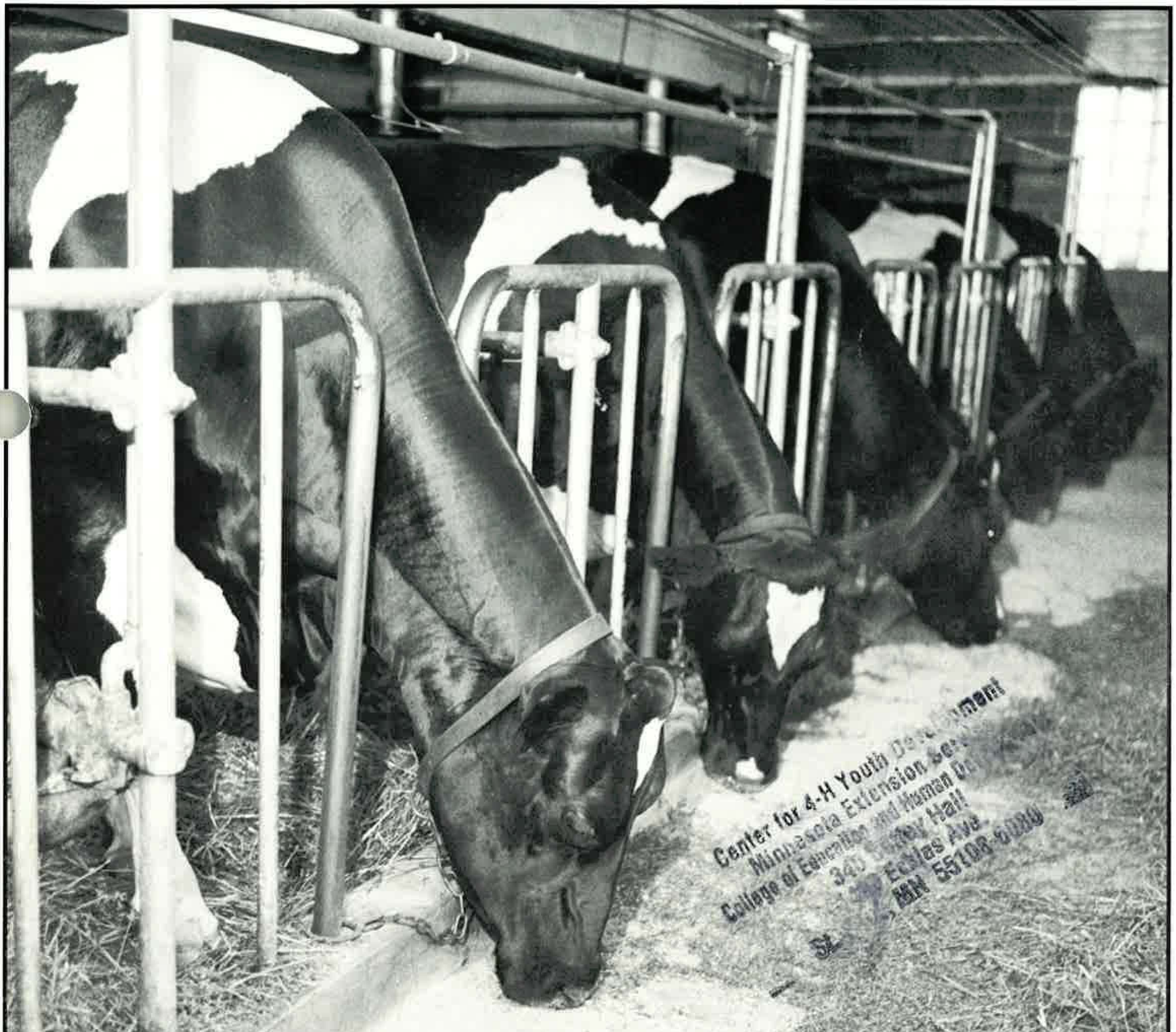
BU-0469-F
Reviewed 1996

North Central Regional Extension Publication 346

feeding the DAIRY HERD

James G. Linn, Michael F. Hutjens, Randy Shaver, Donald E. Otterby, W. Terry Howard, and Lee H. Kilmer



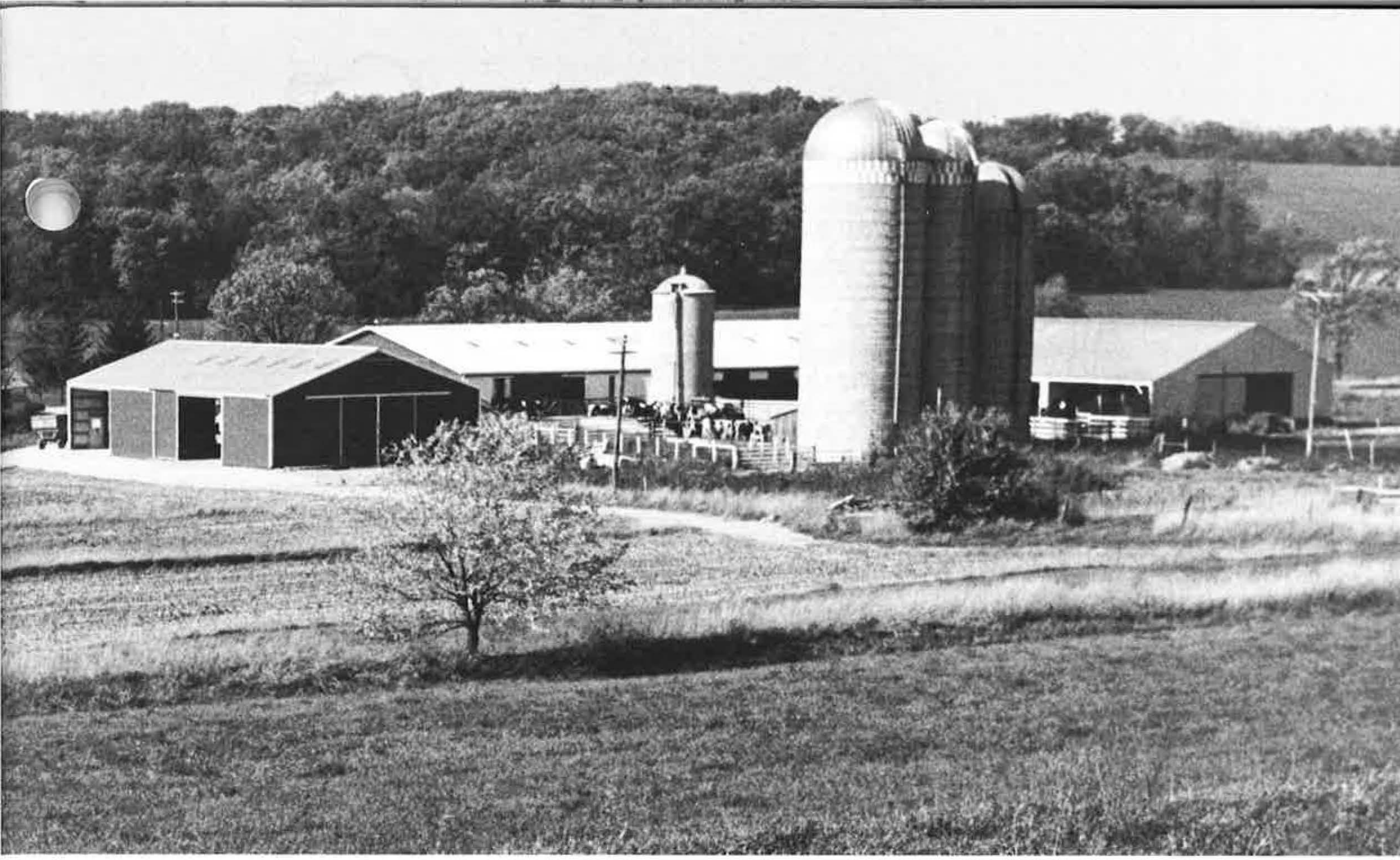
MINNESOTA EXTENSION SERVICE
UNIVERSITY OF MINNESOTA
COLLEGE OF AGRICULTURAL, FOOD AND ENVIRONMENTAL SCIENCES

TABLE OF CONTENTS

Abbreviations used throughout this publication are as follows:

DM	=	dry matter	RFV	=	relative feed value
DMI	=	dry matter intake	UIP	=	undegradable intake protein
CP	=	crude protein	DIP	=	degradable intake protein
NFC	=	nonfiber carbohydrates	SIP	=	soluble intake protein
ADF	=	acid detergent fiber	NPN	=	nonprotein nitrogen
NDF	=	neutral detergent fiber			

The first edition of this publication was authored in 1894 by T.L. Haecker, University of Minnesota. This is the thirty-fourth edition of the publication and the third multistate edition. Information in this publication is intended to assist dairy producers, the feed industry and other agribusinesses in improving milk production per cow and to help the midwest dairy industry better compete on a national basis. The basic information on nutrition and feeding management for dairy animals from birth through their lactation cycles is presented here. The tables and text are based on current research data and the authors' experiences. This publication is intended as a basic reference manual and should be supplemented with fact sheets and other dairy nutrition publications as they become available from the cooperating states.



Dairy farms represent major capital investments in rural communities.

RUMINANT ANATOMY AND PHYSIOLOGY

Anatomy of the Adult

The cow's digestive tract consists of the mouth, esophagus, a complex four-compartment stomach, small intestine and large intestine **(figure 1)**. The stomach includes the rumen or paunch, reticulum or "honeycomb," the omasum or "manyplies," and the abomasum or "true stomach."

The rumen. The rumen (on the left side of the animal) is the largest of four compartments and is divided into several sacs. It can hold 25 gallons or more of material, depending on the size of the cow. Because of its size, the rumen acts as a storage or holding vat for feed. It is also a fermentation vat. A microbial population in the rumen digests or ferments feed eaten by the animal. Conditions within the rumen favor the growth of microbes. The rumen absorbs most of the volatile fatty acids produced from fermentation of feedstuffs by rumen microbes. Absorption of volatile fatty acids and some other products of digestion is enhanced by a good blood supply to the walls of the rumen. Tiny projections called papillae increase the surface area and the absorption capacity of the rumen.

The reticulum. The reticulum is a pouch-like structure in the forward area of the body cavity. The tissues are arranged in a network resembling a honeycomb. A small fold of tissue lies between the reticulum and the rumen, but the two are not actually separate compartments. Collectively they are called the rumino-reticulum. Heavy or dense feed and metal objects eaten by the cow drop into this compartment. The reticulum lies close to the heart. Nails and other sharp objects may work into the tissue and cause "hardware disease" **(see page 36)**. If not prevented by a magnet or corrected by surgery, infection may occur and the animal may die.

The omasum. This globe-shaped structure (also called the "manyplies") contains leaves of tissue (like pages in a book). The omasum absorbs water and other substances from digestive contents. Feed material (ingesta) between the leaves will be drier than that found in the other compartments.

The abomasum. This is the only compartment (also called the true stomach) with a glandular lining. Hydrochloric acid and digestive enzymes, needed for the breakdown of feeds, are secreted into the abomasum. The abomasum is comparable to the stomach of the non-ruminant.

The small intestine. The small intestine measures about 20 times the length of the animal. It is composed of three sections: the duodenum, jejunum, and ileum. The small intestine receives the secretions of the pancreas and

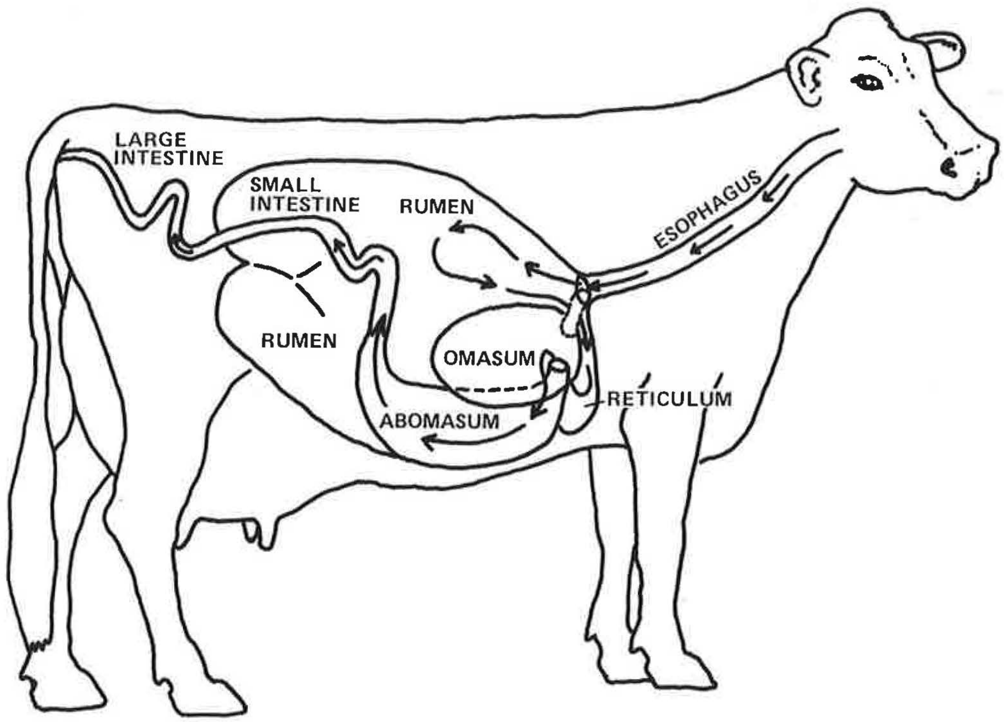


Figure 1. Anatomy of the adult digestive tract.

the gallbladder, which aid digestion. Most of the digestive process is completed here, and many nutrients are absorbed through the villi (small finger-like projections) into the blood and lymphatic systems.

Cecum. The cecum is the large area located at the junction of the small and large intestine, where some previously undigested fiber may be broken down. The exact significance of the cecum has not been established.

Large intestine. This is the last segment of the tract through which undigested feedstuffs pass. Some bacterial digestion of undigested feed occurs, but absorption of water is the primary digestive activity occurring in the large intestine.

Function of the Digestive Tract

Eructation (belching). Large quantities of gas, mostly carbon dioxide and methane, are produced in the rumen. Production amounts to 30 to 50 quarts per hour and must be removed; otherwise bloating occurs. Under normal conditions, distension from gas formation causes the cow to belch and eliminate the gas.

Rumination. A cow may spend as much as 35 to 40 percent of each day ruminating (cud chewing). The actual amount of time spent ruminating varies from very little (when grain or finely ground rations are fed) to several hours (when long hay is fed). Mature cattle spend little time chewing when eating. During rest periods, feed boluses (cud) are regurgitated for rechewing to reduce particle size and for resalivation. Feed is more readily digested by rumen microbes as particle size is reduced.

Motility of the rumen and reticulum. The rumen is always contracting and moving. Healthy cows will have one to two rumen contractions per minute. The contractions mix the rumen contents, bring microbes in contact with new feedstuffs, reduce flotation of solids, and move materials out of the rumen. Lack of or a decrease in frequency of rumen movements is one way of diagnosing sick animals.

Saliva production. As much as 50 to 80 quarts of saliva can be produced by salivary glands and added to the rumen each day. Saliva provides liquid for the microbial population, recirculates nitrogen and minerals, and buffers the rumen. Saliva is the major buffer for helping to maintain a rumen pH between 6.2 and 6.8 for optimum digestion of forages and feedstuffs.

Vomiting. Cattle rarely vomit. Occasionally certain feeds will induce vomiting. Some pasture plants, usually weeds, contain alkaloids that can cause this problem. Should this condition persist, a veterinarian should be consulted.

Digestion of energy feeds in the rumen. Simple and complex carbohydrates (fiber) are digested by rumen microbes and converted into volatile fatty acids. The volatile fatty acids, which consist mainly of acetic, propionic, and butyric acids, are the primary energy source for ruminants (**figure 2**). When large amounts of forage are fed, the formation of acetic acid predominates (60 to 70 percent of total) with lesser amounts of propionic (15 to 20 percent) and butyric (5 to 15 percent) acids occurring. However, when grain feeding is increased or when finely ground forages are fed, the proportion of acetic acid may decrease to 40 percent, while the amount of propionic acid may increase to 40 percent. Such a change in volatile fatty acid production generally is associated with a reduction in milk fat test.

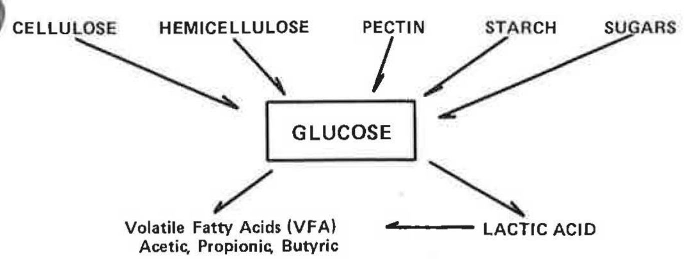


Figure 2. Microbial digestion of feed carbohydrate in the rumen.

Approximately 30 to 50 percent of the cellulose and hemicellulose is digested in the rumen by the microbial population. Sixty percent or more of the starch is degraded, depending on the amount fed and how fast ingested materials move through the rumen. Most sugars are 100 percent digested within the rumen.

The volatile fatty acids are absorbed from the rumen into the blood stream and transported to body tissues, including the udder, where they are used as sources of energy for maintenance, growth, reproduction, and milk production. The cow derives 50 to 70 percent of its energy from the volatile fatty acids produced in the rumen.

Protein and nonprotein nitrogen utilization in the rumen. Some of the protein consumed by the cow escapes breakdown in the rumen **(figure 3)**. Protein undergoing fermentation is converted to ammonia, organic acids, amino acids, and other products. Approximately 40 to 75 percent of the natural protein in feed is broken down. The extent of breakdown depends on many factors including solubility of the protein, resistance to breakdown, rate of feed passage through the rumen, and others. Many rumen micro-organisms require ammonia (breakdown product of protein) for

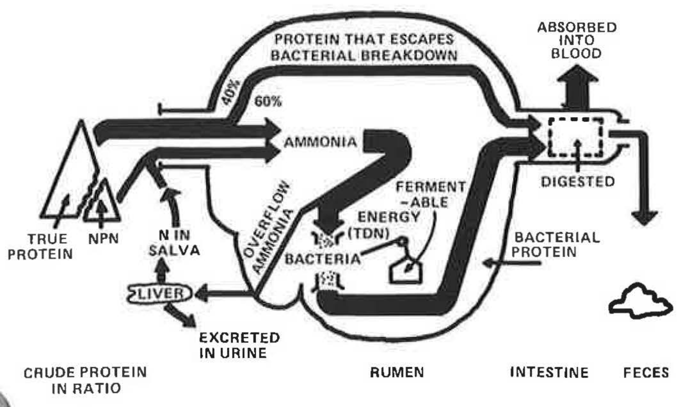


Figure 3. Schematic summary of nitrogen utilization by the ruminant. Source: Satter, 1978. Minnesota Nutrition Conference Proceedings.

growth and synthesis of microbial protein. Ammonia also may be provided from NPN sources such as urea, ammonium salts, nitrates, and other compounds. Rumen microbes convert the ammonia and organic acids into amino acids that are assembled into microbial protein. Excess ammonia is mostly absorbed from the rumen into the blood stream, but small amounts may pass into the lower digestive tract and be absorbed. Feed protein (that escapes breakdown in the rumen) and microbial protein pass to the abomasum and small intestine for digestion and absorption.

Vitamin synthesis. The rumen micro-organisms manufacture all of the B vitamins and vitamin K. Vitamin synthesis in the rumen is sufficient for growth and maintenance. Under most conditions, cattle with functioning rumens do not require supplemental B vitamins or vitamin K in the diet. Niacin (B3) and thiamine (B1) may be needed under stress conditions.

Fat digestion. Most of the digestion and absorption of fat occurs in the small intestine. Rumen micro-organisms change unsaturated fatty acids to saturated acids through the addition of hydrogen molecules. Thus, more saturated fat is absorbed by cows than by simple-stomach animals. Feeding large quantities of unsaturated fatty acids can be toxic to rumen bacteria, depress fiber digestion, and lower rumen pH.

Calf Digestive System

At birth and during the first few weeks of life, the rumen, reticulum, and omasum are undeveloped. In contrast to the mature cow, in the calf, the abomasum is the largest compartment of the stomach **(table 1)**. At this stage of life, the rumen is nonfunctional and some feeds digested by the adult cannot be used by the calf. During nursing or feeding from a bucket, milk bypasses the rumen via the esophageal groove and passes directly into the abomasum. Reflex action closes the groove to form a tube-like structure which prevents milk or milk replacer from entering the rumen. When milk is consumed very rapidly, some may overflow into the rumen.

As long as the calf remains on milk, the rumen remains undeveloped. When calves begin consuming grain and forage, a microbial population becomes established in the rumen and reticulum. End products of microbial fermentation are responsible for the development of the rumen. This occurs as early as 3 weeks of age with most feeding programs. Cud inoculation is not necessary to initiate rumen development. If grain feeding with or without forage is started during the first few weeks of life, the rumen will become larger and heavier with papillae development, and will begin functioning like the adult's when the calf is about 3 months of age.

TABLE 1. PERCENTAGE RELATIONSHIP OF A CALF'S STOMACH COMPARTMENTS WITH INCREASING AGE

Stomach compartment	Age (weeks)						
	0	4	8	12	16	20-26	34-38
	% of total weight						
Rumen-reticulum	38	52	60	64	67	64	64
Omasum	13	12	13	14	18	22	25
Abomasum	49	36	27	22	15	14	11

Source: Warner and Flatt. 1965. In R.W. Dougherty, ed. *Physiology of Digestion in the Ruminant.*

FEED NUTRIENTS

Energy

Energy (includes primarily carbohydrates and fats, but protein also can be used as energy) in a feed may be separated into: 1) the losses that occur in digestion and metabolism, and 2) the remainder that is available to the animal for maintenance and production. **Figure 4** shows this division of energy. Gross energy refers to the total energy in feed, which is determined by complete oxidation (burning) of the feedstuff and measurement of the heat produced. The energy value is expressed in calories. Common feedstuffs are similar in gross energy content, but differ in feeding value because of differences in digestibility. Digestible energy is gross energy minus fecal (manure) loss. These losses will be greater for high fiber rations than for low fiber rations. Other losses include those in urine and gas. In the rumen, considerable methane is produced, representing an energy loss because the animal cannot use methane and must eructate (belch) the gas. These losses, added to fecal losses, are considered in calculating the metabolizable energy. Heat is produced during digestion and metabolism. Other than during cold weather, this heat has no value and represents a loss of energy. The remaining energy is net energy (NE) available for maintenance and production. In the requirement and feed tables for growth, a net energy value for maintenance and net energy value for gain are given. These values differ because animals use energy for maintenance more efficiently than for growth. The efficiency of energy use by lactating cows for maintenance and lactation is similar. Therefore, only one net energy value, net energy of lactation, is used for these two functions.

Total digestible nutrients (TDN) is another method of expressing the energy content of feeds or the energy requirements of cattle. TDN is comparable to digestible energy. It has been in use longer than the net energy system and more values are available for feedstuffs.

