a component of amino acid coenzymes and essential fatty acid metabolism. It assists in the production of red blood cells and in the endocrine system. Pyridoxine is a coenzyme in protein and nitrogen metabolism.

Deficiencies - Indications of pyridoxine deficiency are anorexia, slow growth, and convulsions in all species; anorexia and poor growth in pigs; abnormal feathering and stunted growth in chicks; and lower egg production, poor hatchability, rapid weight loss, and eventually death in hens.

Sources - Dietary sources of pyridoxine include cereal grains (especially wheat) and grain byproducts; green pastures; and green, leafy hay (especially alfalfa). Livestock rations generally do not need pyridoxine supplements. Pyridoxine is synthesized in the rumen of cattle, sheep, and goats and perhaps in the cecum of the horse.

Vitamin B_{12}

Major functions - Vitamin B_{12} is needed for red blood cell maturation and functions as a coenzyme in a variety of metabolic reactions. Cobalt is found in vitamin B_{12} and must be present for

synthesis of the vitamin to occur. This is the only function of cobalt in the animal's body.

Deficiencies - A B_{12} deficiency is shown by slow growth in all species; lack of hind leg coordination in young pigs; reduced litter size and higher pig death rate in breeding swine; and lower egg hatchability in breeding chickens.

Sources - Good dietary sources of vitamin B_{12} include synthetic B_{12}, animal proteins, and fermentation products. Vitamin B_{12} is also available in commercial vitamin premixes. It is apt to be lacking in swine and breeder poultry rations.

Para-aminobenzoic acid

Functions and deficiencies - Para-aminobenzoic acid is essential for the growth of some microorganisms and is an essential part of the folacin molecule. Deficiency symptoms have not been observed in animals.

Sources - Para-aminobenzoic acid is synthesized readily in the intestine tract and is usually not deficient in livestock rations. Dietary sources include lecithin, soybean meal, peanut meal, and synthetic PABA.

Functions, Deficiencies and Sources of Other Water-Soluble Vitamins

Inositol

Functions and deficiencies - In combination with choline, inositol prevents hardening of the arteries and protects the heart. It also helps reduce blood cholesterol. Deficiency symptoms are not demonstrated in animals.

Sources - Inositol is synthesized in the intestinal tract and is generally not deficient in the diet. Dietary sources include synthetic inositol, yeast, and liver meal. Inositol is widely distributed in animal feeds.

Niacin

Major functions - Niacin is an essential part of two coenzymes necessary in cell respiration. It is also necessary for the release of energy from carbohydrates, fats, and proteins.

Deficiencies - General indications of deficiency include poor appetite, slow growth, and unthriftiness. In addition, swine show signs of diarrhea, vomiting, ulcerated intestines, dermatitis, and loss of hair. Niacin-deficient chicks develop an inflammation of the tongue, mouth cavity, and upper esophagus; reduced feed consumption; and poor feather development.

Sources - Some niacin is available in feeds, with meat and bone meal being good sources and green alfalfa being a fair source. However, niacin in cereal grains is largely unavailable, so swine and poultry need dietary supplements of this vitamin.

Additional comments - Niacin is a dietary essential for pigs, chickens, and humans. It is synthesized in the digestive tract of ruminants; therefore, they do not need dietary niacin under most conditions.

Vitamin C

Major functions - Vitamin C is necessary for the formation of collagen, a gelatin-like protein that is the main constituent of the fibrils of connective tissue and bones. Vitamin C is required for the absorption and movement of iron, and in the metabolism of fats and lipids. It is also related to cholesterol control, sound teeth and bones, strong capillary walls, and healthy blood vessels.

Deficiencies - Vitamin C deficiency symptoms have not been observed in farm animals. Normally, they synthesize sufficient amounts in body tissues to meet their needs; therefore, it is not required as a supplement to their diet. However, if a deficiency does occur, its symptoms include scurvy (swollen, bleeding, and ulcerated gums), loosening of teeth, and weak bones. It has been shown that more vitamin C may be needed in times of stress.

Sources - Good sources of vitamin C include synthetic vitamin C, citrus pulp, well-cured hay, and green pasture. Usually, ordinary rations provide adequate vitamin C.

Summary

Vitamins are organic compounds essential for life but needed only in trace amounts. Sixteen vitamins have been identified as essential in animal nutrition. They are classified by their solubility--either fat-soluble or water-soluble. Fat-soluble vitamins can be stored in the body,

reducing the need for dietary sources. Water-soluble vitamins are not generally stored in the body and must be supplied in the animal's diet. Vitamins play a vital role in various body system functions and are an important part of the animal's overall nutrition.

Credits

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Lesson 7:
Water's Role in Animal Nutrition

Water is a very important component in animal nutrition. An animal cannot use proteins, energy, vitamins, and minerals without water. This also applies to humans. Water makes up 50-75 percent of the weight of the human body. It also helps human digestion, cell growth, chemical reactions, body temperature regulation, and joint lubrication. Lack of water creates kidney failure, fever, increased pulse rate, and flushed skin in the human body. Similar functions apply to livestock, as well.

Functions of Water

In livestock, water has many functions. It serves as a body fluid throughout the animal's body. Body fluids are present at every joint in the skeletal system to aid in joint lubrication. Body fluids also lubricate the eyes so they can rotate within sockets, and body fluids accumulate around nerves to provide a cushion. In the ear, body fluids help conduct sound for hearing.

Water also dilutes toxic substances within the body. Undiluted urea can be very harmful, but watered-down urea is carried it safely through the urinary tract.

Water plays an important role in the circulatory system. It acts like a car radiator by transferring heat from one part of the body to another. Animals do not have sweat glands, so they do not perspire. Water cools bodies through evaporation through the animal's skin.

Animals produce gases as byproducts during respiration and digestion. Carbon dioxide and methane are two forms of gas byproducts. These gases are released when they are mixed with water vapor in the lungs and then exit through respiration. Therefore, water plays a major function during gas exchange in the animal's body.

If an animal has an inadequate water supply, it will soon develop a fever because of dehydration. Water plays an important role in regulating animal body temperature. A lack of water also decreases heat transfer, which aids in body temperature regulation.

How do animals recognize their food? How do humans recognize their food? Humans use sight most of the time, but sight can fool the other senses. Animals distinguish food through their sense of taste. Taste buds are used to evaluate food. Water carries chemicals in food to the taste buds so they can decide if it should be eaten. Palatability is extremely important in feeds, because if the animal's taste buds don't recognize the feed, it will not eat the feed.

Since water makes up 60-75 percent of an animal's body weight, it is obvious that the animal would lack form without water. Water maintains the animal's shape in several different ways. Blood consists mainly of water, and without water, blood would not flow. Living cells consist mainly of water, which are the building blocks in which life exists.

As previously mentioned, water plays an important role in blood by acting as a carrier of nutrients in the bloodstream. Without water, nutrients could not be carried to different parts of the body to be utilized.

The last function of water is the elimination of waste products. Byproducts of digestion are carried in urine, which consists of water. In the previous lesson, it was mentioned that water is absorbed to form fecal material. Some water also remains in fecal material to ease its move through the digestive tract.

Daily Requirements for Water

Factors - There are several factors that determine the daily requirements for water needs in animals. The type of species is an important consideration, since larger species like cattle require more water than sheep. Lactating species require more water than a dry species. Age also influences the daily requirements of water. A younger animal requires more water per pound of body weight because it has higher needs for body water. Younger animals have less bone and muscle mass than older animals.

Environment affects the daily requirements of an animal. When environmental temperatures

increase, the need for water increases to maintain a constant body temperature. The amount of exercise an animal gets affects its daily water requirement. An active animal needs more water than a sluggish animal.

Moisture content of a feed also influences daily water requirements. An animal on a high grain diet will need more water than an animal grazing on a fresh green pasture.

Environmental temperature affects requirements, but so does humidity. The higher the environmental humidity, the greater the water intake. The level and kind of production of the animal (whether they are gestating or producing milk, meat, etc.) also affects daily water requirements.

If the mineral content is increased in the diet, the animal will increase the water intake.

Average daily requirements - Listed below are several average daily requirements needed by different species of livestock.