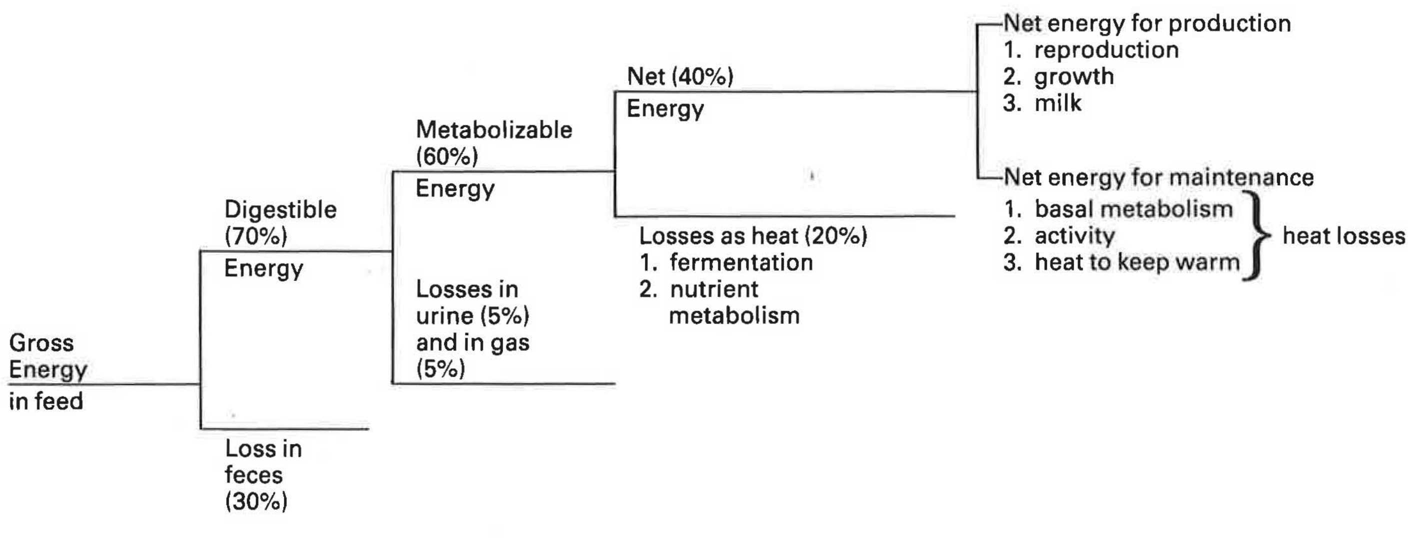
TDN = Digestible nitogen-free extract (carbohydrate)
+ digestible crude fiber + digestible protein
+ (digestible ether extract x 2.25)

Both NE and TDN are given in this publication. NE of lactation (NE_L) can be calculated from TDN:

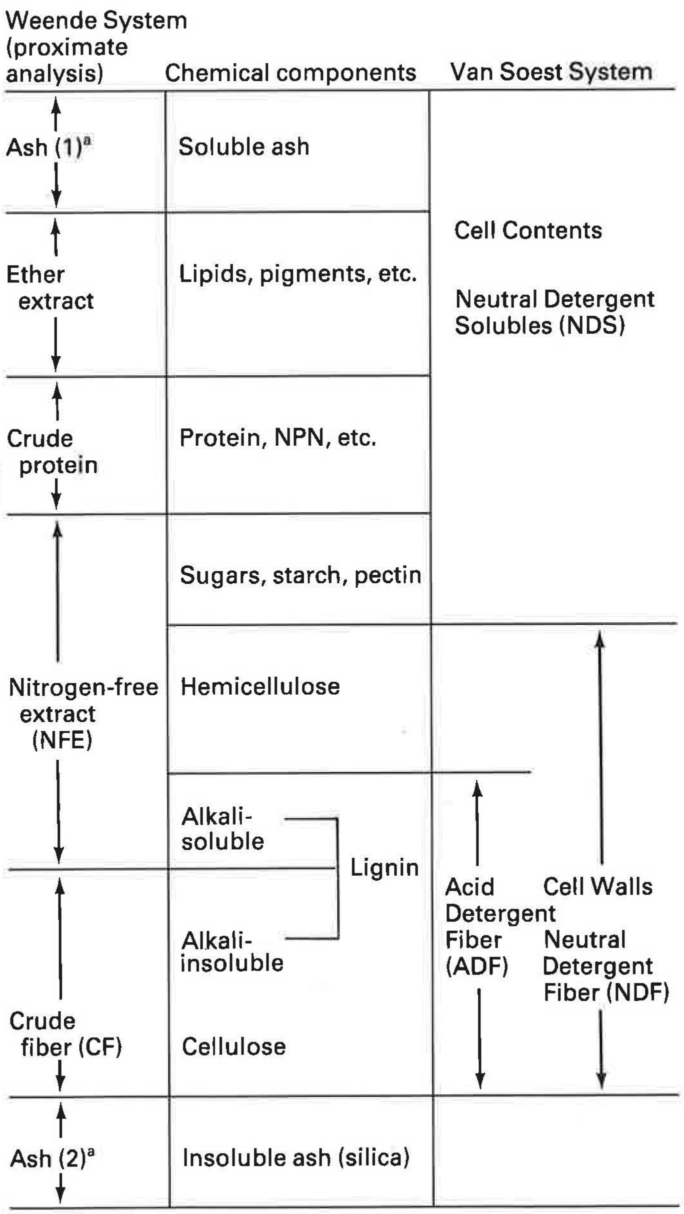
$$NE_L\text{ (Mcal/lb DM)} = (\text{TDN, \% of DM} \times .01114) - .054$$

Carbohydrates. Carbohydrates are the major source of energy in diets for dairy cattle. Between 50 and 80 percent of the DM in forages and grains is carbohydrate. Three major categories of carbohydrate exist in feeds:

Figure 4. Partitioning of ration (60 percent alfalfa and 40 percent corn) energy and losses in a lactating cow.



1) simple sugars (glucose); 2) storage carbohydrates (starch); 3) structural carbohydrate or fiber (cellulose and hemicellulose). Sugars are found in the cells of growing plants and in such feeds as molasses. Starch is the main component of grains. Cellulose and hemicellulose are made up of sugar molecules, as is starch, but are bound together differently. Cellulose and hemicellulose are classified as fiber, giving structure and strength to plant tissues. Simple-stomach animals, such as pigs and poultry, cannot digest much fiber. Adult ruminants digest fiber because the microbial population in the rumen breaks it down into usable products. Lignin, which is also a component of plants, is not a true carbohydrate. This compound is virtually indigestible. Feed digestibility is lowered when lignin is present in large amounts, such as in mature forages.



[a]Total ash from Weende system consists of ash (1) + ash (2).

Figure 5. Relationship among crude fiber, acid detergent fiber, and neutral detergent fiber analyses. Sources: Van Soest and Moore (1966), and Harris (1975[a]).

Three methods are available to measure fiber content of feeds (**figure 5**). Crude fiber (CF) is the oldest method and is the residue of a feed that is resistant to successive boiling with dilute acid and alkali treatments. Crude fiber is not an accurate measure of total fiber or cell walls because much of the lignin and hemicellulose is lost during the analysis. Even cellulose is not totally recovered in the CF fraction. Many feed testing labs no longer report CF, but it is required on feed tags of purchased feeds.

Acid detergent fiber (ADF) consists of cellulose, lignin, lignified nitrogen compounds (heat damaged protein), and insoluble ash. Acid detergent fiber does not represent the total fiber content in feed, as it does not account for hemicellulose. It is a relatively quick method for measuring fiber, often substituting for CF. Equations used to predict the digestibility or energy content of feedstuffs are usually based on ADF or include ADF as a major component.

Neutral detergent fiber (NDF) consists of ADF plus hemicellulose, and is often called cell walls. Because NDF represents the total fiber in a feed, it is highly correlated to intake, rumination, and total chewing time. Corrected for physical form, NDF provides the best measurement of effective fiber for formulating dairy rations.

The fineness at which forages are chopped during harvesting can alter the effectiveness of fiber for maintaining chewing activity. Haycrop silages should be chopped at a minimum of 3/8 inch theoretical length of cut (TLC) to provide 15 to 20 percent (weight basis) of the particles greater than two inches long. Chopping at 1/4 inch TLC provides only about 10 percent of the forage particles greater than two inches long. Corn silage should be chopped at 1/4 to 3/8 inch TLC. Rations based on 1/4 inch TLC silage should include 5 pounds of long stem hay to provide adequate "effective" fiber. Haycrop silage chopped at 3/16 inch TLC with less than 7 percent coarse particles should be fed with 8 to 10 pounds of long hay. Holstein cows need to chew about 11 to 12 hours per day or 12 to 14 minutes per pound of DM eaten to keep milk fat above 3.5 percent.

High fiber by-product feeds supply some "effective" NDF and can be used to partially replace NDF coming from forages in the ration. Whole cottonseed possesses the best forage NDF replacement value of commonly available by-product feeds fed in milking cow rations.

TABLE 2. FATTY ACID PROFILES OF COMMON FAT SOURCES

Fatty acid	Profile	Tallow	Choice white grease	Yellow grease	Poultry fat	Soybean oil
		--------------------	--------------------	% of fatty acids	--------------------	--------------------
Myristic	C14:0	3.1	1.5	1.3	1.1	0.0
Palmitic	C16:0	25.8	23.5	17.6	23.8	11.5
Palmitoleic	C16:1	4.3	3.4	2.3	9.6	0.0
Stearic	C18:0	20.4	12.0	10.2	4.7	4.0
Oleic	C18:1	39.1	44.3	45.9	42.9	24.5
Linoleic	C18:2	2.3	10.7	20.3	16.8	53.0
Linolenic	C18:3	1.3	3.1	0.9	0.9	7.0
Total % unsaturated		49.0	62.2	69.9	70.4	84.5
Total % saturated		51.0	37.8	30.1	29.6	15.5
Ratio unsat/sat		1:1	1.6:1	2.4:1	2.4:1	5.4:1

Source: National Renderers Association (1992)

Starch, sugar, and pectin make up the highly digestible carbohydrate fraction in feeds termed non-fiber carbohydrates (NFC). Subtracting percent (DM basis) NDF, CP, ether extract or fat and ash from 100 provides an estimate of NFC percent in feeds.

(NFC% = 100 - [%NDF + %CP + %fat + %ash])

The term nonstructural carbohydrate is often used interchangeably with NFC but is analytically determined and may be slightly different from NFC.

Carbohydrate status of dairy rations has traditionally been evaluated with regard to measures of structural carbohydrates—ADF or NDF. However, optimum microbial growth in the rumen requires adequate amounts of NFC along with degradable intake protein (DIP) in the ration. Insufficient amounts of NFC in rations depress microbial growth and digestion of feed in the rumen, while excess NFC in rations causes acidosis and/or low milk fat tests.

Fat. The energy content of fat is about 2.25 times the energy in carbohydrates. Diets for baby calves that include large quantities of milk or milk replacer may contain 10 to 35 percent fat in the DM consumed. Fat may be added to the diets of adult ruminants to increase energy density and to reduce feed dustiness. Typical diets usually contain no more than 4 percent fat in the DM. Total fat and oil should be limited to less than 7 percent of the DM in lactating cow rations. Too much fat decreases feed intake, may depress fat and protein content of milk, and may cause scouring. Commonly fed sources of fat include whole cottonseeds, full-fat soybeans, sunflower seeds, tallow, and various rumen-inert fat products.

Fatty acid profile is the most important characteristic of a fat source in determining how much to feed, as it is related to ruminal inertness and postruminal digestibility. Dietary fat comes as either fatty acids or triglycerides (three fatty acids attached to glycerol). The oils found in oilseeds and the fats in animal fats are examples of triglycerides. Rumen bacteria hydrolyze triglyceride to fatty acids and glycerol. The fatty acids in feeds and specialty fats are either saturated or unsaturated, and primarily range from 14 to 18 carbons in chain length. Saturated fatty acids (myristic C14:0, palmitic C16:0 and stearic C18:0) are solid at room temperature; hence the term "hard" fats. Tallow is considered a saturated fat, although about 50 percent of the fatty acids in tallow are unsaturated. Unsaturated fatty acids (palmitoleic C16:1, oleic C18:1, linoleic C18:2, and linolenic C18:3) vary in the temperature at which they become liquid, but as the amount of unsaturation increases, the temperature at which the fat becomes liquid decreases. Whole cottonseed and soybeans have 71 and 85 percent unsaturated fatty acids, respectively. However, feeding oilseeds whole encapsulates the fat and results in a slower digestion, allowing a slow release of fat into the rumen and more uniform conversion of the unsaturated fatty acids to saturated fatty acids by the bacteria. Unsaturated fatty acids interfere with rumen fermentation more than saturated fatty acids. Protected or ruminal inert fats are commercially produced fats that do not affect rumen fermentation.

Protein

Protein is essential for maintenance, growth, and milk production. The protein requirement of dairy cattle is really a requirement for amino acids by the animal tissues. Amino acids are supplied by the digestion of microbial protein, and by feed protein that escapes microbial breakdown in the rumen.

Protein requirements in this publication are expressed as crude protein (CP), either in amounts or as a percentage of the dietary DM. Crude protein is determined by multiplying the nitrogen content in a feed by the factor 6.25 (feed protein averages 16 percent nitrogen). Nonprotein nitrogen compounds, such as urea or ammonium salts, are considered to have a CP value, but supply no amino acids directly. Micro-organisms in the rumen convert nitrogen from NPN sources into amino acids for their use. Digestion of microbial protein in the small intestine releases amino acids for absorption and utilization, the same as amino acids released from the digestion of true proteins (composed of amino acids) in feeds.

Approximately 60 percent of the CP in the typical dairy cow diet is broken down by microbial digestion to ammonia. The rumen microbes must convert the ammonia to microbial protein if the dairy animal is to receive any benefit. Fermentable energy must be available for the micro-organisms to grow and synthesize the necessary amino acids. If rumen ammonia levels are excessively high, the ammonia is absorbed into the blood and recycled or excreted in urine as urea. All feed protein sources are not degraded in the rumen to the same extent. Three protein terms describe the fate of dietary protein in the rumen. Degradable intake protein (DIP) is the portion of feed protein broken down to ammonia or amino acids by the rumen microbes. Soluble intake protein (SIP) is the portion of DIP that is rapidly degraded in the rumen. Generally, SIP is about half of the DIP. Undegradable intake protein (UIP) is the portion of feed protein that is not degraded by the rumen microbes and remains intact as it passes through the rumen. Other terms for UIP include by-pass protein and escape protein. Values for UIP, SIP and DIP can be expressed as either a percent of the dietary DM (for example, a feed may contain 17 percent CP and 6.8 percent UIP in the DM) or as a percent of the CP (for example, 40 percent UIP calculated by 6.8/17). The sum of DIP and UIP, expressed as percent of CP, must equal 100. Diets for high producing dairy cows should contain 19 percent CP with 38 percent of the CP as UIP, 62 percent as DIP and 30 percent as SIP; or 19 percent CP with 7.2 percent UIP, 11.8 percent DIP and 5.7 percent SIP in the dietary DM.

The optimal diet fed to dairy cattle will 1) meet the nitrogen requirement of rumen micro-organisms for maximum synthesis of micro-organism protein and 2) allow for maximum escape or bypass of high quality feed protein for digestion in the small intestine. Protein synthesis by rumen microbes will depend on feed intake, organic matter digestibility, feed type, protein level, and feeding system. Since 4.5 pounds of microbial protein synthesis per day is near the maximum, the remainder of the protein must be derived from UIP sources. Young, fast-growing heifers and high-producing cows may require additional UIP sources beyond their normal diet to meet their amino acid requirements. Brewers grain, distillers grain, corn gluten meal, or heat-treated soybeans are examples of UIP feeds that could be substituted in diets where excess rumen ammonia exists and less than optimal amounts of quality feed protein pass into the small intestine. Excess protein, above requirements, is used as a source of energy.

Vitamins

Vitamins are organic compounds needed in small amounts for life support. They contribute no measurable amount of protein or energy to the animal but function in chemical reactions involving other nutrients. If a vitamin deficiency occurs, definite symptoms appear and become more severe unless corrected.

The vitamins can be classified into two broad groups: 1) water soluble vitamins, and 2) fat soluble vitamins. Water soluble vitamins include the B vitamins: thiamine or B1, riboflavin or B2, niacin, pantothenic acid, pyridoxine or B6, vitamin B12, biotin, and folic acid. Choline is often included in the B complex group. Research indicates that under normal dietary conditions, B vitamins are synthesized in sufficient amounts in the rumen to meet the animal needs. Supplemental B vitamins may be required during diseased conditions, periods of stress, or for very young animals. Supplementing 6 grams of niacin from 2 weeks prepartum to 8 to 12 weeks postpartum can reduce ketosis and minimize fatty liver formation in high-producing cows. Another water soluble vitamin, vitamin C (ascorbic acid),

TABLE 3. SUMMARIZATION OF FAT SOLUBLE VITAMINS IN DAIRY RATIONS

Vitamin	Function(s)	Deficiency symptoms and associated problems	Common feed sources for dairy cattle
A	Essential for normal vision; cellular function; and maintenance of epithelial linings of respiratory, reproductive and digestive tracts.	Night blindness; skin problems; blind, dead or weak calves; reproductive problems.	Carotene sources: green, leafy forages; hays; haylages (little weathering); unfrosted corn silage; synthetic A; vitamin premix; fish liver oil.
D	Normal bone growth and development; absorption of calcium and phosphorus; mobilization of calcium and phosphorus.	Rickets, osteomalacia.	Sun-cured forages; fish liver oils; synthetic premixes.
E	Antioxidant; associated with selenium.	Oxidized flavor in milk; muscle problems; white muscle disease; cardiac muscle abnormalities.	Alfalfa; germ of cereals; wheat germ oil; cereal grains; synthetic premixes.
K	Required for blood clotting.	Hemorrhaging; moldy sweet clover disease.	Green, leafy forages. Ample amounts normally are synthesized in the digestive tract.

TABLE 4. SUMMARIZATION OF MINERALS IN DAIRY RATIONS

Mineral	Function(s)	Deficiency symptoms and associated problems	Feed sources for dairy cattle
Calcium (Ca)	Bone and teeth formation; blood clotting; muscle contraction. .12% in whole milk.	Rickets; slow growth and poor bone development; easily fractured bones; reduced milk yield; milk fever is a disturbance of normal calcium metabolism.	Alfalfa and other legumes; ground limestone; dicalcium phosphate; steamed bone meal
Phosphorus (P)	Bone and teeth formation; P is involved in energy metabolism, part of DNA and RNA. .09% in milk.	Fragile bones; poor growth; low blood P (less than 4-6 mg/100 ml); depraved appetite (chewing of wood, hair and bones); poor reproductive performance.	Monosodium, monoammonium and dicalcium phosphates; steamed bone meal; cereal grains; grain byproducts; oil seed meals.
Sodium (Na)	Acid-base balance; muscle contraction; nerve transmission.	Craving for salt; reduced appetite; if very severe: incoordination, weakness, shivering, and death.	Common salt and buffer products.
Chlorine (Cl)	Acid-base balance; maintenance of osmotic pressure; manufacture of hydrochloric acid in abomasum.	Craving for salt; reduced appetite.	Common salt and commercial supplements.
Magnesium (Mg)	Enzyme activator; found in skeletal tissue and bone.	Irritability; tetany; increased excitability.	Magnesium oxide; forages and mineral supplements.
Sulfur (S)	Rumen microbial protein synthesis, especially when nonprotein nitrogen is fed; found in cartilage, tendons, and amino acids.	Slow growth; reduced milk production; reduced feed efficiency.	Elemental sulfur; sodium and potassium sulfates; protein supplements; legume forages.
Potassium (K)	Maintenance of electrolyte balance; enzyme activator; muscle function; nerve function.	Decrease in feed intake; loss of hair glossiness; lower blood and milk potassium.	Legume forages; potassium chloride; potassium sulfate.
Iodine (I)	Synthesis of thyroxine (hormone).	Big neck in calves; goitrogenic substances may cause deficiency.	Iodized salt, trace mineralized salt and EDDI (ethylene diamine dihydroiodide).
Iron (Fe)	Part of hemoglobin; part of many enzyme systems.	Nutritional anemia.	Forages; grains; trace mineralized salt and commercial supplements.
Copper (Cu)	Needed for manufacture of hemoglobin; coenzyme.	Severe diarrhea; abnormal appetite; poor growth; coarse, bleached or graying hair coat; osteomalacia.	Trace mineralized salt and commercial supplements.
Cobalt (Co)	Part of vitamin B12; needed for growth of rumen microorganisms.	Failure of appetite; anemia; decreased milk production; rough hair coat.	Trace mineralized salt and commercial supplements.
Manganese (Mn)	Growth; bone formation; enzyme activator.	Delayed or decreased signs of estrus; poor conception.	Trace mineralized salt and commercial supplements.
Zinc (Zn)	Enzyme activator; wound healing.	Decreased weight gains; lowered feed efficiency; skin problems; slow healing wounds; listlessness.	Forages; trace mineralized salt, commercial supplements, and zinc methionine.

TABLE 4. (CONTINUED)

Mineral	Function(s)	Deficiency symptoms and associated problems	Feed sources for dairy cattle
Fluorine (F)	Not known if it is essential for ruminants; has been shown to be essential for laboratory animals.	Maximum safe level is 30 ppm. Severe reduction in feed intake; stiffness in legs; enlarged bones. A problem with high fluorine phosphates.	Rock phosphate mineral.
Selenium (Se)	Functions with certain enzymes; associated with vitamin E; maintains the immune system to combat disease.	White muscle disease in calves; retained placenta; improve reproductive performance; lessen subclinical mastitis.	Oil meals; alfalfa; wheat; oats; corn (amount varies with content in soil); commercial supplements.
Molybdenum (Mo)	Part of the enzyme, xanthine oxidase.	Loss of weight; emaciation; diarrhea.	Widely distributed in feeds; deficiency is rarely a problem.

is not required by dairy cattle because they are able to synthesize it within their tissues.

Table 3 shows fat soluble vitamins (with functions, deficiency symptoms, and associated problems) in common feed sources. Vitamin A or its precursor, carotene, is needed for normal vision, and for avoidance of reproductive problems and respiratory disturbances. Carotene is found in green forages and yellow corn. Synthetic forms of vitamin A are available. One milligram of beta carotene provides 400 international units (IU) of vitamin A.

Vitamin D, the sunshine vitamin, is needed for bone growth and development and for absorption and metabolism of calcium and phosphorus. Supplementation of vitamin D is essential when animals are confined without benefit of direct sunlight and receive primarily ensiled forages and grains. Animal sources of vitamin D (called D3) and plant sources (called D2) are biologically equivalent in dairy cattle.

Vitamin E is an antioxidant, reducing off-flavors in milk (1000 IU per cow per day), preventing white muscle disease in calves, lessening the severity and duration of subclinical mastitis, improving reproductive performance, and stimulating the immune system. One milligram of alpha tocopherol equals 1 IU of vitamin E.

Vitamin K normally is synthesized in adequate amounts in the rumen and intestine to meet the animal's needs. Hemorrhage, associated with moldy sweet clover disease, is caused by interference with the function of vitamin K. This problem is discussed in the herd health section.

Vitamins are most commonly supplemented in the diet, but are available in injectable forms. The recommended minimum and maximum vitamin content in diets for dairy cattle are listed in tables **A-14 and A-15.** Vitamin requirements or potency in feeds is expressed in either international units (IU) or United States Pharmacological units (USP). One IU per pound is equal to one USP per pound.

Minerals

Minerals have both structural and regulatory functions. They are needed for bone and teeth formation, hormone actions, enzyme activation, and water balance. They are a structural part of hormones (iodine in thyroxine as an example) and hemoglobin (iron).

The minerals needed in largest amounts (macro minerals) by the dairy cow include: calcium, phosphorus, magnesium, sodium, chlorine, sulfur, and potassium. Sodium and chlorine usually are provided in the form of salt. Minerals required in small amounts (trace minerals) include iron, copper, manganese, zinc, iodine, cobalt, and selenium. Other minerals may be required in very minute amounts, including molybdenum and fluorine. **Table 4** lists functions, deficiency symptoms, and feed sources of minerals. Feed **tables A-9, A-10,** and **A-11** present the amounts of calcium and phosphorus in some common feeds. **Table A-12** shows the composition of calcium and phosphorus supplements. **Table A-13** gives major or macro mineral composition of some common feeds and mineral supplements. **Table A-14** and **A-15** list recommended minimum and maximum mineral levels in diets for cows and heifers.

Sodium, potassium, chloride, and sulfur are strong ions and have a significant influence on acid-base regulation in the cow. When cations (minerals with a positive charge) exceed anions (minerals with a negative charge) in a solution the pH will be basic (above 7) and when anions exceed cations, the solution will be acidic (pH less than 7). The dietary cation-anion difference (DCAD) is the milliequivalent (meq) difference between the major cations and anions in a diet. The DCAD can be calculated when the percentages of Na, K, Cl and S (DM basis) in the diet are known:

DCAD, meq/100 grams of DM = [(%Na/.023) + (%K/.039)] - [(%Cl/.0355) + (%S/.016)]

Feeding a diet with a negative DCAD (anionic diet) in late pregnancy may reduce milk fever problems through alterations in calcium metabolism. Lactating cows need a high cationic diet to replenish the outflow of minerals in milk.

Many commercial mineral supplements are available. When a mineral supplement is chosen, mineral(s) needed to balance the diet should be considered. A supplement that properly meets the need should be selected. Cost per unit of the mineral needed should be the primary consideration. This can be determined by dividing the cost of the supplement (per hundred lb or per ton) by the number of pounds of element in the supplement. (Example: 15 percent phosphorus ÷ $15.00 per cwt = $1 per pound of phosphorus.)

Trace mineralized salt is a common source of salt and trace minerals. The adequacy of trace mineralized salt to meet requirements of an animal will depend on the potency of trace minerals in the salt and productivity level of the animal. Trace mineralized salt does not contain appreciable amounts of magnesium, sulfur, or potassium. In many diets, these minerals are present in adequate amounts and do not require supplementation. However, if they are needed, proper supplements will have to be provided. Magnesium oxide is a common source of magnesium. Sulfur can come from elemental sulfur, sodium sulfate, magnesium sulfate, or potassium sulfate. Potassium is available in potassium salts such as potassium chloride or potassium sulfate. Many commercially formulated feeds contain trace mineral information on the feed tag.

Mineral excesses should be avoided because of interaction with other minerals and possible toxicity. For example, even though copper is needed in small amounts, it can be toxic. Lead causes toxicity and can be a problem when stanchions and stalls are painted with a lead-base paint. Such paint should be avoided in painting barn equipment and other items to which cattle have chewing access.

Water

Water is the nutrient required in the largest amount by dairy cattle. The amounts of water (gallons per day) needed by cattle for growth, maintenance, pregnancy, and milk production are estimated in **Table 5**. An equation can also be used to estimate water intake of lactating dairy cows.

Water intake (gal/day) = 4.22 + (0.19 x DM intake) + (0.108 x pounds of milk) + (0.374 x ounces of sodium) +(0.06 x minimum daily temperature in F)

A lactating cow consuming 40 pounds of DM and 3 ounces of sodium, producing 65 pounds of milk and experiencing an average minimum temperature for the week of 50° F should consume an average of 22.5 gallons of water per day [4.22 + (0.19 x 40) + (0.108 x 65) + (0.374 x 3) + (0.06 x 50)].

Fresh water should always be available for cattle. Water supplies contaminated with bacteria or high in nitrates and sulfates may cause health problems and reduce animal performance. A guideline for acceptable water quality standards for dairy cattle is in **Table A-4**.

TABLE 5. WATER INTAKE FOR DAIRY CATTLE

		Temperature (F)		
Weight (lb)	Milk (lb)	40° and below	60°	80°
		-------gallons/day-------		
Heifers				
200	—	2.0	2.5	3.3
400	—	3.7	4.6	6.1
800	—	6.3	7.9	10.6
1200[a]	—	8.7	10.8	14.5
Dry cows[a]				
1400	—	9.7	12.0	16.2
1600	—	10.4	12.8	17.3
Lactating cows[b]				
1400	20	12.0	14.5	17.9
	60	22.0	26.1	24.7
	80	27.0	31.9	38.7
	100	32.0	37.7	45.7

[a]Maintenance and pregnancy.
[b]Maintenance and milk production

FEEDSTUFFS

Feedstuffs are often classified as forages and concentrates, but these divisions are not always clearly definable. Concentrates usually mean high quality, low fiber feeds and include the cereal grains, milling by-products, protein sources, and fats. Concentrates have a high digestible energy content per unit of weight or volume. The energy is derived mostly from starches, sugars, other readily available carbohydrates, and fats or oils. Forages are characterized by being more fibrous (greater than 20 percent ADF) or bulky and generally represent the vegetative portion of a plant. The digestible energy content of forages is usually lower per unit weight or volume than concentrates, with most of the energy derived from cellulose or hemicellulose. Classification problems arise with high quality, immature forages, as these are more like concentrates than forages. For example, bud stage alfalfa with 24 percent ADF and 36 percent NDF is classified as a forage, while beet pulp with 33 percent ADF and 54 percent NDF is classified as a concentrate.

Forages

Legumes and grasses. Legumes and grasses are a major source of forage for dairy animals. These forages are excellent sources of protein, carotene, calcium, and other minerals if harvested and stored properly. High quality forages can make up as much as two-thirds of the ration DM, with cows consuming 2-1/2 to 3 percent of their body weight in forage DM. High quality forages fed in balanced rations will supply much of the protein and energy needs for milk production.

Important considerations in harvesting alfalfa and grasses are cutting date and stage of maturity. With advancing maturity, plants decrease in protein, energy, calcium, phosphorus, and digestible DM, while increasing in fiber. As fiber, NDF, and especially ADF, increases, the lignin content of the plant also increases. Lignin is indigestible and makes other nutrients less available.

Legumes and grasses can be harvested as low-moisture silage, haylage, or as hay. Silage and haylage offer the advantages of less leaf loss, less time for field curing, and usually, reduced labor in harvesting. Legume-grass silage should be put up at 35 to 40 percent DM in a bunker silo, haylage at 40 to 50 percent DM in a stave silo, and 50 to 60 percent in an oxygen-limiting silo. If too wet, undesirable fermentations develop and cattle eat less feed. Forage ensiled too dry does not ferment properly and can mold or heat excessively. Legume or grass silages should be chopped (3/8-inch theoretical length of chop—TLC) and at proper moisture for ensiling. Rapid filling, good packing, and sealing are additional keys to good preservation.

Hay should not be baled or stacked until the DM content is at least 80 percent. Otherwise, heating and molding can develop.

Legume and grass haylages and wet hay can heat excessively and lose feeding value. Prolonged and excessive heating is indicated by a brownish, caramelized appearance. It causes protein to join with carbohydrate, lowering available protein and energy in the feed. Crude protein analyses do not reflect changes in available protein; therefore, an available protein test must be run. Heat damage, which can occur in any kind of storage structure, can be avoided or reduced by keeping silos in good repair and harvesting, ensiling, and storing the crop using good management practices.

Corn silage. Good corn silage contains nearly 50 percent grain on a DM basis. It is an excellent source of energy for dairy cattle. If it is properly made, cows will eat large amounts of this feed. Corn silage requires protein and mineral supplementation to be balanced for high milk production.

To attain maximum yield, corn should be harvested for silage when it has reached physiological maturity: kernels are fully dented, milk line is 1/2 to 2/3 down from the crown and cells at the base of the kernel (when dissected) are turning black. DM content should be approximately 35 percent (ear is 55 to 60 percent DM when the whole plant is 32 to 38 percent DM). Immature corn silage is usually wetter, below 32 percent DM, and yields less total dry feed per acre. Seepage losses from the silo occur when material below 32 percent DM is ensiled. If corn becomes too dry before ensiling, field losses are greater and the feed may not ensile as well (poor compaction, molding, and lower palatability).

Sorghum silage. Sorghum can be used for silage in areas adapted to 95-day relative maturity or longer corn hybrids. Forage sorghum equals corn in yield, but grain sorghum usually does not yield as well as corn except during drought conditions. Energy and intake potential are lower than with corn silage.

Small grains. Oats, barley, triticale, wheat, and rye can be harvested as forage, although yield per acre is usually less than corn, legume, or grass forages. Harvest in the boot stage for highest quality. Delaying harvest until soft dough increases DM yields, but reduces quality. Peas or beans can be included with small grains to increase protein content. These crops should be wilted to 60 percent moisture before ensiling.

Straws. Oat, barley, and wheat straws are low in energy, protein, minerals, and vitamins. They should be limited in rations for lactating cows and used only when additional fiber is needed. If adequately supplemented, some straw can be used for dry cows and older heifers.

Stover. Corn stover, properly supplemented, can be used in heifer and dry cow rations. It is low in protein and energy, and therefore, is not recommended for feeding to milk cows.

Pastures. If well managed, pastures are a good source of nutrients. They have the added advantage of eliminating feed handling and manure hauling. Proper fertilization and management is necessary to maintain a good pasture. Trampling is a problem and results in nutrient wastage. Moving cattle and maintaining fences are major disadvantages. Frequent rotations of small lots reduce loss, but require more labor. Large herds are not handled easily in pasture situations. Additional grain is needed for high-producing cows. As quantity and quality of pasture changes during the summer, cattle need to be supplemented with stored forages and other feeds.

Green chop. Harvesting feeds by field chopping and feeding immediately has the advantage of reducing field losses. However, cutting every day can be a major problem during wet weather or during peak work periods.

Forage evaluation. The nutrient content of forages can vary greatly. Stage of maturity, species composition, harvesting conditions and methods, growing conditions, moisture content at harvesting, and storage all affect nutrient content. To achieve optimum production from forage-based rations, the nutrient content of forage must be known and rations formulated to account for forage nutrient contributions and deficiencies.

The minimum forage tests required for determining forage nutrient composition are: DM, CP, ADF, NDF, calcium (Ca), and phosphorus (P). Heat damaged or caramelized forages should be tested to determine losses in CP available to the animal. These losses are not shown in a CP analysis alone. An adjusted crude protein (ACP) corrected for heat damage losses should be used in ration formulation.

Knowing DM is necessary for determining DM intake of animals and evaluating storage problems. Forages ensiled too wet reduce intake and have a butyric acid fermentation. Ensiling too dry results in heat damage.

Crude protein is a mixture of true protein and NPN. Nitrogen analysis times 6.25 equals CP. Adjusted crude protein (ACP) is the amount of crude protein available to the animal. In most forages, 12 percent or less of the total CP is unavailable. If no heat damage or protein loss to the animal has occurred, CP and ACP are equal.

Acid detergent fiber is highly related to digestibility. As ADF increases, digestible DM (DDM) or TDN and energy content of forages decline. Estimates of digestibility and energy content of forages can be made from ADF using the following equations (DM basis):

Legumes and grasses:

TDN (%) or DDM (%) = 88.9 - (ADF% x .779)

NE_L (Mcal/lb) = 1.044 - (ADF% x .0123)

Corn silage:

TDN (%) = 87.84 - (ADF% x .7)

NE_L (Mcal/lb) = 1.044 - (ADF% x .0132)

Neutral detergent fiber, or cell walls, is a good predictor of forage intake. The potential DMI, as a percentage of body weight, of a forage when fed alone can be estimated from:

$$\text{DMI (\% of BW)} = \frac{120}{\text{Forage NDF\% (DM basis)}}$$

Relative feed value (RFV) incorporates quality factors calculated from ADF and NDF into a useful index for comparing legume and legume-grass mixtures. The higher the RFV, the higher the quality and production potential of the forage. High-producing cows should be fed forages with a RFV of 120 or higher. A forage containing 41 percent ADF and 53 NDF is considered to have an RFV of 100. The equation to calculate RFV is:

$$\text{RFV} = \frac{\text{DDM x DMI}}{1.29}$$

A representative sample of the feed is critical for testing. For hay, a minimum of 15 bales (18 to 20 optimal) should be sampled from different locations in the stack. A sampling probe or bale core is needed to obtain representative samples. Haylage or silage samples are best obtained at the time of ensiling. Two or three grab samples from every other load during silo filling will provide a representative quantity for mixing and further subsampling. Grab samples should be refrigerated during collection to prevent deterioration and change in chemical composition. Combine all grab samples, mix well, and remove one quart of material for testing. Heat damage can only be tested on feeds after ensiling.

Energy Concentrates (Grains and By-Product Feeds)

The main nutrient contribution of grains and by-product feeds is energy. Oats and barley are moderately high in CP. Processing grain (rolling, crimping, cracking, or grinding) increases its digestibility when fed to cows. As much as 30 percent of the whole grain will pass through cows intact if the grain is not processed before feeding. Breaking the seed coat increases digestion. Coarse-textured, processed grain enhances palatability and intake. Fine grinding of grain can increase digestibility, but can also lower milk fat percent and cause rumen acidosis. Pelleted grain is not dusty, and may increase palatability and intake, but has the same disadvantages as finely ground grain on rumen fermentation. Because young animals chew their feed more thoroughly than adults, whole grains can be fed up to 12 months of age.

Barley is a good source of energy and protein. If barley is used in large amounts in dairy cattle rations, cattle should be adjusted gradually. Rolling is superior to fine grinding for palatability. If barley is finely ground, it shouldn't make up more than 50 percent of the grain ration.

Beet pulp can be obtained either in plain form or as molasses beet pulp. It is relatively high in energy, adds highly digestible fiber and bulk to diets, and enhances palatability. Maximum feeding rate is 30 percent of the ration DM.

Cottonseed, whole or fuzzy, is a medium protein, high fat, high fiber, and high energy feed. Whole cottonseed is white and fuzzy, while de-linted cottonseed is black and smooth in appearance. The amount fed should not exceed 7 pounds per cow per day.

Corn gluten feed is a relatively high fiber, medium energy, medium protein by-product of the corn wet milling industry. The by-product is sold as either a dry or wet product. Corn gluten feed (wet or dry) should not exceed 25 percent of the total ration DM.

Corn, ear or corn and cob meal is a relatively high energy feed relished by cows. It contains 10 percent less energy than shelled corn. However, the fiber supplied by the cob aids in maintaining fat test and keeping cows on feed.

Corn, shelled is the most common grain fed to dairy animals. It is one of the highest energy feeds available for use in dairy rations. Where corn can be grown successfully, it is generally an economical source of energy. Because of its high caloric density, good management (determining the amount to feed, frequency of feeding, mixing with other feeds, etc.) is needed to obtain maximum consumption without causing digestive disturbances.

Corn, high moisture offers these advantages:

1. Grain can be harvested 2 to 3 weeks earlier, reducing field losses and harvest problems associated with adverse weather.
2. Storage and handling losses are reduced.
3. It fits automated feeding programs.
4. The expense of drying grain is eliminated.
5. Grain is highly palatable.
6. Daily labor of grain processing or grinding is reduced.

High moisture ear corn should be stored from 28 to 32 percent moisture and processed prior to storage. The wet cob is more digestible than the cob in dry corn.

High moisture shelled corn should be stored within a moisture content of 25 to 30 percent. In airtight silos, the shelled corn can be stored whole or ground, and rolled upon removal from the silo. In conventional silos, bags or bunkers, it should be processed (ground or rolled) before storing. Propionic acid can be used effectively to treat and preserve high moisture corn for dairy cattle.

Hominy feed is a fine, dusty ground corn feed from which the bran and gluten have been removed. It is the by-product from the manufacture of hominy grits. Fat content is generally about twice that of corn grain, but quite variable. Hominy can replace corn in the diet, but is low in starch.

Fat is a concentrated energy source. Several kinds of animal and vegetable fats or oils are available for feeding. Amounts to feed and responses from feeding will vary with fatty acid (saturated or unsaturated) composition of the fat. Total added fat in diets should not exceed 4 percent (DM basis) with animal, vegetable or rumen inert fats individually not exceeding 2 percent.

Molasses (cane and beet) supplies energy and is used primarily to enhance the acceptability of the ration. The amount used should be limited to 5 to 7 percent of the grain mix (10% in pelleted feeds) to maintain flow characteristics in automatic feeding equipment and to avoid undesirable rumen effects.

Oats contain 15 percent less energy but 20 to 30 percent more protein than shelled corn. The advantage of adding oats to dairy rations is that it adds fiber and bulk, and may help maintain rumen function.

Screenings are often an economical buy. However, they vary in protein and energy content, can be unpalatable, and in some instances are difficult to digest.

Sorghum grain or milo can be used to replace corn in diets. The energy content is about 90 percent that of corn, and protein content is variable (7 to 12 percent CP). Milo must be ground before feeding to prevent whole seed passage, but grinding lowers palatability because of dustiness.

Soybean hulls, soybean flakes, or soyhulls are all similar feeds. All are good sources of highly digestible fiber and may replace starch in the diet, but not forage fiber. Limit amounts to 33 percent of the grain ration.

Wheat is not used often because price is usually too high. It is acceptable in dairy cattle rations in reasonable amounts (less than 50 percent of the grain ration). It is high in energy and relatively high in protein. Cattle should be adjusted slowly to rations containing wheat.

Wheat bran is included to add bulk and fiber to the diet. It is relatively high in protein and phosphorus, improves ration palatability, and functions as a laxative.

Wheat midds consist of fine particles of wheat bran, wheat shorts, wheat germ, and other products from the wheat milling process. Midds are a moderate source of protein and energy, and must not contain more than 9.5 percent crude fiber. Grain rations with more than 20 percent midds have decreased milk production.

Whey (dried and liquid) can be fed to dairy cattle. Dried whey can be added to grain mixtures up to 10 percent of the mix. Dried whey also can be added to forages at the time of ensiling at a rate of 20 to 100 pounds per wet ton of forage. Liquid whey can be offered to cattle on a free choice basis. Because liquid whey is over 90 percent water, 15 to 25 gallons need to be consumed daily to obtain substantial amounts of DM. Whey contains large quantities of lactose (milk sugar) and small amounts of protein and minerals. Liquid whey should not be over 36 hours old because it will become acidic and cattle will not drink it. Flies can be a problem if strict sanitation is not practiced.

Protein Supplements

Bloodmeal is dried blood from animal processing plants. Spray or ring dried bloodmeal is superior to batch dried because less heat damage occurs. Bloodmeal is high in true protein, UIP and the amino acid lysine. Limit the amounts fed to less than 1 pound per cow per day and do not feed in diets high in moisture, as palatability can become a problem.

Brewers grain, a by-product of the beer industry, is available dry or wet. Wet brewers grains contain 70 to 80 percent water. Feeding more than 20 percent of the ration DM or 40 to 50 pounds of wet feed per cow has been shown to reduce intake and milk production. On a DM basis, brewers grains are high in protein and a fair source of energy.

Canola meal is a relatively new high-protein supplement produced from the crushing of canola seeds for oil. New varieties of canola, previously called rapeseed, are low in goitrogenetic compounds. Canola meal can be substituted for soybean meal in diets.

Corn gluten meal is produced from wet milling of corn for starch and syrup. Two corn gluten meals are produced, a 40 percent and 60 percent CP supplement, with the 60 percent being the most common. Both supplements are good sources of UIP. Energy content of corn gluten meal is only slightly less than corn grain. Limit amounts to 5 pounds per cow per day because of palatability problems.

Cottonseed meal is a high protein by-product from the extraction of oil from whole cottonseed. It is quite palatable, but may be variable in CP content. Cottonseed meal and other cottonseed products can contain a toxic substance known as gossypol. Limit the total amount of cottonseed products in diets to 8 pounds per cow per day or less.

Distillers dried grains, with or without solubles, is a by-product of grain fermented for alcohol production. Corn is the most common grain fermented, but other grains are used, and the composition of the distillers grains will vary depending on grain source. Dried distillers grains are moderate sources of CP (23 to 30 percent), but a good source of UIP if not heat damaged.

Feather meal is hydrolyzed poultry feathers. High quality feather meal is both high in CP (85 to 92 percent) content and digestibility, but low in several important amino acids. Feather meal is rather unpalatable and should be introduced into diets gradually and limited to 1 to 1.5 pounds per head per day. Combinations of feather meal and blood meal are recommended for balanced amino acid supplementation.

Fishmeal is a by-product of the fish industry. It includes bones, head, trimmings, and fish parts. Quality can vary, depending on source and handling. Fish oil reduces fiber digestion in the rumen, and should be limited to 50 grams per day. Limit fish meal to 1 to 2 pounds per day.

Linseed meal is a product of the flax industry and is a good protein supplement (39 percent). It is very palatable and can be used as a replacement for soybean meal.

Malt sprouts consist of dried sprouts and rootlets produced during the malting (sprouting) of barley for beer. The feed is similar to dried brewers grain, especially in UIP, but bitter tasting, reducing palatability. Limit amounts in the diet to less than 5 pounds per cow per day or 20 percent of the grain mix.

Meat and bone meal is a rendered and dried product from animal tissue. It does not contain horn, hide, hair, manure, or stomach contents. Meat and bone meal is a good source of CP, UIP, calcium and phosphorus. Limit amounts fed to 2.5 pounds or less per day. Meat and bone meal needs to be handled properly and stored in dry places to avoid salmonella contamination.

Soybeans are an excellent source of CP and fat (18 percent) for dairy cattle. Raw soybeans can be fed up to 5 pounds per cow per day. Cows should be adjusted to beans gradually to avoid diarrhea and off-feed. Raw beans contain urease, an enzyme that releases ammonia from urea when soybeans and urea are mixed together. Urea and raw beans should not be mixed and stored together. Microbial degradation in the rumen reduces anti-protein factors in raw beans (trypsin inhibitor, for example). Roasting, extruding, or other heat processing reduces anti-protein factors and urease activity and increases UIP value of the soybeans. Heating temperature (290 to 300^0 F) and steeping time (30 to 45 minutes) must be carefully controlled to avoid under- or overheating soybeans. Heat-treated soybeans can be fed up to 8 pounds per day. Cost of processing, including bean shrinkage, should be evaluated.

Soybean meal is the most common and usually the most economical vegetable protein supplement. The most common soybean meal contains 44 percent CP as fed. Two other sources of soybean meal are: dehulled soybean meal (48 percent CP), and expeller or old processed soybean meal (42 percent CP and 5 percent fat). Many commercial supplements contain substantial amounts of soybean meal.

Sunflower meal protein supplements range from 28 to 45 percent protein. The protein percentage varies inversely with fiber percentage: lower protein, higher fiber. Sunflower meal is a good source of protein and phosphorus. Palatability problems have been observed in some herds when sunflower meal is topdressed.

Urea. Urea is a NPN compound containing about 46 percent N. It has a protein equivalent of 287 percent (46 percent N x 6.25). It is a good source of SIP. Urea fits best in diets high in carbohydrate energy (grains and corn silage), low in protein, and low in SIP. Limit amounts fed to .4 pounds per cow per day, 1 percent in grain mixes, or 0.5 percent in corn silage (10 lb/ton added at ensiling). If urea or another NPN source like ammonia is added to corn silage, the amount of urea included in a grain mix should be reduced so that the intake of urea or urea equivalency does not exceed the maximum of .4 pounds per cow per day. Urea is not a palatable feed and should be mixed thoroughly into the grain mix or silage. Urea is best utilized when incorporated into total mixed rations (TMR) and/or fed frequently in mixtures with other feeds.

Urea can be used in making up a high-protein concentrate. A mixture of 87 pounds of ground shelled corn and 13 pounds of urea is equivalent in energy and crude protein to 100 pounds of soybean meal. A mixture of 56 pounds of ground shelled corn, 7 pounds of urea, and 37 pounds of soybean meal also equals 100 pounds of soybean meal in total energy and protein equivalent, and can be used as a substitute for soybean meal. However, it should not be used as a protein topdress because of bitter taste and possible feed refusal. When fed according to recommendations, urea is a good CP source and has not been shown to affect reproduction efficiency.

FEEDING THE DAIRY HERD

Dairy Cow Nutrition

Nutrient requirements vary with the stage of lactation and gestation. **Figure 6** illustrates the shape and relationship of curves for milk production, fat percentage, protein percentage, DM intake, and body weight change during lactation. Five distinct feeding phases can be defined to attain optimum production, reproduction and health of dairy cows:

- Early lactation—0 to 70 days (peak milk production) after calving (postpartum).
- Peak DM intake—70 to 140 days (declining milk production) postpartum.
- Mid- and late lactation—140 to 305 days (declining milk production) postpartum.
- Dry period—60 to 14 days before the next lactation.
- Transition or close-up period—14 days before to parturition.

Phase 1. Early lactation—0 to 70 days postpartum. Milk production increases rapidly during this period, peaking at 6 to 8 weeks after calving. Feed intake does not keep pace with nutrient needs for milk production, especially for energy, and body tissue will be mobilized to meet energy requirements for milk production. Adjusting the cow to the milking ration is an important management practice during early lactation. Increasing grain about 1 pound per day after calving will increase nutrient intake while minimizing off-feed problems and acidosis. Excessive levels of grain (over 60 percent of the total DM) can cause acidosis and a low milk fat percentage. Fiber level in the total ration should not be less than 18 percent ADF, 28 percent NDF. Forage should provide at least 21 percentage units of NDF or about 75 percent of the total NDF in the ration. Physical form of the fiber is also important. Normal rumination and digestion will be maintained if greater than 20 percent of the forage is 2 inches in length or longer. Chopping (less than 3/8 inch theoretical length of chop—TLC), grinding, and/or pelleting all reduce physical form of fiber and its effectiveness to stimulate rumination.