Beef cattle
- Growing cattle
  - 100 lbs. = 1.5 gallons
  - 400 lbs. = 5 gallons
  - 800 lbs. = 7 gallons
- Mature cattle
  - Fattening = 9 gallons
  - Lactating = 10-15 gallons

Lactating dairy cattle
- Average production = 12-25 gallons
- Heavy production = 35+ gallons

Growing sheep
- 20 lbs. = .5 gallons
- 50 lbs. = .4 gallons
- 150-200 lbs. = 1+ gallons

Swine
- Growing swine
  - 50 lbs. = 1+ gallons
  - 100 lbs. = 1.5+ gallons
- Mature swine
  - Pregnant = 5+ gallons
  - Lactating = 6+ gallons

Sources of water - There are several sources of water that an animal can use. Drinking water is the first source. It must be fresh, clean, and provided at all times for the animal's use. Water provided by feeds is the second source. Each feed provides a different moisture content. Fresh green pastures have an 80 percent moisture content. Green cut forages, such as silage, have a 65-75 percent moisture content. Dry harvested forages, such as hay, have a 15 percent moisture content. Harvested grains, such as corn, have only 10-15 percent moisture content.

The last source is water produced by body metabolism. This source should not be figured in a ration, because it supplies an insignificant percentage of water. Water can be produced when fats, proteins, and carbohydrates are digested and metabolized.

Water Toxicity

What is water toxicity and how does it occur? Water toxicity is water dehydration accompanied by concentration of sodium and other ions in the brain cells that cause cerebral edema. Water toxicity occurs in animals that have been without water for a long time and suddenly have access to fresh water. The animal basically overdoses itself on water by drinking too much. Dehydrated body tissues can't handle the sudden overdose of water.

Water toxicity occurs more commonly in younger animals. As mentioned earlier, younger animals have a higher water content in their bodies because they lack muscle and bone mass. Younger animals will try to drink 35-50 percent of their body weight within a half hour period.

There are several symptoms that define water toxicity. They are hemoglobinuria (red urine), diarrhea, irregular heartbeat, body hair standing on end, excessive salivation, extended head and neck, nervous signs, and finally coma and death. Fluids usually collect in soft tissues under the skin and is most apparent as swollen and puffy eyelids.

The most noticeable symptom of water toxicity is the extension of the head and neck. This symptom is similar to a young calf sucking on its mother, with the neck extended and head laid back.

The animal also shows some nervous signs. It might have an unstable walk and appear

disoriented. The animal might also excessively rub and lick its body.

If water toxicity is detected soon enough, treatment can be effective. Saline or hypertonic glucose can be given intravenously to remove excess water from body tissues. The animals can drink salt water to pull excess water from body tissues, but this must occur before animal drinks the initial overdose of water.

Water toxicity is a slow process, so there is time to correct its effects. It takes 4-6 hours for water toxicity to kill an animal. It is always smart to observe animals that haven't had fresh water for a long time for water toxicity symptoms. Observation is a good management practice when an animal breaks from its normal routine.

Effects of Inadequate Water Supply

An inadequate water supply means a lack of water, not an absence of water. Several things occur when animals have a low water intake or the water is not fresh. A lack of appetite signals an inadequate water supply. The less water an animal drinks, the less feed it eats. Remember, water plays an important role in digestion. Since a lack of appetite occurs, weight loss is also a sign of inadequate water supply. When an animal is losing weight, its performance and production are reduced considerably.

A lack of water causes the blood to thicken in the animal because water composes the highest percentage of blood. Inadequate water supply can be fatal because it leads to dehydration and water toxicity.

Good management practices also include knowing normal body functions that can influence water intake. If the animal develops scours or diarrhea, the water requirement increases because of the digestive disturbance. Respiration is a normal body function that affects an animal's water intake. During respiration, moist air is exhaled. Respiratory problems could occur if inadequate water supply is not provided. Regulating body temperature is another normal body function. In the animal's body, heat is transferred by the release of moist air through the skin. When the environmental temperature and humidity increase, so will the water intake of the animal.

Summary

Understanding the roles of nutrients is vital for the management of livestock. A deficiency in one or more nutrients can cause severe losses in the production of livestock. Water is critical in maintaining all animal body functions; understanding this concept will lead to success as a livestock producer.