Protein is a critical nutrient during early lactation. Meeting or exceeding crude protein requirements during this period helps stimulate feed intake and permits efficient use of mobilized body tissue for milk production. Rations may need to contain 19 percent or more crude protein to meet requirements during this period. The type of protein (degradable or undegradable) and amount of protein to be fed will depend on ration ingredients, method of feeding, and milk production potential of the cow. A good guideline for many dairy producers to follow is to feed 1 pound of soybean meal or equivalent commercial supplement per 10 pounds of milk starting at 50 pounds of milk. If urea is fed, it would be best fed with corn silage or as part of the grain mix. Maximum amount to feed is .2 pounds per cow when ration protein level is high.

Low peak production and ketosis problems occur when nutrient levels are not met. Low peak production translates into low lactation production. A loss of 1 pound in peak milk production equates to a 220-pound loss for the lactation. If grain intake is increased too rapidly or is too high, off-feed, acidosis, and displaced abomasum are possible.

To increase nutrient intake:

- Feed top quality forage.
- Make sure the diet contains adequate amounts of CP, DIP and UIP.
- Increase grain intake at a constant rate after calving.
- Consider adding fat (1 to 1.5 lb/cow/day) to diets.
- Allow constant access to feed.
- Minimize stress conditions.

Phase 2. Peak DM intake—second 10 weeks postpartum. Cows should be maintained at peak production as long as possible. Feed intake is near maximum and can supply nutrient needs. Cows should no longer be losing body weight, and are either maintaining weight or slightly gaining weight (**figure 6**).

Grain intake can reach but should not exceed 2.5 percent of the cow's body weight (1300-lb cow can consume up to 32 lb of DM from grain). Adding grains or feeds high in digestible fiber to the ration may be necessary to help maintain an optimal rumen environment when these high levels (55 to 60 percent of the ration DM) of grain are being fed. In general, rations should not contain more than 40 percent NFC. Forage quality should still be high with intakes of at least 1.5 percent of the cow's body weight (DM basis) to maintain rumen function and normal fat test.

Potential problems during this period include a rapid drop or decline in milk production, low fat test, silent heat (no observed heat), and ketosis.

To maximize nutrient intake:

- Feed forages and grain several times a day.
- Feed the highest quality feeds available.
- Limit urea to .2 pound per cow per day.
- Continue to minimize stress conditions.

Phase 3. Mid- to late lactation—140 to 305 days postpartum. This phase will be the easiest to manage. Milk production is declining, the cow is pregnant, and nutrient intake will easily meet or exceed requirements. Grain feeding should be at a level to meet milk production

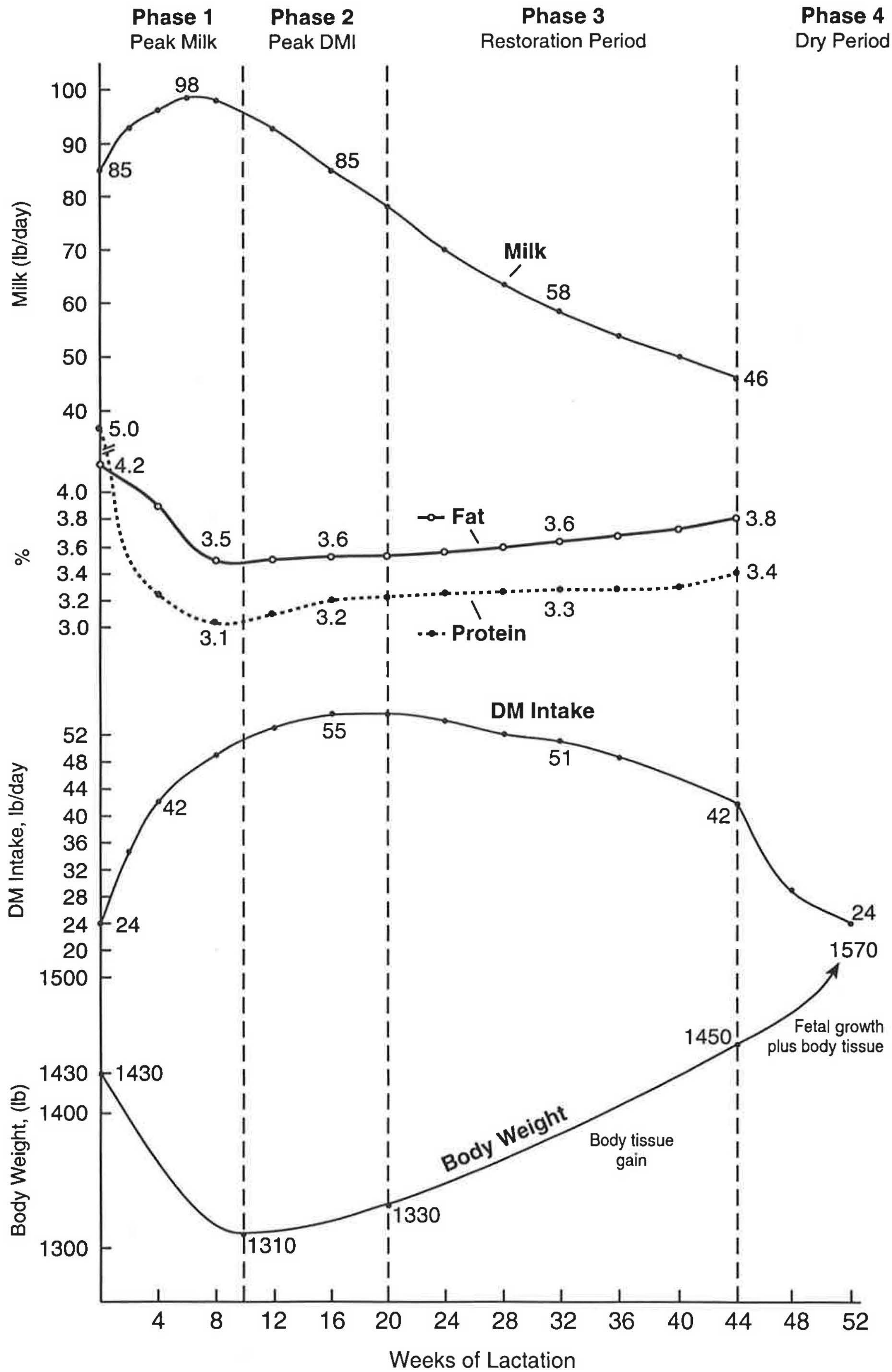


Figure 6. Lactation cycle phases with corresponding changes in milk production, milk fat percentage, milk protein percentage, DM intake, and body weight.

requirements and begin to replace body weight lost during early lactation. Lactating cows require less feed to replace a pound of body tissue than dry cows. Young cows should receive additional nutrients for growth (2-year-old, 20 percent more; 3-year-old, 10 percent more than maintenance). Consider NPN as a source of supplemental protein.

Potential problems during this phase are few. Milk production should slowly decline at an 8 to 10 percent drop per month. Avoid over-conditioning cows.

Summary—Phase 1, 2, and 3. Compare your current feeding program with the following guidelines:

1. Protein: 18 to 19 percent CP (DM basis) in early lactation decreasing to 13 percent in late lactation. Undegradable or bypass protein (UIP) should be 35 to 40 percent of the CP in early lactation and 30 to 35 percent of CP in late lactation. About 30 percent of CP should be soluble protein (SIP).
2. Net energy-lactation: .78 Mcal per pound of DM or greater in early lactation decreasing to .72 Mcal per pound in late lactation, and .6 Mcal per pound during the dry period.
3. Forage amount: Minimum of 1.5 pounds of forage DM per 100 pounds of body weight. High quality legume forages should be the major source of forage fed during early lactation.
4. Fiber: A minimum of 18 percent ADF in the dietary DM during early lactation increasing to 21 percent or greater in late lactation. Forages should provide a minimum of 21 percent NDF in the dietary DM.
5. Nonfiber carbohydrates: 35 to 40 percent of the dietary DM.
6. Fat: Maximum of 7 percent of the total ration DM with no more than 4 percent from supplemental fat. Limit fat from oilseeds to 2 percent of the ration DM.
7. Salt: 0.5 percent of the ration DM or 1 percent of the grain mix.
8. Mineral: Approximately 1 percent of the grain mix should be a calcium-phosphorus mineral.
9. Urea: Maximum of .4 pounds of urea per day or 1 percent of the grain mix.
10. Vitamins: Supplemented A, D, and E in rations to meet requirements.
11. Ration form: Forages and grains should not be chopped or ground too fine.

Phase 4. Dry period—60 to 14 days before parturition. The dry period is a critical phase of the lactation cycle. A good, sound dry cow program can increase milk yield during the following lactation and minimize metabolic problems at or immediately following calving.

A dry cow feeding program separate from lactating cows is required. Diets should be formulated to specifically meet the nutrient requirements of dry cows: body maintenance, fetal growth, and replacing any additional body weight not replaced during phase 3. DM intake will be near 2 percent of the cow's body weight. Forage intake should be a minimum of 1 percent of body weight or 50 percent of the dietary DM. Grain feeding should be according to needs, but not exceeding 1 percent of body weight. One half of 1 percent of body weight in grain fed per day is usually sufficient in most dry cow feeding programs. Limiting the amount of feed DM offered to less than 2 percent of body weight may be necessary when rations contain only corn silage or other high energy feeds, to avoid over-conditioning of cows. Feeding low quality forages such as corn stalks or grass hay is preferable to limit feeding. If limit feeding is necessary, be sure ration is balanced to supply all nutrients in their correct amounts. A minimum of 12 percent CP in the DM is recommended.

Meet calcium and phosphorus needs, but avoid large excesses. Calcium intakes of 60 to 80 grams and phosphorus intakes of 30 to 40 grams are sufficient for most cows. Dry cow rations above .6 percent calcium and .4 percent phosphorus (DM basis) have substantially increased milk fever problems. Provide adequate amounts of vitamin A, D, and E in rations to improve calf survival and lower retained placenta and milk fever problems. Trace minerals, including selenium for most producers, should be adequately supplemented in dry cow diets.

Problems such as milk fever, displaced abomasum, retained placenta, fatty liver syndrome, fatty liver formation, and poor appetite, along with other metabolic disorders and diseases, are common in fat cows at freshening.

Key management factors include:

- Observe body condition of dry cows and adjust energy feeding as necessary.
- Meet nutrient requirements and avoid excessive feeding.
- Change to a transition ration starting 2 weeks before calving.
- Avoid excess calcium and phosphorus intakes.
- Limit salt to 1 ounce and limit other sodium-based minerals in the dry cow ration to reduce udder edema problems.

Phase 5. Transition period—14 days before to parturition.

The transition or close-up dry cow feeding program is critical to adjusting dry cows and springing heifers to the lactation ration and preventing metabolic problems. Some grain, if not previously fed, should be fed starting two weeks before freshening. Introduction of grain is necessary to begin changing the rumen bacteria population over from an all-forage digestion population to a mixed population of forage and grain digesters. Also, addition of some ingredients used in the lactation ration during this period minimizes the stress of ration changes after calving. Some suggested management strategies during this period include:

- Provide 6 to 10 pounds of grain to adapt rumen microbes to fermentable carbohydrates and stimulate rumen papilla formation. The added grain sources, fed individually or as part of a lactating TMR, should be feeds that the fresh cow will be receiving.
- Increase protein in the ration to between 14 and 15 percent of the ration DM. Feeding some of this additional protein in the form of undegradable protein may be beneficial in supplying amino acids for fetal growth.
- Limit fat in the ration to .25 pounds. High fat feeding will depress DM intake.
- Maintain 6 to 10 pounds of long hay in the ration to stimulate rumination. If corn silage or a lactation TMR is fed, limit DM amounts to 1 percent of body weight.
- Remove salt from the ration if edema is a problem.
- If niacin (to control ketosis) and/or anionic salts (to help prevent milk fever) are going to be used, they should be included in the ration during this period.

Calf Nutrition

Colostrum (either dam's colostrum or mixed colostrum from first milking of older cows) fed to calves as soon after birth as possible (ideally within 30 minutes and certainly within 4 hours) protects against disease. Early feeding of colostrum at 4 to 5 percent of birth weight is necessary because:

1. Newborn calves have no antibodies to provide natural protection against disease until they receive colostrum.
2. Calves' ability to absorb immunoglobulins (the disease protection component) is substantially reduced after 24-36 hours.
3. Calves may become infected with highly pathogenic (disease-causing) bacteria immediately after birth.
4. Colostrum is a concentrated source of ready available nutrients.

Within the first 24 hours after birth, calves should receive 12-15 percent of their birth weight as first-milking colostrum. Half of this should be within 4 to 6 hours after birth, and the remaining half 12 hours later. Hand feeding of colostrum through a nipple bottle or esophageal feeder is preferred to nursing, and assures that the calf receives the required amount of colostrum. Quality of colostrum can be determined by use of a colostrometer. Most calves require 200 to 300 grams of immunoglobulin to acquire passive immunity. Low quality, bloody or mastitic colostrum should not be fed.

Excess colostrum is a highly nutritious feed and can be fed after the calf has received the first milk colostrum during the first 24 hours of life. Undiluted excess colostrum contains about a third more solids than milk or reconstituted milk replacer, and is highly digestible. Storage and subsequent use of excess colostrum is highly desirable. It may be fed fresh; frozen or stored, then thawed prior to feeding; or stored as sour (fermented) colostrum.

Naturally fermented sour colostrum, stored in clean containers away from excessive heat, is an acceptable feed for calves more than 3 days old. Preservation of colostrum may also be achieved by adding propionic acid at 1 percent by weight (1 cup/6 gallons of colostrum).

Colostrum supplements. When colostrum is not available or quality is poor, commercial colostrum supplements may be useful. These contain bovine immunoglobulins and are prepared from cheese whey, colostrum from immunized cows, or monoclonial antibody technology. Efficacy may differ according to type of product and conditions of use. These preparations may be useful to enhance the antibody (IGg) content of low quality colostrum and increase low antibody titers in calves.

Comparing colostrum, transitional milk, milk and milk replacer. The composition of milk secretions changes rapidly after calving. First milk is considered true colostrum; secretions obtained for 4 to 5 days after the first milking are transitional milk. The first six milkings are higher in nutrients than normal milk or reconstituted milk replacers. In comparing milk replacers with a cow's natural

TABLE 6. COMPOSITION AND CHARACTERISTICS OF COLOSTRUM, WHOLE MILK AND RECONSTITUTED MILK REPLACER (1 LB POWDER + 7 LB WATER)

Item	First milking	Second milking	Second day	Third day	Whole milk	Reconstituted milk replacer
Specific gravity, g/ml	1.056	1.040	1.034	1.033	1.032	
Total solids, %	23.9	17.9	14.0	13.6	12.9	12.5
Fat, %	6.7	5.4	4.1	4.3	4.0	2.50
Nonfat solids, %	16.7	12.2	9.6	9.5	8.8	11.25
Protein, %	14.0	8.4	4.6	4.1	3.1	2.8
Lactose, %	2.7	3.9	4.5	4.7	5.0	variable
Ash, %	1.1	1.0	.8	.8	.7	variable
Vitamin A, g/100 ml295.0	190.0	95.0	74.0	34.0		variable
Immunoglobulins, %	6.0	4.2	1.0	—	—	0

TABLE 7. PROTEIN SOURCES IN MILK REPLACERS

A. Optimum	B. Good	C. Inferior
Skim milk powder	Chemically modified soy protein	Meat solubles
Buttermilk powder	Soy concentrate	Fish protein concentrate
Dried whole whey	Soy isolates	Distillers' dried solubles
De-lactosed whey		Brewer's dried yeast
Casein		Oat flour
Milk albumin		Wheat flour

secretions, take into account variations in both replacer quality and dilution rate. **Table 6** shows a comparative analysis using a high quality milk replacer at standard dilution rates.

Milk replacers vary in quality. Study the feed tag. The best milk replacer contains 22 percent protein, all derived from milk products. The protein level should be 22 to 24 percent when chemically modified soy protein, soy isolates, or soy concentrates are used because plant proteins are less digestible than milk protein. **Table 7** lists various sources of protein according to acceptability in milk replacers. Compare the protein sources listed on your milk replacer feed tag with this list.

The fat level in a good milk replacer powder should be at least 10 percent and may be over 20 percent. The higher fat level tends to reduce the severity of diarrhea and provides additional energy for growth. Good-quality animal fats are preferable to most vegetable fats. Soy lecithin, especially when homogenized, is another acceptable fat source and improves mixing properties of the replacer.

Carbohydrate sources that the calf can use include lactose (milk sugar) and dextrose. Two common carbohydrate sources that should be excluded from milk replacers are starch and sucrose (table sugar).

Mastitic milk or discard milk can be used as liquid feed for young calves. Discard milk is defined as unmarketable milk from cows that were treated with antibiotics. This milk can be fed fresh in the same manner as whole milk. Extremely abnormal milk (bloody or watery) should not be fed. Excess discard milk can be fermented or preserved chemically. Milk collected for three to six milkings after antibiotic treatment will ferment normally. Milk from the first milking after treatment does not ferment well alone, but usually ferments well when mixed with all unmarketable milk following treatment.

Properly managed feeding of mastitic milk to calves will not increase mortality or cause mastitis in these animals when they freshen. Calves fed pasteurized milk containing an added culture or live *Staphylococcus aureus* did not show evidence of the organism in body tissues 10 to 14 days after exposure. Also, at first lactation, heifers fed *Staphylococcus aureus* in pasteurized milk, as calves, did not have a greater incidence of infection than controls. Mastitic milk should not be fed to calves less than 2 days old, as the intestine is permeable to large protein molecules. Diarrhea is no more prevalent in calves fed mastitic milk than in calves fed whole milk. It is recommended that calves fed mastitic milk be housed separately to prevent suckling and introduction of organisms into the teat canal. Calves fed milk containing antibiotics should not be marketed for meat unless a suitable withdrawal period is used before slaughter. Although mastitic milk may be slightly higher in solids than whole milk, recommended feeding rates are similar.

Amount to feed, feeding frequency, and age of weaning. A prime consideration in raising the calf is to provide adequate DM for growth. DM from liquid feed should equal 1 percent of birth weight and should be fed from birth to weaning. For a 100-pound Holstein calf, 1 pound of DM daily could be provided from 8 pounds of milk, 6 pounds of surplus colostrum, 7 pounds of transitional milk, or 1.1 pounds of milk replacer plus 7 pounds of water. Estimate the DM percentage in the liquid diet and dilute as necessary in relation to the total volume offered the calf. Liquid feeds can be fed warm or cold, but using warm water will make mixing of replacer easier and may improve acceptability of replacer by calves.

Feeding milk or milk replacer by open pail is a common practice, although many calf raisers choose nipple feeding by pail or bottle. No real advantage in calf health or performance has been shown for either method. Automated feeding equipment can be used, but good management and observation are needed if the goal of weaning healthy calves is to be achieved. Always use and feed only from clean equipment.

Most calf raisers feed twice daily. For example, a 100-pound calf can be fed 4 pounds (2 quarts) of milk in the morning and 4 pounds of milk in the afternoon. Feeding twice daily assures at least two observations per day of the calf and probably is more satisfying to the calf. Weak or unthrifty calves may benefit from even more frequent feedings. Once-a-day feeding of milk-fed calves has proven successful except when calves are housed in the extreme cold or in otherwise undesirable environments. The keys to its success are keen observation to detect any sickness early and careful feeding of adequate nutrients without overfeeding. Calves fed once a day need the same amount of daily DM as twice-a-day fed calves, but liquid amounts may have to be reduced to avoid digestive upsets. Dry milk replacer can be added to whole or mastitic milk to increase solids content without increasing the volume of liquid fed.

TABLE 8. EXAMPLES OF SOME CALF STARTERS

	Grain starters[1]		
	1	2	3
Ingredients (air dry basis)			
Corn (cracked or coarse ground), %	43.5	29.0	57.0
Oats (rolled or crushed), %	28.0	20.0	
Barley (rolled or coarse ground), %		20.0	
Soybean meal, %	20.0	14.3	16.0
Distillers grains, %		9.0	
Alfalfa, %			20.0
Molasses, %	5.0	5.0	5.0
Dicalcium phosphate, %	.7	.6	.9
Limestone, %	1.7	1.8	.8
TM salt and vitamins, %	.3	.3	.3
Composition (DM basis)			
Crude protein, %	18.5	18.0	18.5
TDN, %	82.0	81.5	81.4
ADF, %	8.0	8.8	9.2
Calcium, %	.4	.9	.9
Phosphorus, %	.5	.5	.5
Vitamin A, IU/lb	1500	1500	1500
Vitamin D, IU/lb	500	500	500
Vitamin E, IU/lb	11	11	11

[1]Hay may be offered free choice with starters 1 and 2.

Although this procedure resulted in satisfactory gains and health, it has not been adopted as yet by many calf growers. If once-a-day feeding is practiced, calves should be observed at least once in addition to feeding time for general health and well-being.

Feeding programs for calves in hutches can be similar to those used for calves in nurseries during most of the year. During extremely cold weather, feeding rates should be increased because energy requirements of the calves will be greater. Increasing the amount fed by factors of 1.25 to 1.5 and offering the feed three times daily has helped provide the nutrients needed by these calves. Young calves that appear to be extremely cold and are doing poorly should be placed in warmer quarters.

Abrupt weaning of calves at an early age is an acceptable practice. Research has shown that calves may be weaned successfully at 3 weeks of age, but most producers wean between 4 and 8 weeks. Weaning later than 8 weeks could lead to fat calves. If they are weaned at 21 days, calves may have slightly depressed growth rates the first month after weaning. However, by 12 weeks of age, early-weaned and later-weaned calves (6 weeks) are of similar weights. Weaning according to starter intake (1 to 1-1/2 lb/day) is a good practice. Abrupt weaning usually stimulates dry feed consumption. Starter intake can be encouraged by placing the dry feed in the pail immediately after the liquid has been consumed. In general, early weaning can reduce feed and labor costs and good results can be obtained with weaning at 21 to 35 days. Calves doing poorly or calves eating less than 1 pound of starter per day should remain on a liquid feed until performance improves and dry feed is consumed in satisfactory amounts.

Preventing calf scours. Scours can develop as a result of several conditions. Avoid these if at all possible.

1. Overcrowding—provide 24 to 28 square feet of bedded area or about 20 square feet of building floor space for calves raised in confined, elevated stalls.
2. Inadequate ventilation—provide a minimum of 4 air exchanges per hour in winter, 15 in summer. Avoid direct drafts on the calf.
3. Wet, damp calves—provide adequate bedding and good ventilation, and avoid spraying calves with water when cleaning facilities to help prevent calves from becoming chilled. Provide plenty of dry bedding in maternity stalls.
4. Overfeeding—irregular amounts and too much of the wrong concentration or wrong kind of liquid diets are common causes of calf scours.
5. Low resistance—vitamin A, D, and E supplementation (oral or injectable forms) immediately after birth is helpful in increasing the calf's natural resistance to scours, especially if colostrum is low in vitamin A content.
6. No first-milk colostrum—don't assume the newborn calf has nursed. Many newborn calves don't receive enough colostrum to be protected from calfhood diseases. Feed colostrum, preferably by hand, as soon as possible after birth (minimum of 2 to 3 quarts to large breed calves; 3 pints to the smaller breed calves).
7. Dirty utensils—clean the feeding utensils thoroughly after each feeding. Store upside down to drain all water out. Small amounts of excess wash water are perfect areas for bacteria to multiply rapidly.