Credits

Livestock Nutrition and Feeding (Student Manual). 2nd ed. Columbus, OH: Ohio Agricultural Education Curriculum Materials Service, 1991.

Cullison, Arthur Edison. *Feeds and Feeding.* Reston, VA: Reston Publishing Co., 1987.

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Lesson 8:
Environmental Effects on Nutrition

Environment simply means everything surrounding an animal--weather, shelter, other animals, nutrition, etc. These surroundings can and do affect growth, development, and production in all animals.

An Animal's Environment

Environmental control includes nutrition, space requirements, light, air temperature and velocity (wind), relative humidity, wet bedding, dust, ammonia buildup, odors, and manure disposal. Enhancing these factors can enhance animal performance.

Factors with the most impact on an animal's nutritional needs are nutrition, weather and facilities/shelter, health, and stress.

Weather's Effects on Nutrition Requirements

Webster's dictionary defines weather as a "state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness and cloudiness."

Animals have a thermo-neutral (comfort) zone (C to F in Figure 8.1). This is the range within which the animal can perform with little discomfort by using physical regulation (such as shivering or seeking shade). Extreme weather can cause wide fluctuations in animal performance.

An animal's requirements increase as temperature, humidity, and air movement (wind) exceed or fall short of the animal's comfort zone. These three factors also influence an animal's heat loss. Animals adapt to weather in the following ways.

Cold weather - In cold weather, heating mechanisms used include (1) increased insulation from growth of hair and more fat, (2) increase in thyroid activity, (3) seeking protective shelter and warming sunshine, (4) huddling together, (5) consumption of more feed, which increases the heat increment and warms the animal, and (6) increasing activity. The most important heating mechanisms are body activity and amount of feed consumed.

TABLE 8.1 - Comfort Zones of Animals

Class of animal	*Temperature*		*Acceptable humidity (%)*
	Comfort zone (°F)	*Optim. (°F)*	
Cattle			
Beef cow	40-70	50-60	50-75
Steer, enclosed building	40-70	50-60	50-75
Dairy cow	40-70	50-60	50-75
Dairy calves	50-75	65	---
Sheep			
Ewe	45-75	55	50-75
Feeder lamb	40-70	50-60	50-75
Newborn lamb	75-90	---	---
Swine			
Sow, farrowing house	60-70	65	60-85
Newborn pigs	80-90	85	60-85
Feeder/finishing	60-65	60	60-85
Horses			
Horse	45-75	55	50-75
Newborn foal	75-80	---	---
Poultry			
Layers	50-75	55-70	50-75
Broilers	85-95	70	50-75
Turkeys	95-100	---	---

Credit: Ensminger, M. E. *The Stockman's Handbook.* 7th ed. Danville, IL: Interstate Publishers, Inc., 1992. Used with permission.

Hot weather - In hot weather, cooling mechanisms include (1) moisture vaporization (from the skin and lungs), (2) avoidance of the sunshine (seeking shade), (3) depression of thyroid activity, and (4) loafing (including lessening the production of meat, milk, and eggs, since they increase heat production).

The diagram in Figure 8.1 shows (1) influence of thermal zones and temperature on warm-blooded animals, and (2) the peak of milk yields in the spring, followed by the summer slump due to the high temperatures and lower-quality forages.

Heat production (metabolism) is plotted against ambient temperature to depict the relationship between chemical and physical heat regulation. Terms pertaining to Figure 8.1 follow.

Optimum temperature - This is the most comfortable temperature for the animal, and the greatest amount of energy can be used for production and feed efficiency (D to E in Figure 8.1).

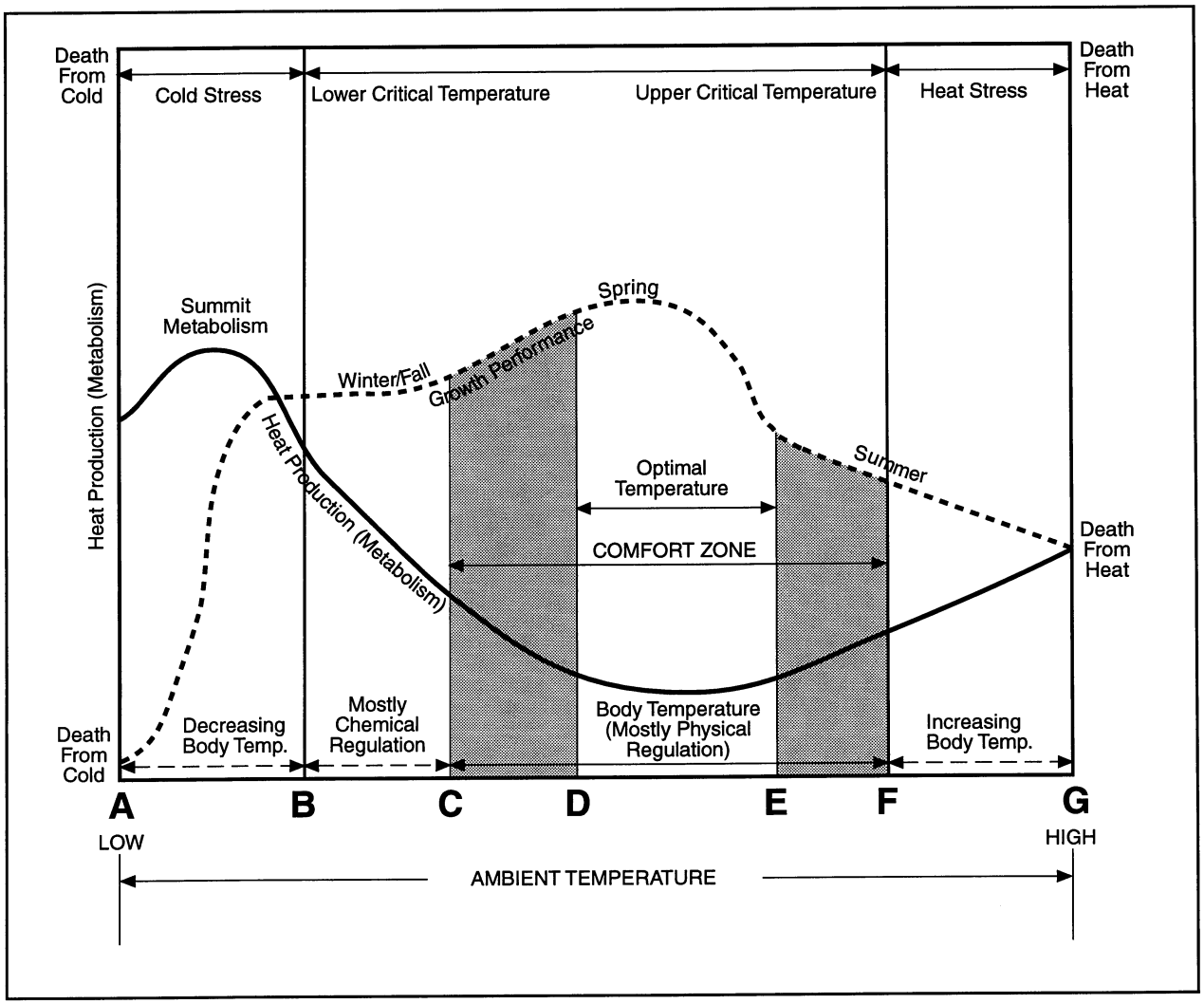
Lower critical temperature - The low point of the cold temperature beyond which the animal cannot maintain normal body temperature. In the zone below C, chemical temperature regulation is utilized (such as using fat deposits or increased respiration). When the environmental temperature reaches below point B, the chemical-regulation mechanism is no longer able to cope with cold. The body temperature then drops, followed by death.

Upper critical temperature - This temperature is the high point on the range of the comfort zone, beyond which animals are heat stressed and physical regulation cools them (F).

The cow produces the maximum yield of milk during the spring when the temperature is optimum (D to E) and the minimum yield in the summer when it is hot (F to G).

Comfort zone, optimum temperature, and both upper and lower critical temperatures vary. Factors include different species, breeds, ages, body sizes, physiological and production status,

FIGURE 8.1 - Thermo-Neutral Zone (Comfort Zone)



adaptations, climate, feed consumed (kind and amount), the activity of the animal, and the opportunity for evaporative cooling.