Use of electrolytes. Early detection of sickness and prompt corrective action is important to prevent scours. When a calf has only a mild case of scours (not off-feed, not depressed, and no fever), feeding an oral electrolyte solution in addition to milk or milk replacer usually is beneficial. A suggested regimen is 4 feedings daily of 2 to 2.5 pints of milk or milk replacer, followed in 10 minutes by the same amount of an electrolyte solution. As the diarrhea begins to subside, the volume of electrolyte solution can be gradually decreased. Oral electrolyte solutions can be purchased commercially. If not readily available, an electrolyte mixture can be made by combining these kitchen cabinet ingredients:

Mixture 1
1 package MCP pectin
1 teaspoon low-sodium salt
2 teaspoons baking soda
1 can beef consommé soup
Add water to make 2 quarts

Mixture 2
4 teaspoons of table salt
3 teaspoons of baking soda
1/2 cup of "light" corn syrup
Add water to make 1 gallon

Starter rations. A good quality, palatable calf starter should be offered during the first week of life. The best calf starters are high in energy, free of excessive fines, and contain 18 percent CP (DM basis). To encourage intake, starters should consist of whole, coarsely ground, cracked, or rolled grains. Molasses (up to 5 percent of the mixture) improves palatability and minimizes fines and dust. Finely ground feeds become "pasty" and are undesirable. Whole grains, especially oats, can be fed with starter rations to calves up to 3 months of age. Calf starters should be fed until calves are about 12 weeks of age. Intake should be limited to 3 to 5 pounds per calf each day.

Many good commercial calf starters are available and convenient to feed. Simple, home-mixed calf starters may be equally acceptable. **Table 8** gives examples of some good starter rations.

Additives. Coccidiostats and/or ionophores may be useful in reducing coccidiosis and in promoting growth. Some products (for coccidiosis) may be included in both milk replacers and starters. Ionophores can be used in starters to improve gain and feed efficiency. Other additives, such as direct-fed microbials and yeast products, have not been found to consistently improve growth rates.

Hay or silage for the young calf. While calves may begin nibbling on good quality hay as early as 5 to 10 days of age, it is not necessary to feed forages before 8 to 10 weeks of age. If forages are inconvenient because of the housing and management system, it may be desirable to incorporate a forage factor (more fiber) into the starter ration. Ration 3 **(table 8)** is an example of a suitable ration for calves not receiving hay or silage. Extremely high moisture silages and pastures should not be fed before 3 months of age because the high moisture content can limit intake and growth. Low moisture haylage is acceptable if it is kept fresh.

Water. Calves fed limited liquid (such as in a once-a-day feeding program) should receive supplemental water, especially during warm weather. Water can be offered free choice starting on day 4 of life. Make sure water is fresh and pails are cleaned daily. Calves offered water during the liquid feeding period (birth to 4 weeks) tend to consume more starter and perform better than calves just fed the liquid feed.

Summary of feeding program in early life. A carefully planned feeding program is necessary if calves are to thrive and grow. The feeding program can be summarized as follows:

Day 1	Dam's colostrum
Day 2	Dam's colostrum
Day 3	Dam's colostrum
Day 4	Liquid feed of choice, introduce starter and water
Day 5 to weaning	Continue liquid feeding program
Weaning to 12 weeks	Starter (up to 5 lb daily), introduce forage if not previously fed

If quality feeds are used and fed in satisfactory amounts under good conditions of management in the program described, replacement calves that are growthy, vigorous, and healthy should result.

For more information on calf nutrition and management, refer to North Central Regional Extension Publication #205, *Raising Dairy Replacements.*

Heifer Nutrition

Rearing the calf from 12 weeks to 1 year. During this period of the herd replacement's life, free-choice forage and limited grain can be fed. The amount of grain and protein content of the grain mix needed will be determined by the quality of forage(s) being fed. Pasture can be used successfully in the feeding program, but it should not be expected to supply all of the nutrients for calves in this age group. A grain mix and some stored forage are desirable for calves less than 6 months old on pasture. **Table 9** illustrates the grain-concentrate needed for heifers with different forage qualities. If heifers cannot be grouped, a creep feeder is an option. Inclusion of low energy bulky feeds in the creep mix may be necessary to avoid excess energy intake with free choice feeding. Trace mineralized salt and a calcium-phosphorus supplement can be offered free-choice if not adequately supplied in the grain mix. All calves must have access to clean, fresh water.

During this stage of the feeding program, avoid overfeeding grain and allowing calves to become fat. Overconditioned heifers produce less milk in later life than those reared on a more moderate level of nutrition. The key period in mammary gland development is between 3 and 9 months of age. During this period, mammary tissue is growing 3.5 times faster than body tissue. Heifers fed high-concentrate rations from calfhood to breeding age develop less milk secretory tissue in the mammary gland than heifers raised at normal, recommended growth rates. Fattening of heifers prior to puberty appears to have an inhibitory effect on mammary secretory tissue development and/or changes the endocrine stimulation of mammary gland growth. Accelerated growth rates for heifers 15 months of age and older does not affect mammary secretory tissue. Higher protein levels in the diet (14 to 16 percent) may help prevent over-conditioning when heifers are fed high-energy diets.

TABLE 9. HEIFER GRAIN GUIDELINES ACCORDING TO FORAGE QUALITY FOR 1.8 POUNDS PER DAY GAIN

	Heifer weight			
Forage Quality	200-400	500-700	800-1000	over 1000
	---------------lb of grain/heifer/day-----------			
Legume-Grass				
Excellent	2-3	0	0	0
Very good	3-4	1-2	1	0
Fair	4-5	4-5	3-4	3-4
Grass				
Excellent	3-4	0-2	0	0
Very good	4-5	2-3	2-3	2-3
Fair	5-6	4-5	4-5	4-5

If protein content of forage is good, little protein supplement will be required in the grain mix. Grain mixes prepared for the milking herd are acceptable as long as they are properly fortified with minerals and vitamins. Monensin or Lasalocid (ionophores) can be fed in rations for heifers to improve rate of gain (**table 17**).

Feeding program for heifers 1 to 2 years of age (to 2 months before parturition). If good quality forage is available, this may be the only feed required for heifers over 1 year of age. Trace mineral salt and a calcium-phosphorus supplement are recommended on a free-choice basis. Heifers should gain 1.7 to 2.0 pounds per day. If growth is not satisfactory, some grain should be supplied; generally, only a small amount is required. Heifers on good pasture require no grain or additional forage. As pastures mature, dry out, or are heavily grazed, supplemental grain or other feed should be provided. Heifers deficient in energy, phosphorus, or vitamin A will not exhibit estrus.

First estrus in heifers is dependent on a combination of size and weight, but primarily weight. A general guideline is heifers will show their first estrus at 40 percent of their mature weight, which should be before 12 months of age. Heifers fed high planes of nutrition will show estrus at an earlier age than heifers grown at recommended rates, but underfeeding of heifers will delay estrus. Underfed or very slow growing heifers may ovulate, but estrus signs often are suppressed. Heifers in good condition and gaining weight at breeding time generally show more definite signs of estrus and have improved conception rates over heifers in poor condition and/or losing weight. Over-conditioned or fat heifers have been reported to require more services per conception than heifers of normal size and weight. **Table 10** shows desirable weights for first breeding, together with weights for other age categories.

Two months before calving to calving. How heifers are fed during this period can affect milk production during first lactation. Heifers should move from a steady growth rate after breeding to a rapidly growing phase (1.7 to 2.0 lb/day gain) the last two to three months of pregnancy. Heifers growing rapidly at calving time, but needing additional growth during the first lactation, were found to be more persistent milkers than full-sized heifers at calving. Also, heifers slightly undersized at calving (80 percent of normal) will reach full milk production potential and normal size if fed sufficient nutrients for both growth and milk production during the lactation.

TABLE 10. DESIRABLE WEIGHTS AND BODY CONDITION SCORES FOR DAIRY HEIFERS

Age in months	Body Condition Score	Brown Swiss or Holstein	Ayrshire M. Shorthorn or Guernsey	Jersey
		-------------------------lb-------------------------		
Birth		90 - 100	65 - 75	55 - 60
1		120 - 130	90 - 100	70 - 80
2	2.2	170 - 190	150 - 160	110 - 120
4	2.2	275 - 300	240 - 250	190 - 200
6	2.3	390 - 410	320 - 340	270 - 280
12	2.8	740 - 760	590 - 610	510 - 520
14*	3.0	800 - 850	670 - 690	570 - 600
18	3.2	1050 - 1100	850 - 870	750 - 775
22	3.5	1250 - 1300	1025 - 1075	900 - 950

* Breed heifers in this weight range. Heifers should weigh about 60% of their mature weight when bred. With proper feeding, heifers should reach these weights and have good skeletal growth at 14 to 16 months of age.

The exact amount of grain to feed before calving will depend on forage quality, size, and condition of the heifer. A thumb rule would be to feed grain at 1 percent of body weight starting about 6 weeks before calving. Be sure rations are balanced in protein, minerals, and vitamins. Excess salt intakes can contribute to udder edema and should be avoided the last 2 weeks before calving.

Well-grown heifers will have a minimum of problems at calving, but ease of calving can be affected by plane of nutrition in two ways: 1) an effect on calf size, and 2) an effect on fatness of the dam. At equal body weights, fat, over-conditioned heifers are almost always younger and consequently will have less skeletal growth than leaner, normally grown heifers. Thus, fat heifers have higher rates of dystocia because of small pelvic openings and usually a larger-than-normal sized calf at birth. Underfed or poorly grown heifers also will require more assistance at calving and have a higher death rate at calving than normal sized heifers.

FEEDING SYSTEMS

A successful dairy feeding system is defined as one that delivers the needed nutrients to each cow at the correct time (stage of lactation) to maintain maximum milk production. No one system is correct for all dairy producers. The feeding system selected must consider delivery of forages, grain, protein and minerals, either individually or in various combinations.

Forage Systems

Forages are classified as feeds high in fiber and low in digestible nutrients, and include whole plants of corn, small grains (such as oats, barley, or wheat), legumes, and grasses. Forages are the primary source of fiber required by the cow to maintain rumen digestion and function as well as to stimulate rumen microbial growth, rumination, and saliva production. Forages are usually a more economical source of nutrients than grains, protein supplements, or mineral-vitamin premixes.

Forage selection depends largely on agronomic considerations (such as soil types, climate, yields, and nutrient yield per acre). Forage quality must be the primary consideration regardless of forage type. High quality forage will be consumed in larger amounts and is more digestible than mature, lower quality forages. Addition of grain to diets cannot completely compensate for lowered animal performance from low quality forages.

Forages can be of several different types, each varying in chemical composition, moisture content, and physical form. The trend over the years has been to increase the use of ensiled forages due to convenience, ease of mechanization, reduced labor, more uniform quality, increased yield per acre compared with pasture, and lower field losses compared with hay. Increased harvest losses and potential rain damage (due to extra drying time required) are associated with dry baled hay (**figure 7**). Use of a drying agent at cutting and/or a propionic acid-based preservative to permit baling at a higher moisture level offers a method of

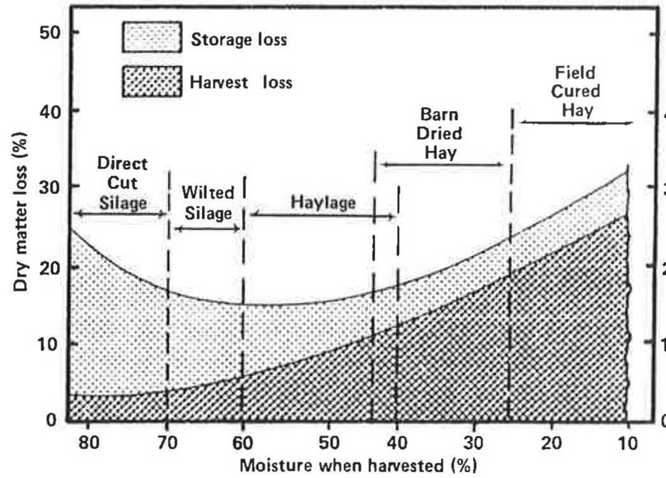


Figure 7. Estimated total harvest and storage losses when legume-grass forages are harvested at varying moisture levels and by different methods.

reducing drying time. **Table 11** lists the comparative advantages of several methods for storing dry hay. Large round bales and 3-ton stacks are not easily moved and are seldom easily fed in stanchion barns.

Haylage minimizes DM losses and weather risks, and has the advantage of being adaptable to mechanization in harvesting, storing, and feeding. The optimum storage system for haylage or other silages will depend on inventory needs and availability, continuous feed features, refill and/or double filling patterns, and the feed system. Tower silos, both conventional and limited oxygen, bunker silos, and large plastic bags have all been successfully used for storage. **Table 12** compares costs of these systems.

Pastures can provide significant quantities of high quality forages to dairy cows and heifers if managed intensively. Potential benefits of a pasture-based forage system for dairy herds include 1) increased yield and quality of forage from land that previously was unproductive, 2) decreased equipment and fuel for harvesting forages, 3) less manure handling and lower bedding costs, 4) reduced weather related risks in harvesting forages and 5) potential for better animal health because of increased

TABLE 11. COMPARATIVE ANALYSIS OF VARIOUS METHODS OF STORING AND FEEDING DRY FORAGES

Method of storage	Method of feeding	Losses expected: Harvesting	Storage	Feeding	Hours labor required per ton to: Store	Feed	Tons hay required[a]
		%	%	%			
A. Conventional bales	Individually in stanchions or group fed at rack	20	4	5	2.00	1.11	137
B. Large round bales	Stored inside, fed in rack	20	4	4	0.10	0.55	135
	Stored outside, fed on ground	20	11	22	0.10	0.40	166
C. 3-ton stack	Stored outside, fed in rack	20	9	4	0.08	0.24	135
	Stored outside, fed on ground	20	9	28	0.08	0.17	171
D. Cubed or pelleted	Individually in stanchion or group fed at bunk	Usually purchased	2	2	(Depends on facilities & equipment)		130

[a]Tons of hay required for 50-cow herd consuming 2.5 tons per cow annually (13.7 lb daily). Additional forage from another source assumed.

TABLE 12. ECONOMIC COMPARISONS FOR VARIOUS FORAGE STORAGE UNITS AT TWO CAPACITIES

Silo type and size	Capacity (tons DM)	Total investment	Ownership costs (per ton DM)
Metal oxygen-limiting			
25 x 80	200	$ 82,000	$67.65
25 x 90	325	113,800	57.77
Concrete oxygen-limiting			
20 x 72	170	62,000	60.18
30 x 100	510	120,000	38.82
Concrete stave			
20 x 70	155	30,250	32.20
30 x 80	425	52,500	20.38
Concrete bunker			
10 x 30 x 185	750	24,800	5.13
12 x 40 x 112	500	23,800	7.38
Bagger and bags			
5 bags	250	34,500	32.13
25 bags	750	38,000	11.91

Source: T.D. Hewitt, 1986, Dairy Herd Management, Vol. 24, No. 12, p. 29.

exercise. Limitations to pasture-based forage systems are: 1) maintenance of high yields and quality of forages during the entire growing season, 2) correct supplementation to maximize productivity and profitability from pasture forages and 3) the short length of the grazing season in some areas.

The optimum forage system for a given farm depends on the amount of forage required, storage method, and ease of accessing forages of different qualities. Situations often leading to forage allocation problems include second cutting hay piled on top of first cutting hay; a conventional top-unloading upright silo with first cutting haylage on the bottom, second cutting haylage in the middle, and third cutting haylage on top; or a conventional top-unloading silo with haylage on the bottom and corn silage on top. These situations do not allow for the optimal utilization of forages, as one quality of forage must be fed to all animals until it is depleted. Different animals can utilize different quality forages more efficiently. An optimal forage system allows for the segmenting of forages by quality. The solution may be to have several smaller silos instead of a few large units. This approach would also allow for a gradual shift between forage types rather than abrupt changes.

Dairy producers storing more than 1,000 tons of silage annually, especially corn silage, find that bunker silos are more economical and are more reliable because they are less vulnerable to power failure or breakage of mechanical unloading equipment.

Forages are most often fed free-choice or in a total mixed ration (TMR). When fed free-choice, forage should be available to cattle at all times. Cows without forage or feed for more than 3 hours per day are not full fed. DM intake, and consequently milk production, is reduced when cows are not full fed.

Grain Systems

Tie-stall barns. Feeding cows housed in a tie-stall or stanchion barn generally requires more labor than feeding cows housed in a free-stall barn. Grain can be fed by mixing all ingredients (complete grain mix) except forage, or can be fed separately (high moisture corn) from other ingredients (topdress feeding of protein supplement and/or mineral and vitamin supplement). It can also be included in a TMR. Mechanical equipment is available that minimizes labor needed to hand feed grain. This varies from a simple push cart to computerized monorail feeders to fully automated overhead auger systems filling storage containers located at each cow stall.

Free-stall or loose housing herds. Feeding correct amounts of grain in a parlor is difficult due to the limited time cows are actually in the parlor. Also, parlor efficiency is usually compromised when all or a major portion of grain is fed in the parlor. Elimination of parlor grain feeding will reduce dust and defecation in the milking area, improve cow flow, and reduce overfeeding of low producers and underfeeding of high producers.

Several mechanized grain-feeding systems are available to replace or supplement the parlor grain feeding system.

1. Free-choice, electronic grain feeders. These units allow cows equipped with an identification unit (either a magnet, key, or chain) access to a feeding station. These systems do not restrict access time or amount of grain consumed per feeder visit. Careful management is required to avoid digestive problems. The major advantages of these systems are a lower initial investment and a simple design.
2. Preset or computerized grain feeders. These systems control the maximum amount of grain individual cows receive during a set period of time. Initial costs of these systems vary widely depending on herd size and complexity of the system. Some features associated with computerized feeders include:
    a. A printer to list individual and total daily grain intakes.
    b. Identification of cows not consuming their allocated grain amount.
    c. Ability to proportion the grain allocation over time.
    d. Ability to proportion more than one grain mix or bin contents.
    e. Warning system to signal a feed blockage, component problem, or power interruption.
    f. Milk data combined with other information to provide more herd management information.
    g. Capability of providing the entire daily grain allocation for individual cows and/or for the whole herd through computer feeders.

Regardless of which feeder system is selected, successful adoption requires excellent management. Recommended number of cows per feeder is between 20 and 25. Stall length, protection of the unit, and location of the unit relative to cow traffic patterns also can affect success of the unit. **Table 13** lists typical rates at which cows consume various types of grain.

TABLE 13. CONSUMPTION OF VARIOUS GRAIN FORMS

Type of grain	Lb per minute
Pelleted	1 to 1.2
Coarsely ground or cracked	.75
Average to finely ground	.50

Another method of feeding grain in free-stall or loose housing is through a TMR with forages and all other feeds combined. Separation of cows into production groups is recommended for this method to succeed.

A survey of the top 50 DHIA herds in Minnesota in 1991 indicated method of grain feeding had no effect on milk production **(Table 14)**. Success with any method requires that the nutrient content of the grain portion of the ration complement the forage program and provide the nutrients necessary to meet requirements for the desired level of milk production.

TABLE 14. RELATIONSHIP BETWEEN FEEDING SYSTEM AND MILK PRODUCTION[1]

Feeding System	No. Herds	DHIA Herd Milk (lb/cow/year)	Average Fat %	Average Protein %
Total Mixed Ration (TMR)	16	24,131	3.67	3.13
Grain fed separate from forage				
Computer	13	24,598	3.67	3.13
Hand	21	23,535	3.84	3.16

[1]1990 Minnesota survey

The amount of supplemental protein fed is usually controlled by making it part of a grain mix or TMR, or by top dressing. However, lick wheels are one means by which protein supplementation is offered free-choice. Intake of urea-molasses (liquid supplements) from lick wheels usually averages from 1 to 2 pounds per animal daily. If feed is limited, intake can increase to 5 to 10 pounds per day and can result in urea toxicity problems. Lick wheels generally are not recommended for lactating cows with differing protein needs, since cows are unable to balance protein needs. The lick wheels may have value, however, when the protein requirement of all animals in a group is uniform, such as with dry cows and growing heifers. Consider cost of liquid supplements and do not depend on the cows's ability to balance protein needs.

Mineral Systems

Two basic systems for feeding minerals are:

1. Force feeding systems where the minerals are mixed with grain and/or forage, fed in a total mixed ration, or topdressed.
2. Free-choice systems where cows have unrestricted access to various mineral mixtures. Cafeteria-style mineral feeders are an example.

Several studies have demonstrated dairy cattle are unable to balance their mineral requirements through free-choice feeding alone. Therefore, a cow's mineral requirement, including salt, should be met through force feeding in the ration, with supplementary calcium-phosphorus minerals and salt offered free-choice. Mineral sources should be evaluated on cost per unit of mineral and quality of mineral source.

Total Mixed Rations

Total mixed rations (TMR), or complete rations, are defined as those with all the forage and grain ingredients blended together, formulated to specific nutrient concentration, and fed free-choice. The main advantages to TMR feeding are:

1. Cows consume the desired proportion of forages when two or more forages are offered.
2. Cows consume the desired amount of forage relative to the amount of grain offered.
3. There is less risk of digestive upsets.
4. Feed efficiency improves.
5. It allows for greater use of unpalatable feeds, NPN sources, and commodity feeds.
6. There is potential to reduce labor required for feeding.
7. It allows for greater accuracy in formulating and feeding.

The potential disadvantages include:

1. It requires a significant equipment investment in a mixer.
2. It creates a need to group cows into two or more groups.
3. Rations must be carefully formulated and continually checked.
4. Pasture feeding and large amounts of long hay are difficult to incorporate into rations.

Small mixing units and feed carts equipped with weigh cells are available. These work well in smaller herds (40 to 60 cows) or herds in tie-stall or stanchion barns. Equipment cost will vary depending on size, mobility, mechanization, and weighing devices involved. Electronic load cells are most accurate (1/10 to 1/4 of 1 percent) but require a level setting. Weigh bars can be used on uneven slopes (such as mobile mixer-truck) but are less accurate (1 percent). Both types are acceptable when managed properly.

Dividing cows into production strings is a critical factor for the success of TMR feeding. Consider the following guidelines for grouping cows:

1. A minimum of two production groups plus a dry group. More groups may be required as herd size increases. A separate group for first-calf heifers is advisable because of their smaller size, lack of competitiveness, and additional growth requirements compared with mature cows.
2. Once fresh cows have recovered from calving (usually 3 to 7 days), put them in the high group to challenge them nutritionally for 3 months. Move cows to a lower production group when milk output does not warrant keeping them in a higher production group and/or body condition is restored.
3. Drastic drops in milk production should not occur when cows are moved from a higher to a lower production group if rations are properly formulated.
4. Several options are available for moving cows.
   a. Move small groups of cows, rather than individuals.
   b. Move cows at feeding time to minimize cow interactions.
   c. Move cows on a regular schedule.
   d. Consider reproductive status when moving cows. Try to limit heat detection to one group.
   e. Increase grain by 5 pounds for several days after cows are shifted if computer feeder is being used.
5. Formulate rations to meet nutrient requirements of the top third of the cows in each group.

RATION FORMULATION

The objective in formulating rations is to provide animals with a consumable quantity of feed stuffs that will supply all required nutrients in adequate or greater amounts and do so in a cost effective way. Today, almost all rations are formulated with the aid of a computer compared with only a few years ago when all rations were hand calculated. Use of computers has resulted in more complete evaluations of nutrient profiles in rations and allowed for economics to be included in ration formulation decisions. The four most common ways of expressing computer ration information are:

Analyze. A ration analysis is a summation of all feeds in the ration and the nutrients they contribute. An analysis does not balance the ration, and therefore does not correct any nutrient deficiencies or excesses. The amount of each feed fed, along with its nutrient composition, must be known to obtain an accurate ration analysis.

Balancer. A ration balancer program combines feeds to meet the nutrient specifications set for a ration. The amount of each feed to be included in the ration will be determined based on its nutrient contributions and how it fits with other feeds in meeting nutrient specifications. A balancer program does not consider feed costs or profit.

Least cost. A typical least cost formulation involves specifying the nutrient requirements or constraints for the ration and then finding the combination of feeds that meet or exceed these constraints at the lowest cost per pound of DM. Least cost formulations change as feed costs change. An opportunity or break-even cost for feeds not used in the ration will often be given. When the price of an unused feed goes below the opportunity price, it is considered a good buy and the ration should be reformulated to see how much of that feed can now be used in the ration.