Animals that consume large quantities of roughage or high-protein feeds produce more heat during digestion; hence, they have a different critical temperature than the same animals fed a high-concentrate, moderate-protein ration. During hot summer months, experienced cattle feeders decrease the roughage and increase the concentrate of finishing cattle.

High humidity increases both high and low temperature stresses. There is less of a cooling effect from evaporating moisture and respired air. As humidity increases, discomfort and nutrient utilization decrease proportionately.

Air movement (wind) results in body heat being removed at a more rapid rate than when there is no wind. In warm weather, air movement can make the animal more comfortable, but in cold weather it adds to the stress temperature. (See Table 8.2.) At low temperatures, the nutrients required to maintain the body temperature are increased as the wind velocity (wind chill) increases.

Rain reduces feed intake by 10-30 percent. Mud reduces feed intake by 5-30 percent, depending upon its depth and the amount of bedded area.

There are several ways in which animals cope with inclement weather. These include adaptation, environmentally controlled buildings, and increased/decreased nutrient needs. Adaptation is shown by Brahman cattle being more heat tolerant and British breeds, such as Herefords, being more cold tolerant.

Other Factors Affecting Nutritional Needs

Gestation - Nutrient requirements for pregnant females are most critical during the last third of the gestation period (trimester), when the developing fetus grows most. Especially critical are nutrient requirements for young females during the first pregnancy. Poor nutrition at this stage will result in a poorly developed fetus and poor growth of the mother.

Lactation - Producing milk requires a liberal supply of energy, protein, minerals, and vitamins in the ration. After giving birth, feed requirements increase tremendously because of milk production. A female suckling young needs approximately 50 percent greater feed allowance than during the pregnancy period.

TABLE 8.2 - Wind-Chill Factors for Cattle with a Winter Coat

Wind speed (mph)	Temperature (°F)										
	-10	-5	0	5	10	15	20	25	30	35	40
5	-16	-11	-6	-1	3	8	13	18	23	28	33
10	-21	-16	-11	-6	-1	3	8	13	18	23	28
15	-25	-20	-15	-10	-5	0	4	9	14	19	24
20	-30	-25	-20	-15	-10	-5	0	4	9	14	19
25	-37	-32	-27	-22	-17	-12	-7	-2	2	7	12
30	-46	-41	-36	-31	-26	-21	-16	-11	-6	-1	3
35	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10
40	-78	-73	-68	-63	-58	-53	-48	-43	-38	-33	-28

Credit: Taylor, Robert E. *Beef Production and Management Decisions.* 2nd ed. New York: MacMillan Publishing Co., 1994, p. 333. Reprinted by permission of Prentice Hall, Upper Saddle River, N.J.

Stress - Stress is any environmental factor that is counter-productive to an animal's well-being, either external or internal. Animals under stress demand the very best nutrition.

Many kinds of management-related stress affect animal production: excitement, the presence of strangers, changing animals that are together, crowding, disease, hauling, how animals are handled, and weaning.

The right kind of animal handling can reduce stress. Preconditioning reduces the amount of stress present at weaning. It involves starting

young animals on feed and vaccinating them before weaning. Proper handling during vaccinations, movement, and hauling can greatly reduce stress and its results.

Health - Health is the state of complete well-being--not merely the absence of disease. It is estimated that animal diseases and parasites in the U.S. decrease animal productivity by 15-20 percent. Nutrition could be involved in 85 percent of veterinary-treated cases.

Muddy lots - Muddy lots often plague livestock producers, especially during the winter months. Mud increases scours and other diseases in newborn animals and reduces production and feed efficiency in older animals. California Agricultural Experiment Station studies show that mud can reduce finishing cattle gains and increase the feed required per pound of gain by 10-35 percent.

It is important to minimize this problem by picking a location for the feedlot that allows for proper drainage. Mounds that are 6-12 feet high provide finishing cattle a dry place on which to lie. Also, lessening the number of cattle in the feedlot during the muddy periods is an effective method of controlling the mud problem.