Maximum profit. A true maximum profit ration program includes a least cost function, incorporates milk price information, and uses a maximum profit (income over feed cost) as one of the constraints or specifications to formulate on. The difference between maximum profit and least cost or balanced rations is that the computer selects feeds and a milk production level to obtain a maximum profit; whereas, in least cost or balanced rations the computer selects only feeds to meet the nutrient requirements specified for a given level of milk production.

Ration Formulation Thumb Rules—Lactating Cows

1. **DMI** needs to be known. Use **table 15** as a guideline.
2. **Forage DM** minimum is 40 percent of the total DM intake or approximately 1.5 percent of body weight.
3. Maximum **grain DM** is 60 percent of total DMI, or not more than 2 percent of body weight. Between 10 and 70 pounds of milk per day, feed grain at 1 pound per 3 pounds of milk, and above 70 pounds of milk, feed grain at 1 pound per 3.5 pounds of milk.
4. Minimum recommended acid detergent fiber (ADF) in ration DM is 18 percent, with 19 to 20 percent preferable, especially when fat is fed.
5. **Neutral detergent fiber** (NDF) should be at least 28 percent of the ration DM. Forages should account for 75 percent or more of the total ration NDF (1.2 percent of body weight or 21 percent of ration DM).
6. **Protein** needs to meet requirements (17 to 19% in early lactation rations). A low rumen degradable protein source may be beneficial in early lactation rations for high producing cows. Limit urea to .4 pounds per cow per day and preferably to not over .2 pounds per day in phase 1 and 2.
7. Maximum total fat in rations is 7 percent of the DM. A guideline is no more than 2 percent added fat from any one of three sources, animal, vegetable or rumen inert. Increase calcium to .9 to 1 percent, magnesium to .3 percent, and ADF to 20 percent or more in the ration DM when feeding fat.

8. Salt should be included in the grain mix at 1 percent or fed at the daily individual cow rate of 1 ounce for maintenance plus 1 ounce for every 30 pounds of milk.
9. A calcium-phosphorus mineral source should be included in the grain mix at 1 to 2 percent or fed at an approximate rate of 1 ounce per 10 pounds of milk.
10. Supplement vitamins (A, D, and E) and trace minerals in the ration to meet requirements.

Hand Calculated Rations

Step 1. Use tables A-6, A-7, and A-8 to determine nutrient requirements. Forage tests, feed tags, and tables A-9, A-10, and A-11 should be used as sources of nutrient information in feedstuffs.

Step 2. Weigh the amount of each forage fed. Calculate pounds of DM from each forage.

$$\frac{\text{lb fed} \times \text{\% DM}}{100} = \text{lb DM fed}$$

Step 3. Determine nutrient contribution of forages. Multiply pounds of forage DM by nutrient content.

Example:

$$\frac{\text{lb forage DM} \times \text{\% CP (DM basis)}}{100} = \text{lb CP from forage}$$

Step 4. Subtract nutrients contributed from the forages from the nutrient requirements determined in step 1.

Step 5. Total the pounds of forage DM fed and subtract this amount from the projected total DMI given in **table 15**. The difference is the amount of grain needed.

Step 6. The Pearson Square technique can be used to determine proportions of different grains in a grain mix, based on net energy, or more commonly, to determine the protein content of the grain mix. An example for protein will be given here.

1. Write the desired protein percentage in the grain mix in the middle of the box. Determine the percentage by dividing the amount of protein needed by the estimated amount of grain DM.

   Example: 17%

2. Write the protein percentage (DM basis) of the grain and protein supplement in the left corners of the square.

   Example: 10 and 50%

3. Subtract diagonally and write differences in right corners. These numbers are parts or proportions.

   Example: 17 - 10 = 7 and 50 - 17 = 33

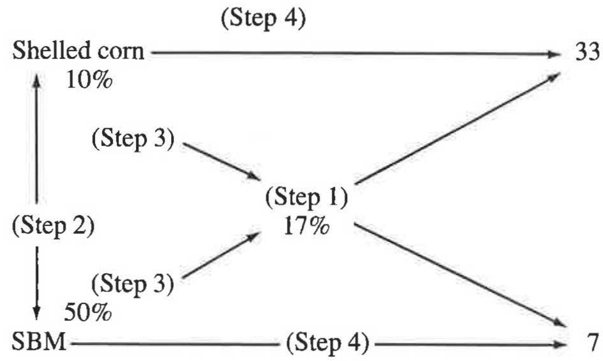
   To convert to a percentage, add the parts and divide the total into each individual part or proportion.

   Example: 33 + 7 = 40
   Percent SBM is 7 ÷ 40 x 100 = 18%

4. Multiply the size of the batch mix times the percentage of each ingredient to get the pounds of DM necessary. The pounds of DM must be divided by the percent DM of the ingredient to convert to an as-fed basis.

   Example: $\frac{2000 \times 18\%}{100} = 360$ lb of SBM DM

   $\frac{360 \times 100}{90\% \text{ DM}} = 400$ lb as fed



Total parts 40
(Step 5)

Percentage shelled corn = 33/40 x 100 = 82%
Percentage SBM = 7/40 x 100 = 18%

In this example 1 ton of DM would contain 1640 pounds of shelled corn and 360 pounds of soybean meal.

TABLE 15. DRY MATTER INTAKE GUIDELINES

Milk[a]	900	1100	1200	1300	1500
lb/day	% of body weight[b]				
20	2.6	2.3	2.2	2.1	2.0
30	3.0	2.7	2.6	2.5	2.3
40	3.4	3.1	2.9	2.8	2.5
50	3.8	3.4	3.2	3.1	2.8
60	4.1	3.7	3.5	3.4	3.1
70	4.6	4.0	3.8	3.6	3.3
80	5.1	4.3	4.1	3.8	3.5
90		4.7	4.4	4.1	3.7
100		5.0	4.7	4.4	3.9

[a] Fat corrected milk = (milk lb x .4) + (fat lb x 15).
[b] Intakes may be up to 18% less for cows in early lactation.

BALANCED RATION CHECK SHEET

Cow Data: Weight, lb 1300 Milk, lb/day 80 Fat, % 3.5 Age, months 48 Days in Milk 120 Weight gain, lb/day 1

(Milk lb x .4) + (Fat lb x 15) = 74 lb FCM

Requirements	Crude protein	Net energy	Calcium	Phosphorus
Maintenance (table A-6)	.89	9.6	25	17
Gestation (table A-6)	—	—	—	—
Growth - heifers (table A-6)	—	—	—	—
Production (table A-7, A-8)	6.72	24.8	109	66
Weight gain (table A-6)	.32	2.32		
Total	7.93	36.72	134	83

DM Intake

Total (table 14)

Body weight (cwt) x Intake % of body weight = Pounds of DM

13 x 3.70 = 48.1

Feed

Kind of feed	lb feed	x	% DM	=	lb DM
Hay	20	x	88	=	18
Corn silage	25	x	40	=	10
Corn, HMSC	20	x	75	=	15
Protein suppl (SBM)	6.5	x	90	=	5.8
Mineral 20:10	.5	x	96	=	.5
Total					49.3

Nutrients Provided (tables A-9, A-10, and A-11)

A x 1 = Crude protein (CP)
A x 2 = Net energy, Mcal (NE)
A x 3 = Calcium (Ca)
A x 4 = Phosphorus (P)

Feed	A DM lb		1 CP %		CP lb	2 NE Mcal/lb		NE Mcal	3 Ca g/lb		Ca g	4 P g/lb		P g
Hay	18	x	18	=	3.2	.61	=	11.0	6.4	=	115	1.0	=	18
Corn silage	10	x	8.5	=	.85	.70	=	7.0	.9	=	9	1.0	=	10
Corn	15	x	10	=	1.5	.92	=	13.8	0	=	0	1.4	=	21
SBM	5.8	x	50	=	2.9	.84	=	4.9	1.4	=	8	3.1	=	18
Mineral	.5	x	0	=	0	0	=	0	91	=	46	45	=	22
Total					8.45			36.7			178			89
Difference from requirements (+,-)					+.52			0.0			+44			+6

Fiber balance

Feed	DM lb		ADF %		ADF lb	DM lb		NDF %		NDF lb
Hay	18	x	31	=	5.6	18	x	42	=	7.6
Corn silage	10	x	26	=	2.6	10	x	48	=	4.8
Corn	15	x	3	=	.5	15	x	9	=	1.4
SBM	5.8	x	10	=	.6	5.8	x	12	=	.7
Total					9.3					14.5

Ration % 9.3/49.3 = 18.9 14.5/49.3 = 29.4

NDF from forage, % 12.4/49.3 = 25.2 or 12.4/14.5 = 85.5% of total

PURCHASING FEED

Feed Tag Interpretation

Most dairy producers buy some feed. It may be a complete grain mix, protein supplement, urea-molasses liquid, mineral supplement, vitamin mix or feed additive. However, some dairy producers do not know what they are buying. Is it worth $10 or $15 per hundred? What will it do? A feed tag can give clues to these and other questions.

Protein. Protein is one nutrient that should receive close attention. The sample feed tag **(figure 8)** guarantees a minimum of 36 percent crude protein equivalent or 36 pounds of crude protein per 100 pounds of feed. If a source of NPN (urea, ammonium salt, etc.) is used, it will be listed below the crude protein level as "percent equivalent crude protein from nonprotein nitrogen (NPN)."

Many commercial protein supplements contain some NPN, usually as urea. The amount of crude protein equivalent supplied by NPN is listed on the tag. For example, supplement XYZ contains 36 percent crude protein, of which 11.2 percent crude protein is supplied by NPN. This means that 100 pounds of supplement contains 36 pounds of crude protein, of which 11.2 pounds of crude protein is

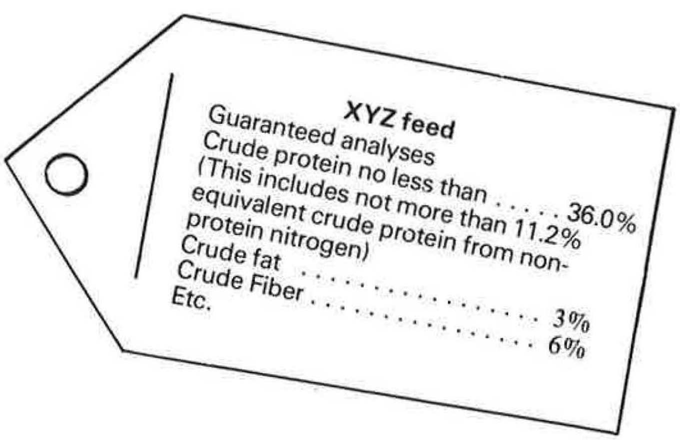


Figure 8. Sample feed tag.

supplied by NPN. The percent of urea in the supplement may be calculated as follows:

$$\frac{11.2 \times 100}{287^*} = 3.9\%$$

*Divided by 287 because urea contains 46 percent nitrogen. Protein contains 16 percent nitrogen. Thus, 6.25 x 46 percent nitrogen = 287 lb of crude protein equivalent in 100 lb of urea.

If high producing cows are fed 4 pounds of this commercial supplement daily, the cow consumes 0.16 pound of urea. This is a safe level of urea feeding (3.9% x 4 lb = 0.16 lb/cow/day).

Fat. Fats and oils contain 2.25 times more energy than the same weight of starch or sugar (carbohydrates). Fats increase palatability and prevent dustiness. Most grain mixes contain less than 5 percent and protein supplements less than 10 percent fat. The total ration should not contain more than 7 percent fat from all sources.

Animal and/or vegetable fat can be used by the dairy cow. Milk production and/or fat test must increase to pay for added fat. High-producing cows that cannot consume enough grain may respond economically to added fat. Fat test may increase or decrease depending on the type of fat and method fed.

Crude fiber. Crude fiber is a critical component. Since most feed tags do not list an energy value (no practical way to measure accurately), the guaranteed fiber level gives a hint.

As fiber level increases, energy level usually declines. Generally, for each 1 percent rise in fiber, TDN level drops about 1 percent. Fiber levels should be checked, especially in pelleted or complete dairy mixes **(table 17)**.

Minerals and vitamins. Other guaranteed nutrients, such as minerals and vitamins, should be considered when looking at a feed tag. If the feed is bought primarily for phosphorus or vitamins, calculate cost per pound or unit of that nutrient.

TABLE 16. RELATIONSHIP OF CRUDE FIBER TO ENERGY LEVEL (TDN) IN FEED[a]

Feed		Crude fiber %	ADF %	TDN %
Shelled corn		2	3	91
Ear corn		9	11	85
Barley		6	8	83
Soybean meal		7	9	85
Oats		12	15	76
Screenings	Sample A (good quality)	8	10	77
	Sample B (fair quality)	18	22	61
	Sample C (poor quality)	31	36	55
Alfalfa (mid-bloom)		31	38	56
Corn cobs		36	44	47

[a] Values expressed on a 100% DM basis.

Feed ingredients used in making the mixture are listed below the guaranteed analysis. The percent or amount of each ingredient does not appear, but generally ingredients are listed in a descending order of amounts used in making the feed. Different amounts can be used as long as the guaranteed levels of nutrients are met. For example, one batch of feed could contain wheat bran this week and wheat midds next week. This can affect palatability and intake, but is not a problem with reputable feed companies.

Collective terms. There may be collective terms on feed tags. The various groups with some examples of feeds in each group follow:

1. Animal protein products: animal products (meat solubles, blood meal), marine products (fish meal), and milk products (whey, casein).
2. Forage products: alfalfa meal, corn plant silage, hay.
3. Grain products: barley, corn, oats, rice, wheat.
4. Plant protein products: soybean meal, sunflower meal, linseed meal, cottonseed meal, peanut meal.
5. Processed grain byproducts: wheat bran, brewers grain, flours, malt sprouts, midds, and gluten feeds or meals.
6. Roughage products: hulls (oats, barley, rice, soybeans), cobs, husks, pulps (beet, citrus), and straws.

If individual ingredients are named on the label, there is sometimes an "and/or" designation. This allows alternative ingredients for registration purposes (example: soybean meal and/or linseed meal).

Feed Additives

Many feeds contain ingredients that are not nutrients, but function in other ways. **Table 17** lists common additives, their functions, and current recommendations.

TABLE 17. COMMON FEED ADDITIVES

Additives	Function(s)	Recommendation
Anhydrous ammonia (NH3)	Source of nonprotein nitrogen (NPN) for ruminants; improves fiber digestibility, and serves as a forage preservative.	Add 7 lb/wet ton of corn silage; 20 lb/ton of baled hay; 40 to 60 lb/ton administered as a gas for 1 to 3 weeks for straw or corn stalks.
Amprolium (Coriad)	Prevents and treats coccidiosis in young calves. Add 2.25 mg/lb of body weight for 5 to 21 days to milk or milk replacer.	Calves may increase weight gain 10 to 20 lb in the first 16 weeks of life. This improvement does not always occur. Calves may develop disease organisms resistant to the drug. No advantage is observed in older heifers or cows. Check specific product labels for level and withdrawal time.
Anionic salts ($MgSO_4$, NH_4Cl, $CaCl_2$, NH_4SO_4, $CaSO_4$)	Acidifies diets, stimulating intestinal absorption and bone mobilization of calcium, aiding in the prevention of milk fever.	Add to close up dry cow ration 2 to 3 weeks prepartum. Increase dietary calcium to between 150 and 180 grams. Remove anionic salts after calving.
Bentonite	A clay mineral which swells 5 to 20 times in the rumen and has adsorption properties. Adds bulk in the ration and slows the rate of feed passage. Also used as a binder in pelleting feed.	Bentonite can correct milk fat depression due to heavy grain feeding. Add 5% (100 lb/ton) in the grain mixture. Fat test will not increase above normal. Cows may consume large amounts when offered free choice.
Beta-carotene	Source of beta-carotene and vitamin A. The corpus luteum (yellow body) on the ovary contains high levels of beta-carotene, which may influence reproduction. Immune function may be enhanced.	Feed 180 to 300 mg/cow starting 2 week preparation until cow is diagnosed pregnant. Not routinely recommended.
Buffers (see sodium bicarbonate, sodium sesquicarbonate and magnesium oxide)		

TABLE 17. COMMON FEED ADDITIVES (CONTINUED)

Additives	Function(s)	Recommendation
Choline	Involved with lipid synthesis and secretion from the liver.	Cows with fatty liver problems fed high grain diets, ketotic cows, and high-producing cows. Must bypass rumen to be effective.
Fat (oil)	Source of concentrated energy (2.25 times higher than starch) that can increase milk yield and fat test.	Early lactation (120 days postpartum) when cows are in negative energy balance (losing body weight). General recommendation is 1 lb/cow/day of supplemental fat.
Ionophores Monensin (Rumensin) or Lasalocid (Bovatec)	Antibiotics (coccidiostats) which alter rumen fermentation, increasing propionic acid and decreasing acetic. Improves rate of gain in heifers.	Illegal to feed to lactating or dry dairy cows. 60 to 300 mg/day for heifers.
Larvacide	Prevents the development of fly larvae in manure.	Cattle must consume it daily. Sanitation is essential since it controls only flies that breed in manure.
Magnesium oxide	Source of magnesium (54% by weight). Corrects milk fat depression. Increases the uptake of milk fat precursors at the mammary gland. Alkalizing effect in the rumen.	Milk fat depression from high grain feeding may be corrected with .2 lb/cow/day. More response occurs when combined with sodium bicarbonate. It will not raise test above normal. Magnesium oxide is unpalatable.
Methionine (methionine hydroxy analog, MHA)	An essential amino acid used in protein and fat synthesis. Fat test may increase.	Milk yield responses are not consistent. May help fat test in top-producing cows.
Mineral—chelated	Mineral is chemically bound to organic matter, which increases solubility and absorption.	No research to indicate increased milk production. May improve immune function.
Niacin	Water soluble B vitamin that is needed for energy transformation, slows fat mobilization, controls fatty liver and increases feed intake.	Feed 6 mg/cow/day from 2 weeks prepartum to 10 weeks postpartum to fat cows, ketotic-prone cows and high-producing cows.
Propionic acid	Serves as a feed preservative which acidifies the feed and inhibits mold growth. Normal acid in the rumen of a cow.	Add 1/2 to 1-1/2% of the feed. Level will depend on feed moisture level and length of storage.
Propylene glycol	Liquid or dry product converted to blood sugar in the liver of the cow. Increases circulating blood glucose (sugar).	Effective way of preventing primary ketosis by maintaining blood sugar levels. It must be administered before cows go off feed and may be unpalatable. Some cows require drenching. Administer 8 ounces twice a day until ketones disappear from the milk (use ketone test kit).

TABLE 17. COMMON FEED ADDITIVES (CONTINUED)

Additives	Functions	Recommendation
Sodium bicarbonate/ sodium sesquicarbonate	Maintain desired pH (6.2 to 6.8) in the rumen, which improves feed intake and digestibility, corrects volatile fatty acid production, and can help maintain normal milk fat test.	Feed 1/4 to 1/2 lb/cow/day when corn silage is the main forage, during periods of heat stress, when off-feed is a problem such as during the early postpartum period, or when the ration DM is low (below 50%).
Urea	Source of nonprotein nitrogen for ruminants.	Add 10 lb/ton of wet corn silage or 1% incorporation into the grain mix. Maximum of .4 lb of urea/cow/day.
Yeast	Irradiated yeast is a source of vitamin D and B-complex vitamins. Changes the fermentation pattern in the rumen.	No advantage in adding yeast to livestock rations with sufficient B-complex vitamins. Yeast will not persist in the rumen because of acids present. Consistency of the manure may change.
Zinc methionine (Zin-Pro)	Source of zinc. Organic chelated form plus methionine, which is not degraded in the rumen.	4.5 g/cow/day is suggested for cows with feet and leg problems (4% zinc product).

Dollar Value of Common Feedstuffs

A comparative dollar value of some common feedstuffs can be obtained by using the factors **in table A-16.** The feed evaluation factors consider energy and protein from corn and soybean meal for all feeds and fiber from alfalfa hay for forages. To obtain an estimated dollar value of a feed on the list:

1. Multiply the current price of corn ($/cwt) by the evaluation factor for the feed listed in the corn column.
2. Multiply the current price of soybean meal ($/cwt) by the evaluation factor for the feed listed in the soybean meal column.
3. If the feed to be evaluated is a forage, multiply the price for alfalfa hay ($/cwt) containing approximately 16 percent CP and 38 percent ADF by the factor listed in the alfalfa hay column.
4. Add figures from 1 and 2 or 1, 2 and 3 for forages together. All dollar values will be on an as-fed or wet basis.

Example—Corn silage, well eared

Shelled corn—$2.50/bushel = $4.46/cwt
Soybean meal—$10.00/cwt
Alfalfa hay—$60.00/ton = $3.00/cwt

Corn silage, $/cwt = (.190 x $4.46) + (-.059 x $10.00) + (.262 x $3.00)

= $1.05/cwt or $21.00/ton @ 35% DM

Example—Sunflower meal (28% CP)
Shelled corn - $4.46/cwt
Soybean meal - $10.00/cwt

Sunflower meal, $/cwt = (-.325 x $4.46) + (.638 x $10.00)

= $4.93/cwt @ 90% DM

DAIRY COW DISEASES AND DISORDERS

Good herd health management programs include: checking all animals daily for injury or sickness; handling animals quietly to prevent excitement and injury; consulting with a veterinarian regarding specific disease problems; and implementing a preventive program.

Table 18 summarizes the more common nutritional diseases and disorders. Consult your veterinarian regarding treatment of these conditions. Early detection, early diagnosis, and prompt corrective treatment will keep losses at a minimum.

TABLE 18. DESCRIPTION AND PREVENTION OF DAIRY COW DISEASES AND DISORDERS

Name	Description	Prevention
Acidosis - acute (indigestion, engorgement toxemia)	The rumen may develop an acid condition (pH of 4.0 to 4.5) that impairs rumen function and digestion. The animal has a poor appetite and a dull appearance. Later, faster pulse rates may be observed together with sunken eyes and a dehydrated appearance.	Avoid accidental access or rapid changes to a high-energy feed, such as grain mixture, or too much high moisture corn. Early diagnosis and treatment are very important in severe cases to maintain life of animals.
Acidosis - chronic (off-feed, founder)	The rumen develops an acid condition below pH 6 for several hours per day. DM intake may drop, fat test varies, and sore feet can develop.	Feed balanced rations with adequate fiber form and length. Limit grain intake to 5 to 7 lb per meal. Ration moisture should not exceed 50 percent. Add a buffer.
Bloat	An excessive accumulation of gases in the rumen. Severe bloat occurs on legume pastures. Breathing becomes labored and excessive salivation is common. Left side of the cow balloons.	Feed at least 10 lb dry hay before permitting grazing or recommended levels of bloat-preventing drugs.
Chemicals - Insecticides - Parasiticides - Herbicides - Pesticides	Occasionally cattle have been contaminated with chlorinated hydrocarbon compounds such as DDT, dieldrin, heptachlor, PCB, PBB or plasticizers. These compounds are fat soluble, collect in the body fat deposits, and eventually are excreted in milk.	Dairy farmers must be cautious about feeds that could be contaminated by direct application or drift from aerial application. Always follow directions on label of insecticides, herbicides, wormers, and chemical products. Consult with veterinarian, extension agent, or sales personnel before using a product if there are any questions about its use.
Displaced abomasum (twisted stomach)	The fourth compartment of the cow's stomach moves in the body cavity after calving; it may twist, preventing passage of feedstuffs. Occurs most frequently at calving time in cows fed a high level of grain or low forage (ensiled) rations. Limited passage of "putty-like" feces. Veterinarian's diagnosis is by detecting a "pinging" sound using a stethoscope.	Feed a minimum of 5 lb of long hay; avoid finely ground or chopped feeds; avoid abrupt ration changes; rations must contain adequate fiber quantity and quality for good rumination. Control other diseases (mastitis and metritis are examples).
Ergot	Fungus which infects the flower of cereal grain, causing the seed to develop a large purplish-black growth. Ergot toxicity is due to alkaloids that can cause restricted blood flow, abortions, and reduced milk flow.	Avoid grains that contain over .06 percent (6 kernels in 10,000). Dilute ergot-infected feed with wholesome feed, avoid feeding to pregnant animals, and watch animals for symptoms (lameness, muscle tremors, or lower milk yield).
Fatty liver syndrome	Cows have lowered level of liver function due to enlarged liver infiltrated with fat. Symptoms include a reduced appetite; secondary conditions may occur, such as ketosis, off-feed, and impaired immune system.	Feed a balanced ration (protein, minerals, and vitamins) to meet requirements. Prevent excessive weight gain during the dry period, to avoid fat cow syndrome, and prevent metabolic disorders.