Temperature's Effect on Feed Requirements and Production Yields

Dairy cattle - The optimum temperature for the production of milk is 55-64°F. Temperatures below optimum result in a reduced water intake and approximately 35 percent increase in feed intake (down to -4°F). There is a corresponding reduction in milk production. This decrease can be corrected by increasing the proportion of concentrate in the diet (20 percent roughage/80 percent concentrate) and providing shelter. Higher concentrate levels help maintain milk yield without excessive loss of body weight.

Temperatures above the optimum result in an increase in water intake, a decrease in feed intake at 77-81°F, with greater decrease above 85°F. There is a decrease in dry-matter intake and a corresponding decrease in milk yield. At 95°F, milk yield might drop as much as 33 percent. Using confined housing for lactating dairy cows will help reduce the impact of weather extremes.

Beef cattle - The temperature range of 59-77°F is best for beef production. Variations from this range change feed intake as follows:

1. 77-95°F: depressed feed intake 3-10 percent
2. 41-59°F: increased feed intake 2-5 percent
3. 23-41°F: increased feed intake 3-8 percent
4. 5-25°F: increased feed intake 5-10 percent
5. Below 5°F: increased feed intake 8-25 percent

During cold weather, increase the amount of roughage for cattle on a restricted feed intake. However, with cattle on full feed, increasing the amount of roughage during cold weather can *decrease* the amount of energy available, thus reducing productivity.

Sheep - There is little experimental data available for sheep that describes the interaction of temperature and feed intake. Sheep can tolerate colder climatic extremes than other animals. Fleece length and the feeding level affect feed intake as temperatures change. Sheep need higher energy intake during cold stress. This can be economically met by increasing the roughage in the ration. During hot weather, decrease the roughage to lower the amount of heat produced by digesting the feed.

Swine - A temperature range of 64-70°F is considered optimum for growing/finishing swine. For each 1.8°F of temperature drop, the feed requirement increases 1-1.4 oz. daily. Heavier hogs are more sensitive to hot weather than lightweight hogs.

Poultry - Laying hens can adjust to a fairly wide range of temperatures. When temperature change occurs, feed intake will change temporarily and then return to approximately the level before the temperature change. Adequate drinking water is more critical for poultry growth or productivity. Compared to water intake at 70°F, water intake is doubled at 90°F and is 2.5 times greater at 98°F.

Summary

Livestock nutrient requirement tables are generally based on the assumption that no environmental stress is present. Feed and nutritional requirements need adjusting for changes in the animal's environment. Efficiency of nutrient use is affected by the weather and facilities, stress, and health.

Credits

Ensminger, M. E. *The Stockman's Handbook.* 7th ed. Danville, IL: Interstate Publishers, Inc., 1992.

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Lesson 9:
Formulating and Balancing Rations

An animal must receive the proper amounts of nutrients in the right proportion to efficiently produce meat, milk, eggs, wool, work, etc.

General Principles in Formulating Rations

A ration is balanced when it provides the nutrient needs of the animal in the proper proportions. Balanced rations have nutrient allowances that are only 1-3 percent below the animal's requirement. Nutrient requirements are listed in tables usually available from the National Research Council. Diets must include a minimum level of dry matter for proper digestive tract functioning. Diets are commonly balanced to meet the protein, energy, calcium, phosphorus, and vitamin A requirements for the animal. Also, the cost of the nutrients should be considered when formulating a ration.

Protein - The amount of protein in the diet can be measured by crude protein (CP) or digestible protein (DP) content. For nonruminants, include essential amino acids in the ration. It is acceptable to have the protein content of the formulated diet as much as 5-10 percent above the nutrient requirements listed in the tables. However, remember that protein is an expensive part of the diet; using excessive amounts will substantially raise the cost of the ration.

Crude protein refers to all of the nitrogenous compounds in a feed. It is determined by finding the nitrogen content and multiplying the result by 6.25. The nitrogen content of protein averages about 16 percent. Not all crude protein is digestible.

Digestible protein refers to a ration's approximate amount of protein available for use by the animal. Digestible protein is the difference between the feed's protein content and what is found in feces. About 60 percent of a roughage ration and 75-85 percent of a high-concentrate ration is digestible.

Energy - Four measures of energy commonly used when formulating diets are digestible energy (DE), total digestible nutrients (TDN), metabolizing energy (ME), and net energy (NE). The energy provided in the diet should not be more than about five percent above requirements because animals are limited in the total amount of energy they can use.