TABLE 18. (CONTINUED)

Name	Description	Prevention
Foot rot	A break in the skin or hoof, usually between the toes, allowing bacteria to enter. Symptoms are a rapid, progressive lameness; swollen foot; characteristic foul odor. Infection often gets into joints, spreads up the leg, and may kill the cow.	Clean yards and facilities of foreign materials that might cause a break in the skin or hoof. Soft, non-callused feet on stubble or wire grass pastures are highly susceptible. Small stones lodging between the toes can also be a problem. Feed recommended iodine and zinc levels. Use a foot bath with copper sulfate (2%).
Grass tetany (hypomagnesemia)	May be observed in cows on lush grass pasture high in nitrogen, resulting in low absorption of magnesium. They will suddenly develop tetany, walk with a stiff gait, fall, go into convulsions, and die.	Watch cattle closely when pasturing grass field fertilized heavily with nitrogen. Supplement 2 oz. of magnesium oxide daily during the danger period.
Hardware disease	Results from a puncturing of reticulum by a sharp object. The animal will have a sudden lack of appetite, a reluctance to move, and a careful gait. Respiration is frequently rapid, pulse rate is fast, and rectal temperature is 100° F or higher.	Avoid making hay or silage from fields containing old fences or recently abandoned buildings. Avoid using baling wire. Give magnets to cows when a herd problem exists.
Ketosis (acetonemia)	Most frequently observed in well-conditioned cows 2 to 6 weeks after calving, resulting from rapid utilization of body reserves and impaired carbohydrate metabolism. Cows refuse to eat grain, then silage and finally hay. They gaunt up and milk production drops rapidly within a few days.	Gradually increase grain intake after calving to avoid indigestion and subsequent disease. Some hay is preferred to high silage rations. Avoid fat cows. Use propylene glycol or sodium propionate if ketosis becomes a herd problem. Early detection possible by using "kits" to test milk or urine. Adding 6 g of niacin can be beneficial. Supplemental fat feeding may also help.
Low fat test	Severe fat test depression (i.e., 3.8% to 2.8% or less) is associated with high levels of grain feeding and/or small feed particle size. Cows usually drop in milk production and gain weight.	Increase amount and length of fiber in ration. Add bentonite at 5%, or sodium bicarbonate or sodium sesquicarbonate at 1% (or 0.4 lb daily) to the grain ration.
Mastitis	Infection of the mammary gland caused by any one of several bacterial organisms. Staphylococcus or streptococcus organisms are most frequently involved. Symptoms vary with degree of inflammation. Acute cases show a swollen and painful udder and frequently cause the cow to go off-feed. Chronic cases have slightly swollen quarters and small flakes in milk.	No feed is known to cause or cure mastitis. However, a sudden addition of nutrients may result in a marked increase in production and cause more stress. This, in turn, might cause subclinical cases. For prevention of mastitis, consult a veterinarian. Feeding recommended levels of selenium and vitamin E may be helpful.
Milk fever (parturient paresis)	Occurs at calving; caused by a sudden shortage of blood calcium. First sign is staggering, then difficulty in rising, and finally down and not able to rise. Cows are usually down with head turned back towards the flank. Delayed treatment results in death of cow or slow response to treatment.	Feed low calcium (less than 100 g) - phosphorus (30 to 40 g) ration during the dry period. Feed milk fever-prone cows a specific calcium deficient ration 10 to 14 days before calving, or add anionic salts to the ration.

TABLE 18. (CONTINUED)

Name	Description	Prevention
Moldy feed toxicity (aflatoxins)	The fungus, Aspergillus flavus, and certain other molds, may produce toxic substances when feed grains are stored under conditions of high moisture and poor ventilation. They develop fatty liver degeneration, large adrenal glands and oversized bile ducts, reduce feed intake, have a lowered milk production, and may have a poor reproductive performance. Death in adult animals is rare.	Suspected feeds should be laboratory tested to determine if dose levels exceed 0.45 mg aflatoxin per 100 lb of body weight. Limit aflatoxin to 20 ppm in the total ration DM to avoid milk residue problems.
Nitrite poisoning (nitrate poisoning)	Toxicity is due to an excessive intake of nitrates or nitrites. Blood hemoglobin cannot carry oxygen to the body cells resulting in labored breathing, frothing at the mouth and a brownish color of the nonpigmented skin within a few hours after feeding. Abortions can occur. Death can occur within an hour in extreme cases.	Stressed plants (frost or drought) and weeds can be dangerous. Does not accumulate in grain portion of plants. Levels below 1000 ppm nitrate nitrogen are safe. Dilute the problem feed with wholesome feed based on feed test results.
Poisonous plants	Several hundred plants are known to be toxic to livestock under certain conditions. Bracken fern, algae, and nightshade are common poisonous plants. Cattle will eat whatever is available when feed is scarce, consuming enough of a toxic plant to produce toxic or even fatal effects.	Fortunately, cattle that consume adequate amounts of other feeds will seldom eat enough of a poisonous plant to do any harm.
Polioencephalomalacia or PEM (cerebrocortical necrosis)	Central nervous system condition characterized by circling, head pressing, blindness, convulsions, and death. An enzyme that destroys thiamine contributes to the problem.	Feed 150 mg of thiamine, control lactic acid acidosis, and avoid plants and molds that contain thiaminases.
Prussic acid poisoning	Drought or frost-stressed hybrid sorghums or sudan grass produce toxic hydrocyanic acid. Symptoms are rapid breathing, depression, stupor, convulsions, paralysis, and cherry red blood. Death may follow.	Avoid feeding young plants or secondary growth below 24 inches tall. Silage or dry hay reduces the risk. If an animal shows symptoms, call a veterinarian immediately and remove all animals from the pasture.
Sweet clover poisoning	Animals hemorrhage (failure of blood to clot) resulting from sweet clover hay that has developed a white mold producing dicoumarol. Stiffness or lameness first appears 2 to 4 weeks after introduction of damaged sweet clover. Patches of blood under the skin may appear later. Death may occur early without warning.	Avoid feeding moldy sweet clover hay or silage. A preliminary feeding trial with only a few animals is suggested if the feed is questionable. If symptoms suggest sweet clover poisoning, call a veterinarian immediately.
Udder edema	Edema is an excessive accumulation of fluid in the udder under the skin. Usually occurs at calving and is more severe in first lactation cows.	Limiting access to either sodium or potassium salts during the dry period. Avoid excess grain. Treatment includes stimulating circulation by massaging the udder. Diuretics should be used with care and direction of a veterinarian.

TABLE 18. (CONTINUED)

Description	Description	Prevention
Urea toxicity (ammonia toxicity)	Too much urea at one time or insufficient carbohydrate intake results in excessive ammonia in the rumen. Animals show an uneasiness, muscle and skin tremors, excessive salivation, labored breathing, incoordination, and bloat. Animal urinates excessively.	No more than 0.4 lb of urea should be fed per cow per day.

APPENDIX TABLES

TABLE A-1. SAMPLE BUDGET OF COST AND RETURNS FOR A MILK COW AND HER REPLACEMENT AT THREE DIFFERENT LEVELS OF PRODUCTION (NOTE: REPLACEMENT ANIMALS ARE BASED ON A 30% CULL RATE; REPLACEMENT HEIFER ADDS APPROXIMATELY $400 COSTS/COW)

	Level of production, lb sold/yr		
	16,000	19,000	22,000
Income			
Milk, @ $11.00/cwt	$2,000	$2,375	$2,750
Cull cow and calf sales	$340	$370	$400
Total income	**$2,340**	**$2,745**	**$3,150**
Feed costs			
Corn equivalent (bushels)	100	115	130
@ $2.50/bu	$250	$288	$325
44% CP supplement (cwt)	10.2	14.3	18.3
@ $12.50/cwt	$128	$179	$229
Corn silage, 2.7 tons DM @ $60.00/ton	$224	$224	$224
Alfalfa/Alf-grass, 5.5 tons DM @ $60.00/ton	$495	$495	$495
Milk replacer, calf starter, salt and minerals	$55	$65	$75
Total feed cost	**$1,152**	**$1,250**	**$1,348**
Other costs			
Milk hauling @ 50 cents/cwt	$80	$95	$110
Marketing deductions 30 cents/cwt	$48	$57	$66
Breeding fees	$32	$36	$40
Veterinary care, medicine and drugs	$60	$70	$80
Bedding	$95	$95	$95
Power and fuel	$70	$75	$80
Supplies, soap, inflations, etc.	$45	$45	$45
Overhead (DHI, legal, etc.)	$70	$70	$70
Total other costs	**$500**	**$543**	**$586**
Labor costs, 65 hr @ $6.00/hr	$390	$390	$390
Management value, 8% of income	$187	$220	$252
Labor and management costs	$577	$610	$642
Total costs	**$2,229**	**$2,403**	**$2,576**
Return to facilities, livestock, and risk	**$111**	**$342**	**$574**

Adapted from: A-2731 Wisconsin Farm Enterprise Budgets - Dairy Cows and Replacements.

TABLE A-2. SAMPLE BUDGET FOR RAISING HEIFERS TO 1350 LB IN 24 MONTHS

Feed costs	Example costs $
Milk replacer, 40 lb @ 50 cents/lb	20.00
Calf starter, 90 lb @ 12 cents/lb	10.80
Corn, shelled, 40 bu @ $2.50/bu	100.00
44% CP supplement, 240 lb @ $11.00/cwt	26.40
Ca-P mineral, 60 lb @ 22 cents/lb	13.20
TM salt, 45 lb @ 8 cents/lb	3.60
Forage DM, 6.0 ton @ $60.00/ton	360.00
Total feed costs (birth to 24 months)	$ 534.00

Other costs	Example costs $
Original value of calf	125.00
Labor, 24 hr @ $6.00/hr	144.00
Housing—depreciation, repair, interest, tax, and insurance	140.00
Equipment—depreciation, repair, interest, tax, and insurance	100.00
Livestock—interest, taxes, and insurance	110.00
Bedding cost	75.00
Veterinary care, medicine and drugs	25.00
Breeding fees	27.00
Power and fuel	21.00
Supplies and utilities	21.00
Overhead	18.00
Interest @ 11% on 1/2 forage, corn, and bedding	30.80
Total other costs	$ 836.80
Total cost/replacement heifer	$1,370.80

Adapted from: A-2731 Wisconsin Farm Enterprise Budgets - Dairy Cows and Replacement Heifers.

TABLE A-3. ESTIMATING WEIGHT OF DAIRY ANIMALS ON BASIS OF HEART GIRTH MEASUREMENTS

Heart girth inches	Weight lb	Heart girth inches	Weight lb	Heart girth inches	Weight lb
26	80	49	374	72	1069
27	84	50	394	73	1111
28	89	51	414	74	1153
29	95	52	434	75	1197
30	101	53	456	76	1241
31	108	54	478	77	1285
32	118	55	501	78	1331
33	128	56	526	79	1377
34	138	57	552	80	1423
35	148	58	579	81	1469
36	158	59	607	82	1515
37	168	60	637	83	1561
38	180	61	668	84	1607
39	192	62	700	85	1659
40	208	63	732	86	1712
41	224	64	766	87	1764
42	240	65	800	88	1816
43	258	66	835	90	1868
44	276	67	871	91	1921
45	294	68	908	92	1975
46	314	69	947		
47	334	70	987		
48	354	71	1027		

Measure animal with steel carpenter's tape or a heavy nonstretchable tape. Place tape just behind front legs and behind shoulders, and pull up snug.

TABLE A-4. WATER QUALITY GUIDELINES FOR DAIRY CATTLE

Analysis	Acceptable range[1]	Effects/problems from high levels
pH	6.0-8.0	Reduction in water intake. Very high pH waters (above 8.5) may cause alkalosis.
Total Dissolved Solids (TDS) Total Soluble Salts (TSS) Salinity	0-1000 ppm	Above 3000 ppm temporary diarrhea may occur. High levels cause water refusal and persistent diarrhea.
Hardness	0-120 ppm	Generally no problems.
Iron	0-3000 ppm	Reduced intake-taste.
Nitrate nitrogen	0-100 ppm	See table 19.
Nitrite nitrogen	0-10 ppm	Reproductive problems with abortions at very high levels.
Sulfate	0-500 ppm	Reduced water intake, diarrhea.
Total bacteria Coliform bacteria	0-1000/ml 0-50/100ml	General health and dease problems.

[1]ppm (parts per million) = 1 milligram/liter (mg/l); 1 grain = 17.1 ppm

TABLE A-5. DAILY NUTRIENT RECOMMENDATIONS FOR GROWING HEIFERS

	Body weight (lb)	Daily gain (lb)	Intake DM (lb)	Crude protein (lb)	NE_m (Mcal)	NE_g (Mcal)	TDN (lb)	Ca (g)	P (g)	Vitamin (1000 IU)	
										A	D
Large breeds	200	1.7	6.2	1.0	2.5	1.5	4.3	18	9	4	0.6
	300	1.7	8.1	1.3	3.4	1.8	5.6	20	12	6	0.9
	400	1.7	10.0	1.6	4.2	2.1	6.8	22	14	8	1.2
	500	1.7	12.0	1.8	5.0	2.3	7.9	23	16	10	1.5
	600	1.7	14.0	1.9	5.8	2.5	9.1	24	18	12	1.8
	700	1.7	16.2	2.0	6.5	2.8	10.3	25	19	14	2.1
	800	1.7	18.5	2.2	7.2	3.0	11.5	26	20	16	2.4
	900	1.7	21.0	2.5	7.8	3.2	12.8	29	21	18	2.7
	1000	1.7	23.7	2.8	8.5	3.3	14.1	29	21	19	3.0
	1100	1.5	25.2	3.0	9.1	3.1	14.7	29	21	21	3.3
	1200	1.5	28.4	3.4	9.7	3.2	16.1	30	21	23	3.6
Small breeds	100	1.1	3.0	0.5	1.5	0.7	2.2	10	6	2	0.3
	200	1.3	5.8	0.9	2.5	1.3	4.1	17	9	4	0.6
	300	1.3	7.9	1.3	3.4	1.6	5.3	19	11	6	0.9
	400	1.3	10.0	1.5	4.2	1.8	6.6	20	13	8	1.2
	500	1.3	12.2	1.6	5.0	2.0	7.8	22	15	10	1.5
	600	1.3	14.6	1.8	5.8	2.3	9.1	23	17	12	1.8
	700	1.3	17.3	2.1	6.5	2.5	10.4	24	18	14	2.1
	800	1.3	20.2	2.4	7.2	2.7	11.8	25	19	16	2.4
	900	1.3	23.7	2.8	7.8	2.9	13.4	29	19	18	2.7
	1000	1.1	25.6	3.1	8.5	2.5	14.1	29	19	20	3.0

TABLE A-6. DAILY NUTRIENT RECOMMENDATIONS FOR LACTATING DAIRY COWS

Body weight (lb)	Crude protein (lb)	NE_L (Mcal)	TDN (lb)	Ca (g)	P (g)	Vitamin A (1000 IU)	Vitamin D (1000 IU)
Maintenance of mature lactating cow*							
700	0.62	6.0	5.8	13	10	24	10
800	0.67	6.7	6.4	15	11	28	11
900	0.71	7.3	7.0	17	12	31	12
1000	0.76	7.9	7.6	19	14	34	14
1100	0.80	8.5	8.2	21	15	38	15
1200	0.85	9.0	8.7	23	16	41	16
1300	0.89	9.6	9.2	25	17	45	18
1400	0.93	10.1	9.8	26	20	48	19
1500	0.97	10.7	10.3	28	21	52	20
1600	1.01	11.2	10.8	30	23	55	22
1700	1.05	11.7	11.3	34	24	59	23
Add for gestation of mature dry cows							
700	1.04	1.8	1.8	9	4	—	—
800	1.17	2.0	1.9	10	5	—	—
900	1.29	2.2	2.1	11	5	—	—
1000	1.45	2.4	2.4	12	5	—	—
1100	1.52	2.5	2.6	13	6	—	—
1200	1.63	2.7	2.7	14	7	—	—
1300	1.73	2.9	2.9	15	7	—	—
1400	1.84	3.0	3.1	16	8	—	—
1500	1.95	3.2	3.2	17	9	—	—
1600	2.06	3.4	3.4	19	9	—	—
1700	2.16	3.5	3.6	20	9	—	—
Milk production—nutrients per pound of milk of different fat percentages							
% fat							
3.0	0.078	0.29	0.28	1.2	0.8	—	—
3.5	0.084	0.31	0.30	1.4	0.8	—	—
4.0	0.090	0.33	0.32	1.5	0.9	—	—
4.5	0.096	0.36	0.34	1.6	1.0	—	—
5.0	0.101	0.38	0.36	1.7	1.0	—	—
5.5	0.107	0.40	0.39	1.8	1.1	—	—
Body weight change during lactation—nutrients per pound weight change							
Weight loss	−0.32	−2.23	−2.17	—	—	—	—
Weight gain	0.32	2.32	2.26	—	—	—	—

*To allow for growth, add 20% to the maintenance allowances, except vitamin A and D during the first lactation and 10% during the second lactation.

TABLE A-7. CRUDE PROTEIN AND ENERGY ALLOWANCES FOR MILK PRODUCTION (ADD TO MAINTENANCE)

	3.0			3.5			3.75			4.0			4.5			5.0		
Milk /day (lb)	CP (lb)	NE_L (Mcal)	TDN (lb)	CP (lb)	NE_L (Mcal)	TDN (lb)	CP (lb)	NE_L (Mcal)	TDN (lb)	CP (lb)	NE_L (Mcal)	TDN (lb)	CP (lb)	NE_L (Mcal)	TDN (lb)	CP (lb)	NE_L (Mcal)	TDN (lb)
1	.078	0.29	0.28	.084	0.31	0.301	.087	0.325	0.312	.090	0.33	0.322	.096	0.36	0.343	.101	0.38	0.364
10	.78	2.90	2.80	.84	3.10	3.01	.87	3.25	3.12	.90	3.30	3.22	.96	3.60	3.43	1.01	3.80	3.64
20	1.56	5.80	5.60	1.68	6.20	6.02	1.74	6.50	6.24	1.80	6.60	6.44	1.92	7.20	6.86	2.02	7.60	7.28
30	2.34	8.70	8.40	2.52	9.30	9.03	2.61	9.75	9.36	2.70	9.90	9.66	2.88	10.80	10.29	3.03	11.40	10.92
40	3.12	11.60	11.20	3.36	12.40	12.04	3.48	13.00	12.48	3.60	13.20	12.88	3.84	14.40	13.72	4.04	15.20	14.56
50	3.90	14.50	14.00	4.20	15.50	15.05	4.35	16.25	15.60	4.50	16.50	16.10	4.80	18.00	17.15	5.05	19.00	18.20
60	4.68	17.40	16.80	5.04	18.60	18.06	5.22	19.50	18.72	5.40	19.80	19.32	5.76	21.60	20.58	6.06	22.80	21.84
70	5.46	20.30	19.60	5.88	21.70	21.07	6.09	22.75	21.84	6.30	23.10	22.54	6.72	25.20	24.01	7.07	26.60	25.48
80	6.24	23.20	22.40	6.72	24.80	24.08	6.96	26.00	24.96	7.20	26.40	25.76	7.68	28.80	27.44	8.08	30.40	29.12
90	7.02	26.10	25.20	7.56	27.90	27.09	7.83	29.25	28.08	8.10	29.70	28.98	8.64	32.40	30.87	9.09	34.20	32.76
100	7.80	29.00	28.00	8.40	31.00	30.10	8.70	32.50	31.20	9.00	33.00	32.20	9.60	36.00	34.30	10.10	38.00	36.40

TABLE A-8. CALCIUM AND PHOSPHORUS ALLOWANCES FOR MILK PRODUCTION (ADD TO MAINTENANCE).

	Milk fat %											
	3.00		3.50		3.75		4.00		4.50		5.00	
Milk /day (lb)	Ca g/day	P g/day	Ca g/day	P g/day	Ca g/day	P g/day	Ca g/day	P g/day	Ca g/day	P g/day	Ca g/day	P g/day
1	1.23	0.77	1.36	0.82	1.41	0.86	1.45	0.91	1.59	0.95	1.68	1.04
10	12	8	14	8	14	9	14	9	16	10	17	10
20	25	15	27	16	28	17	29	18	32	19	34	21
30	37	23	41	24	42	26	44	27	48	28	50	31
40	49	31	54	33	56	34	58	36	64	38	67	42
50	62	38	68	41	70	43	72	46	80	48	84	52
60	74	46	82	49	85	52	87	55	96	57	101	62
70	86	54	95	57	99	60	102	64	111	66	118	73
80	98	62	109	66	113	69	116	73	127	76	134	83
90	111	69	122	74	127	77	130	82	143	86	151	94
100	123	77	136	82	141	86	145	91	159	95	168	104

TABLE A-9. NUTRIENT VALUE OF COMMON FORAGES

Forage	DM %	CP %DM	UIP %CP	DIP %CP	SIP %CP	ADF %DM	NDF %DM	NFC %DM	TDN %DM	Net Energy: Milk Mcal/lb DM	Net Energy: Gain Mcal/lb DM	Fat %DM	Ash %DM	Ca %DM	P %DM
Alfalfa, hay															
-early vegetative	90	23.0	25	75	30	28	38	24.8	66	.68	.42	4.0	10.2	1.80	.35
-early bloom	90	18.0	30	70	29	31	42	27.4	60	.61	.34	3.0	9.6	1.41	.22
-mid-bloom	90	17.0	33	67	28	35	46	25.3	58	.59	.31	2.6	9.1	1.41	.24
-full bloom	90	15.0	40	60	26	37	50	24.1	55	.56	.26	2.0	8.9	1.25	.22
Alfalfa haylage,															
-early bloom	65	18.0	24	76	35	31	42	27.4	60	.61	.34	3.0	9.6	1.41	.22
	50	18.0	22	78	40	31	42	27.4	60	.61	.34	3.0	9.6	1.41	.22
	30	18.0	16	84	55	31	42	27.4	60	.61	.34	3.0	9.6	1.41	.22
Alfalfa (1/2)-grass (1/2)															
-early	50	17.0	29	71	28	33	49	21.9	64	.64	.39	2.8	9.9	.86	.30
-late	50	13.0	35	65	25	40	60	15.5	53	.54	.25	2.2	8.4	.78	.22
Barlage, average	45	9.0	25	75	25	33	60	21.4	63	.64	.26	2.1	7.6	.21	.30
Birdsfoot trefoil,															
-early bloom	90	18.0	30	70	29	33	43	29.5	63	.64	.32	2.1	7.4	1.75	.22
Bromegrass,															
-pasture, spring	25	24.0	20	80	45	30	55	9.0	72	.74	.47	2.6	9.4	.40	.37
-late bloom	90	10.0	40	60	20	43	68	11.3	59	.60	.32	2.3	8.4	.30	.35
Clover, alsike,															
-average	90	14.9	40	60	26	35	46	27.4	58	.59	.31	3.0	8.7	1.29	.26
Clover, ladino															
-pasture	20	22.0	15	85	35	32	36	29.2	65	.67	.44	2.7	10.1	1.35	.31
Clover, red,															
-average	50	16.0	25	75	40	36	46	26.7	55	.56	.26	2.8	8.5	1.53	.25
Corn silage,															
-high in grain	35	8.1	35	65	45	22	42	42.3	72	.73	.47	3.1	4.5	.20	.22
Corn silage,															
-average in grain	35	8.5	30	70	50	26	48	39.5	70	.70	.43	3.0	5.0	.20	.22
Corn silage,															
-low in grain	35	9.0	30	70	55	30	52	33.4	62	.64	.36	3.0	7.2	.34	.19
Corn silage,															
-average in grain,															
with 10 lb urea/T	35	12.0	25	75	65	23	44	39.5	70	.70	.43	3.0	5.0	.23	.22
Cornstover	90	5.9	35	65	55	39	67	18.6	50	.50	.19	1.3	7.2	.57	.10
Oatlage															
-boot	45	14.0	25	75	50	35	58	15.5	61	.59	.34	4.1	8.4	.34	.24
-dough	45	9.0	30	70	45	44	74	5.9	53	.54	.24	4.2	6.9	.37	.17
Orchardgrass,															
-boot	90	15.0	25	75	45	34	61	12.5	65	.67	.40	2.8	8.7	.27	.34
-headed	90	8.4	30	70	40	45	72	6.1	54	.55	.25	3.4	10.1	.26	.30
Peas and oats	50	18.0	28	72	50	30	46	23.5	58	.57	.29	4.0	8.5	.34	.28
Quackgrass	90	11.0	40	60	45	48	79	0.0	52	.48	.20	1.8	8.0	.34	.28

TABLE A-9. NUTRIENT VALUE OF COMMON FORAGES (CONTINUED)

Forage	DM %	CP %DM	UIP %CP	DIP %CP	SIP %CP	ADF %DM	NDF %DM	NFC %DM	TDN %DM	Net Energy Milk Mcal/lb DM	Net Energy Gain Mcal/lb DM	Fat %DM	Ash %DM	Ca %DM	P %DM
Reed canary grass	90	11.0	35	65	40	39	68	11	54	.55	.28	2.7	7.3	.37	.21
Sorghum, silage	30	7.5	30	70	45	38	63	17.8	60	.61	.34	3.0	8.7	.35	.21
Sorghum-sudan grass, silage	30	10.8	30	70	45	42	68	8.6	56	.56	.26	2.8	9.8	.46	.21
Soybean, silage	40	18.2	24	76	35	34	46	23.3	53	.54	.25	2.6	9.9	1.32	.44
Straw, oats	90	4.4	30	70	25	47	70	15.6	50	.50	.19	2.2	7.8	.24	.06
-wheat	90	3.6	30	70	25	54	85	1.8	44	.44	.10	1.8	7.8	.18	.05
-barley	90	4.3	30	70	25	59	80	6.7	49	.49	.24	1.9	7.1	.30	.07
Sweet corn silage, -process residue	30	7.7	30	70	50	34	61	21.2	67	.69	.43	5.2	4.9	.30	.90
Triticale silage, boot	40	17.5	28	72	45	31	55	17.0	60	.61	.34	2.5	8.0	.56	.56
Wheat silage	40	11.9	25	75	45	41	68	10.1	55	.55	.25	2.5	7.5	.27	.27

[1]Values were derived from published and field information compiled by the authors.