Digestible energy is equal to the gross energy of the feed consumed minus the gross energy excreted in the feces.

Total digestible nutrients include the totals of the digestible protein, digestible nitrogen-free extract, digestible crude fiber, and 2.25 times the digestible fat.

Metabolizing energy is the gross energy of the feed consumed minus the energy in the feces, urine, and gaseous products of digestion.

Net energy includes the metabolizable energy minus the heat increment (heat used for digestion or metabolism). It is the energy used for growth, maintenance, production, work, fetal development, and heat production.

Minerals - Calcium and phosphorus are the two minerals generally needed in larger amounts. The ratio of calcium to phosphorus (between 1:1 and 2:1) is just as important as the total amount being fed. Other mineral needs of the animal are generally not considered when balancing rations. There are usually enough minerals provided in the ingredients used or by the addition of trace-mineralized salt.

Vitamins - A vitamin supplement is usually added to the ration to meet the animal's vitamin needs. However, vitamin A requirements might be considered in balancing rations. When low-quality legume hay is included in the diets of pregnant cattle or sheep, a vitamin deficiency can occur. Always add a vitamin supplement to a gestation ration.

Cost of nutrients - The cost per pound of each nutrient must be considered when developing least-cost rations for maximum efficiency. Energy and protein nutrients are the major ones considered when making nutrient cost comparisons.

Steps in Balancing a Ration

Step 1 - Identify the kind, age, weight, and function of the animal(s).

Step 2 - Consult a table of nutrient requirements to determine the nutrient needs of the animal(s). These requirements are called feeding standards. Feeding standards are based on average requirements and might not meet the needs under specific feeding conditions.

Step 3 - Choose the feeds to be used in the ration and consult a feed composition table to determine the nutrient content of the selected feeds.

Step 4 - Calculate the amounts of each feed to use in the ration. Several methods are available. The Pearson Square or algebraic equation methods can be used to balance a ration using two or more feeds. (See Figure 9.1.) Computer programs can also help balance rations.

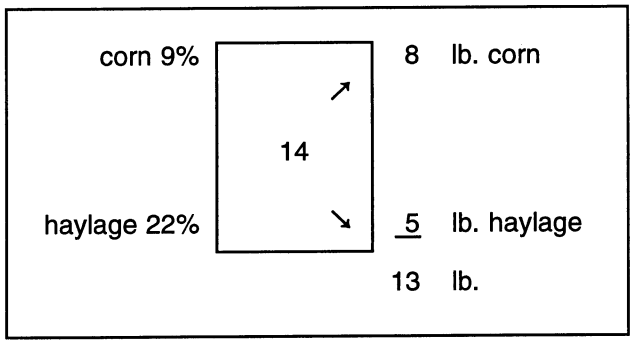
Step 5 - Check the ration formulated against the needs of the animal(s). Be sure it meets the requirements for minerals and vitamins. Check the cost of the nutrients in the ration to determine if this is the most economical ration that is practical to feed.

Eight Essentials of a Balanced Ration

A good ration includes certain basics:

1. Nutrients in the ration should be balanced. Faster gains, less expense, and more profits are the benefits of feeding balanced rations.
2. The ration should contain a variety of feeds. This variety generally increases the palatability of the ration and make it easier to balance the nutrients.
3. The ration should be fresh and appealing. Livestock consume more of a fresh ration, thus increasing productivity.
4. A palatable (good tasting) ration is more readily consumed, adding to the producer's gains.
5. Bulk in the ration is usually more desirable. Feeds such as ground oats, beet pulp, etc., add bulk.
6. A ration should be slightly laxative because a laxative ration usually improves efficiency.
7. The ration should be economical.
8. Since digestive systems of animals are different among species, the ration should be suited to the animal. Cattle and sheep can consume large quantities of roughage, while poultry and swine rations must consist largely of concentrates.

FIGURE 9.1 - Pearson Square Computation



Summary

There are basic nutritional needs for different classes of livestock. For growth to occur, every one of the five nutrients (protein, energy, minerals, vitamins, and water) must be present in sufficient quantity.

Credits

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