TABLE A-10. NUTRIENT VALUE OF ENERGY CONCENTRATES (GRAINS, BY-PRODUCT FEEDS, AND FAT)

	CP %DM	UIP %CP	DIP %CP	SIP %CP	ADF %DM	NDF %DM	NFC %DM	TDN %DM	Net Energy Milk Mcal/lb DM	Net Energy Gain Mcal/lb DM	Fat %DM	Ash %DM	Ca %DM	P %DM	Maximum % of DMI
Barley	14	25	75	20	7	26	56	84	.88	.64	2.1	2.6	.05	.37	55
Beet pulp, plain	10	45	55	30	33	54	31	78	.81	.57	0.5	4.4	.69	.08	30
Corn, ear	9	50	50	16	11	28	58	80	.83	.56	3.7	1.9	.05	.26	60
Corn, HM ear	9	40	60	30	11	28	58	80	.83	.56	3.7	1.9	.05	.26	60
Corn, shelled, ground	10	50	50	12	3	9	75	88	.92	.64	4.3	1.6	.02	.31	55
Corn, HM shelled	10	40	60	45	3	9	75	88	.92	.64	4.3	1.6	.02	.31	55
Corn, cobs	3	65	35	18	35	89	6	47	.46	.11	.7	1.7	.12	.04	10
Corn, gluten feed	26	30	70	50	10	45	19	82	.85	.58	2.4	7.5	.10	.82	25
Cottonseed, fuzzy	24	35	65	35	26	37	11	96	1.02	.74	23.9	4.5	.15	.73	15
Fat	0	0	0	0	0	0	0	177	2.65	2.65	100.0	0	0	0	3
Hominy	12	50	50	19	13	25	55	92	.96	.68	7.7	3.1	.06	.58	60
Molasses, cane	4	0	100	100	0	0	82	72	.74	.54	0.9	13.3	1.19	.11	10
Oats	13	20	80	53	15	32	46	76	.79	.52	5.4	3.4	.07	.39	25
Rye	14	19	81	50	4	9	73	80	.83	.56	1.7	1.9	.07	.36	25
Sorghum (milo)	12	53	47	12	3	9	74	83	.85	.59	3.3	2.1	.05	.35	55
Soybean hulls	12	30	70	20	50	67	14	77	.85	.55	2.1	5.1	.49	.21	10
Wheat	14	20	80	73	8	13	69	88	.92	.64	2.0	1.9	.06	.41	25
Wheat bran	17	29	71	30	15	51	21	70	.77	.44	4.4	6.9	.12	1.32	15
Wheat middlings	19	25	75	40	10	37	34	83	.87	.55	4.9	5.2	.12	1.00	15
Whey	14	10	90	95	0	0	76	81	.90	.60	0.7	9.8	.98	.81	5

TABLE A-11. NUTRIENT VALUE OF PROTEIN CONCENTRATES

	CP %DM	UIP %CP	DIP %CP	SIP %CP	ADF %DM	NDF %DM	NFC %DM	TDN %DM	Net Energy Milk Mcal/lb DM	Net Energy Gain Mcal/lb DM	Fat %DM	Ash %DM	Ca %DM	P %DM	Maximum % of DMI
Bloodmeal	87	70	30	5	0	0	6	66	.69	.42	1.4	5.8	.32	.26	2
Brewers grains, dry	25	53	47	3	24	46	18	66	.69	.42	6.5	4.8	.33	.55	25
Brewers grains,wet	26	45	55	8	23	42	21.3	78	.81	.55	6.5	10.0	.33	.55	25
Canola meal	41	23	77	28	16	27	23	69	.73	.45	1.8	7.5	.67	1.04	*
Corn gluten meal	67	55	45	4	5	14	13	89	1.00	.69	2.4	3.4	.08	.54	5
Cottonseed meal (41)	46	22	59	20	19	26	20	76	.83	.55	1.3	7.0	.22	1.21	*
Distillers grain, corn	25	60	40	15	18	44	16	88	.99	.68	10.3	4.8	.15	.71	25
Feathermeal	85	70	30	9	10	10	0	68	.69	.41	3.2	4	.49	.33	2
Fishmeal	67	80	20	12	0	0	2	73	.79	.50	10.5	20.8	5.65	3.16	4
Linseed meal	38	35	65	20	19	25	29	78	.85	.56	1.5	6.5	.43	.89	*
Malt sprouts	28	53	47	48	18	46	20	70	.72	.45	1.5	4.8	.26	.74	5
Meat and bone meal	50	60	40	15	0	0	6	68	.71	.44	13.7	30.4	12.01	5.82	5
Soybeans, raw	43	20	80	40	10	13	20	91	1.03	.71	18.8	5.5	.27	.65	10
Soybeans, heated	43	48	52	10	10	13	20	91	1.03	.71	18.8	5.5	.27	.65	15
Soybean meal (44)	50	28	72	20	10	12	29	84	.84	.64	1.5	7.3	.30	.68	*
Soybean meal (48)	55	28	72	20	6	9	26	87	.86	.65	1.7	8.0	.33	.73	*
Sunflower meal (28)	31	24	76	30	33	40	20	58	.60	.36	1.2	8.1	.23	1.03	10
Urea	287	0	100	100	0	0	0	0	0	0	0	0	0	0	1

*Add the [illegible]unt needed to balance and meet protein needs.

TABLE A-12. COMPOSITION OF COMMON MINERAL SUPPLEMENTS (DM BASIS)

	Calcium		Phosphorus		Potassium	Magnesium	Sulfur
Supplement	%	g/lb	%	g/lb	%	%	%
Ammonium sulfate[1]	—	—	—	—	—	—	24
Bone meal	31	140	13	59	—	—	2
Calcium carbonate	39	177	—	—	—	—	—
Calcium sulfate	23	104	—	—			19
Dicalcium phosphate	22	100	19	86			
Dolomitic limestone	22	100	—	—	—	10	—
Limestone	34	154	—	—	—	2	—
Magnesium oxide	3	14	—	—	—	56	—
Magnesium sulfate	—	—	—	—	—	20	27
Monoammonium phosphate[1]	—	—	24	109	—	—	2
Monocalcium phosphate	16	72	21	95	—	—	1
Monosodium phosphate	—	—	22	100	—	—	—
Potassium chloride	—	—	—	—	50	—	—
Potassium magnesium sulfate				—	19	12	22
Sodium sulfate		—	—	—	—	—	10
Sodium tripolyphosphate	—	—	25	114	—	—	—

[1]Crude protein equivalency; ammonium sulfate—134 percent, monoammonium phosphate—71%.

TABLE A-13. MINERAL CONTENT OF COMMON FEEDSTUFFS AND TRACE MINERAL SUPPLEMENTS (DRY MATTER BASIS)*

Feedstuff	Cl	Mg	K	Na	S	Co	Cu	Fe	Mn	Zn
	.......................%......................					............ppm x 10,000............				
Barley	0.2	0.1	0.6	0.0	0.2	0.1	7	90	22	38
Corn, ear	0.0	0.1	0.5	0.0	0.1	0.3	3	74	10	25
Corn, shelled	0.0	0.1	0.4	0.0	0.1	0.0	3	57	9	25
Oat grain	0.1	0.2	0.6	0.0	0.2	0.1	11	107	51	45
Linseed meal	0.0	0.7	1.5	0.2	0.4	0.5	28	194	41	36
Soybeen meal	0.0	0.3	2.5	0.1	0.4	0.1	18	247	51	70
Alfalfa, early bloom	0.5	0.3	2.6	0.1	0.3	0.2	4	159	23	13
Bromegrass	—	0.1	1.4	0.1	0.2	0.6	25	91	30	—
Corn silage	0.1	0.2	1.1	0.0	0.1	0.1	3	98	17	12
Timothy	0.5	0.2	1.6	0.2	0.1	0.1	5	140	46	43
Oat hay	0.5	0.3	1.5	0.0	0.1	0.1	15	155	64	39
						................ppm x 10,000...........				
Cobalt carbonate						46.0				
Copper sulfate							25.4			
Iron sulfate								21.8		
Manganese oxide									77.5	
Zinc oxide										36.4

*Abbreviations: Cl = chlorine, Co = cobalt, Cu = cooper, Fe = iron, Mg = magnesium, MN = manganese, K = potassium, Na = sodium, S = sulfur, Zn = zinc, 1% = 10,000 ppm (parts per million).

TABLE A-14. RECOMMENDED NUTRIENT CONTENT OF DIETS FOR DAIRY COWS (DRY MATTER BASIS)

Cow weight (lb)	Milk fat %	Weight gain lb/day	Lactating cow diets — Milk yield, lb/day				
900	5.0	0.5	14	29	44	58	74
1100	4.5	0.6	18	36	55	73	91
1300	4.0	0.7	23	47	70	93	117
1500	3.5	0.8	26	52	78	104	130
1700	3.5	1.0	29	57	86	114	143

	14/18/23/26/29	29/36/47/52/57	44/55/70/78/86	58/73/93/104/114	74/91/117/130/143	Early lact. (weeks 0-3)	Dry pregnant cows	Maximum tolerable levels
Energy								
NE_L, Mcal/lb	0.65	0.69	0.73	0.78	0.78	0.76	0.57	
ME, Mcal/lb	1.07	1.16	1.25	1.31	1.31	1.27	0.93	
DE, Mcal/lb	1.26	1.35	1.44	1.50	1.50	1.46	1.12	
TDN, % of DM	63	67	71	75	75	73	56	
Protein equivalent								
Crude protein, %	12	15	16	17	18	19	12	
UIP, %	4.5	5.4	5.7	6.0	6.3	7.2		
DIP, %	7.9	8.8	9.7	10.4	10.4	9.7		
Fiber content (minimum)								
Crude fiber, %	17	17	17	15	15	17	22	
ADF, %	21	21	21	19	19	21	27	
NDF, %	28	28	28	25	25	28	35	
NDF, % in DM from forage	21	21	21	21	21	21	35	
Ether extract (minimum), %	3	3	3	3	3	3	3	
Added fat (maximum), %	3-4	3-4	3-4	3-4	3-4	3-4		
Minerals								
Calcium, %	0.43	0.53	0.60	0.65	0.66	0.77	0.39	2.00
Calcium, with added fat, %	0.65	0.70	0.75	0.80	0.80-0.90	0.90-1.00		
Phosphorus, %	0.28	0.34	0.38	0.42	0.41	0.49	0.24	1.00
Magnesium, %	0.20	0.20	0.20	0.25	0.25	0.25	0.16	0.50
Magnesium, with added fat, %	0.25	0.25	0.25	0.30	0.30	0.30		
Potassium, %	0.90	0.90	0.90	1.00	1.00	1.00	0.65	3.00
Sodium, %	0.18	0.18	0.18	0.18	0.18	0.18	0.10	
Chloride, %	0.25	0.25	0.25	0.25	0.25	0.25	0.20	
Sulfur, %	0.20	0.20	0.20	0.20	0.20	0.25	0.16	0.40
Iron, ppm	50	50	50	50	50	50	50	1000
Cobalt, ppm	0.10	0.10	0.10	0.10	0.10	0.10	0.10	10
Copper, ppm	10	10	10	10	10	10	10	100
Manganese, ppm	40	40	40	40	40	40	40	1000
Zinc, ppm	40	40	40	40	40	40	40	500
Iodine, ppm	0.60	0.60	0.60	0.60	0.60	0.60	0.25	50
Selenium, ppm	0.30	0.30	0.30	0.30	0.30	0.30	0.30	2.00
Vitamins								
Vitamin A, IU/lb	1450	1450	1450	1450	1450	1800	1800	30000
Vitamin D, IU/lb	450	450	450	450	450	450	540	4500
Vitamin E, IU/lb	7	7	7	7	7	7	7	900

TABLE A-15. RECOMMENDED NUTRIENT CONTENT OF DIETS FOR DAIRY HEIFERS (DRY MATTER BASIS)

	Calf milk replacer	Growing heifers				Maximum tolerable levels
		Calf starter	months of age 3-6	6-12	>12	
Energy						
NE_m, Mcal/lb	1.09	0.86	0.77	0.72	0.63	
NE_g, Mcal/lb	0.70	0.54	0.49	0.44	0.37	
ME, Mcal/lb	1.71	1.41	1.18	1.12	1.03	
DE, Mcal/lb	1.90	1.60	1.37	1.31	1.22	
TDN, % of DM	95	80	69	66	61	
Protein equivalent						
Crude protein, %	22	18	16	14	12	
Fiber content (minimum)						
Crude fiber, %			13	15	15	
ADF, %	—	—	16	19	19	
NDF, %	—	—	23	25	25	
NDF, % in DM from fiber	—	—	17	19	19	
Ether extract (minimum), %	10	3	3	3	3	
Minerals						
Calcium, %	0.70	0.60	0.52	0.41	0.29	2.00
Phosphorus, %	0.60	0.40	0.31	0.30	0.23	1.00
Magnesium, %	0.07	0.10	0.16	0.16	0.16	0.50
Potassium, %	0.65	0.65	0.65	0.65	0.65	3.00
Sodium, %	0.10	0.10	0.10	0.10	0.10	
Chloride, %	0.20	0.20	0.20	0.20	0.20	
Sulfur, %	0.29	0.20	0.16	0.16	0.16	0.40
Iron, ppm	100	50	50	50	50	1000
Cobalt, ppm	0.10	0.10	0.10	0.10	0.10	10
Copper, ppm	10	10	10	10	10	100
Manganese, ppm	40	40	40	40	40	1000
Zinc, ppm	40	40	40	40	40	500
Iodine, ppm	0.25	0.25	0.25	0.25	0.25	50
Selenium, ppm	0.30	0.30	0.30	0.30	0.30	2.00
Vitamins						
Vitamin A, IU/lb	1700	1000	1000	1000	1000	30000
Vitamin D, IU/lb	270	140	140	140	140	4500
Vitamin E, IU/lb	18	11	11	11	11	900

TABLE A-16. FEED EVALUATION FACTORS FOR ESTIMATING DOLLAR VALUE OF FEEDS BASED ON ENERGY (CORN), PROTEIN (SOYBEAN MEAL), AND FIBER (ALFALFA HAY)—PRICES ON AS-FED OR WET BASIS*

		FACTORS		
Feed	**DM**	**Soybean meal**	**Corn**	**Alfalfa hay****
DRY FORAGES:				
Alfalfa—Prime	89	0.191	0.057	0.742
Grade 1	89	0.045	0.067	0.879
Grade 2	89	0.000	0.000	1.000
Grade 3	89	-0.071	-0.080	1.146
Grade 4	91	-0.090	-0.122	1.106
Bromegrass—late veg.	89	-0.116	0.191	0.932
late bloom	89	-0.280	-0.065	1.352
Clover—red—average	89	-0.019	0.053	0.963
Corn—cobs	90	-0.279	0.149	0.982
stover	87	-0.276	0.079	1.059
Oat hay—mature	91	-0.187	0.221	0.912
Orchardgrass—average	89	-0.168	0.038	1.127
Sorghum-sudan—3 ft	89	-0.068	-0.090	1.207
dough	89	-0.174	0.046	1.141
Soybean stover	88	-0.365	-0.147	1.498
Straw—oat/wheat	89	-0.355	-0.066	1.400
Sweetclover hay	87	-0.001	-0.063	0.880
Timothy—immature	89	-0.085	0.141	0.929
mature	89	-0.233	-0.014	1.237
SILAGES				
Corn—well eared	35	-0.059	0.190	0.263
average, 40-60 bu/a	35	-0.054	0.156	0.269
few ears, 5-20 bu/a	35	-0.050	0.113	0.282
stunted	35	-0.046	0.091	0.282
NPN added	35	-0.024	0.116	0.296
Forage sorghum	26	-0.079	0.055	0.321
Oats—boot	30	-0.013	0.010	0.330
dough	32	-0.073	-0.003	0.432
Sorghum-sudan—3 ft	30	-0.023	-0.030	0.407
dough	30	-0.059	0.016	0.384
GRAINS & BYPRODUCTS:				
Barley	89	0.113	0.835	
Brewers grains—dry	92	0.473	0.324	
wet	24	0.123	0.085	
Corn, shelled	89	0.000	1.000	
Corn, ear	87	-0.001	0.882	
Corn gluten feed—dry	90	0.316	0.592	
wet	43	0.146	0.309	
Corn screenings	90	0.184	0.700	
Cottonseeds	93	0.307	0.870	
Cottonseed meal	93	0.949	-0.042	
Distillers-dry gr/sol.	92	0.514	0.531	
Linseed meal	91	0.773	0.122	
Molasses, cane—dry	96	-0.108	0.974	
wet	75	-0.085	0.761	
Oats	89	0.110	0.751	
Sorghum/milo	88	0.068	0.847	
Soy hulls	91	0.081	0.821	
Soybean seed	90	0.785	0.320	
Soybean meal—44%	89	1.000	0.000	
Sunflower meal—28%	93	0.638	-0.325	
Wheat—grain	89	0.110	0.849	
bran	89	0.239	0.603	
mids	90	0.251	0.667	

* See page 34 for example calculation.

** Hay grade 2; 36-40% ADF, 47-53% NDF, 15-18% CP

TABLE A-17. CONVERSION TABLES FOR COMMON WEIGHTS AND MEASURES

Metric conversions

1 ounce = 28.35 grams
1 pound = 454 grams
2.2 pounds = 1 kilogram
1 quart = .946 liter
1 gram = 15.43 grains
1 metric ton = 2,204.7 pounds
1 inch = 2.54 centimeters
1 centimeter = 10 millimeters = .39 inches
1 meter = 39.37 inches
1 acre = .406 hectare

Bushel weights and volumes

Oats = 32 pounds/bushel	25 pounds/cubic foot
Barley = 48 pounds/bushel	38.4 pounds/cubic foot
Shelled corn = 56 pounds/bushel	44.8 pounds/cubic foot
Wheat = 60 pounds/bushel	48 pounds/cubic foot
Corn and cob meal = 70 pounds/bushel	28 pounds/cubic foot
Soybeans = 60 pounds/bushel	48 pounds/cubic foot
Rye = 56 pounds/bushel	44.8 pounds/cubic foot

Weight of one quart of feed

Barley, whole = 1.5 pounds
Barley, ground = 1.1 pounds
Beet pulp, dry = .7 pounds
Corn, shelled, ground = 1.5 pounds
Corn and cob meal = 1.4 pounds
Linseed meal = 1.3 pounds
Molasses, cane = 3 pounds
Oats, whole = 1 pound
Oats, ground = .7 pound
Rye, ground = 1.5 pounds
Soybeans, ground = 1.4 pounds
Wheat, ground = 1.7 pounds

Weight conversions

8 tablespoons = 1/4 pound
3 teaspoons = 1 tablespoon
1 pint = 1 pound
2 pints = 1 quart
4 quarts = 1 gallon = 8 pounds
2,000 pounds = 1 ton
16 ounces = 1 pound
27 cubic feet = 1 cubic yard
1 peck = 8 quarts
1 bushel = 4 pecks

Volume conversion of hay and straw

	Loose	Chopped	Bale (reg)
	lb/cu ft		
Alfalfa	4 to 4.4	5.5 to 7	6 to 10
Non-legume	3.3 to 4.4	5 to 6.7	6 to8
Straw	2 to 3	5.7 to 8	4 to5

Other conversions

1% = .01
1% = 10,000 parts per million (ppm)
1 megacalorie (Mcal) = 1,000 calories
1 calorie (big calorie) = 1,000 calories (small calorie)
1 Mcal = 1 therm

The authors:

James G. Linn is professor and extension animal scientist—dairy nutrition, University of Minnesota.

Michael F. Hutjens is professor and extension dairy specialist, University of Illinois.

Randy Shaver is associate professor and extension dairy specialist, University of Wisconsin.

Donald E. Otterby is professor, dairy nutrition, University of Minnesota.

W. Terry Howard is professor and extension dairy specialist, University of Wisconsin.

Lee H. Kilmer is associate professor and extension dairy specialist, Iowa State University.

North Central Regional Extension Publications are subject to peer review and prepared as a part of the Cooperative Extension activities of the thirteen land-grant universities of the 12 North Central States, in cooperation with the Extension Service–U.S. Department of Agriculture, Washington, D.C. The following states cooperated in making this publication available:

University of Illinois
1301 W. Gregory Drive
Urbana, IL 61801
217-333-2007

Purdue University
301 S. Second St.
Lafayette, IN 47905
317-494-6795

Iowa State University
112 Printing & Publ. Bldg.
Ames, IA 50011
515-294-5247

Michigan State University
P.O. Box 6640
East Lansing, MI 48826-6640
517-355-0240

*University of Minnesota
20 Coffey Hall, 1420 Eckles Ave.
St. Paul, MN 55108-6069
612-625-8173

University of Nebraska
IANR
Comm. and Computing Services
Lincoln, NE 68583
402-472-3023

North Dakota State University
Dept. of Ag. Comm., Box 5655
Fargo, ND 58105-5655
701-237-7881

University of Wisconsin
Coop. Ext. Pub. Distribution, Rm. 245
30 N. Murray St.
Madison, WI 53715-2609
608-262-3346

*Publishing state

BU-0469-F
Reviewed 1996

In cooperation with the North Central Region Educational Materials Project

Issued in furtherance of Cooperative Extension work, Acts of Congress of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture and Cooperative Extension Services of Illinois , Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. Katherine Fennelly, Director of Minnesota Extension Service, University of Minnesota, St. Paul, Minnesota 55108.