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BASIC DAIRY CATTLE NUTRITION

Nutrient Requirements – Deficiency Symptoms

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BASIC DAIRY CATTLE NUTRITION

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DAIRY FARMING is the largest agricultural industry in Michigan. The sale of dairy products and cattle from farms totals about 300 million dollars annually and represents about 35% of Michigan's total agricultural income.

Dairy farming is continually changing to meet new challenges and to maintain or improve its position in the economy. Mechanization of feed handling and group handling of cows have become common practice, resulting in very little attention to the pecularities or habits of individual cows.

Historically, stockmen have observed that certain feeds or feeding practices result in better performance or health of livestock than others. Application of the principles of chemistry, physics and biological sciences to the problems of livestock feeding has allowed scientists to better understand the processes by which nutrients are utilized and to determine the levels of various nutrients required or allowed in the ration to obtain optimum performance and prevent nutrient deficiency symptoms.

Although there are many yet unanswered questions, the science of nutrition is sufficiently well developed to provide practical and useful guidelines for formulating rations and feeding dairy cattle. Application of the specifications in this bulletin will avoid most of the problems caused by inadequate nutrition of dairy cattle in terms of known requirements.

The subject matter of this publication is intended to provide (1) a scientific understanding of dairy cattle nutrition (2) and to interpret and use this as the basis for practical recommendations, guidelines and warnings to the modern, commercial dairy herd manager.

Much of the content is therefore highly technical and presented in scientific language. This is particularly the case in the sections explaining in detail the various steps in the ruminant digestive process. As far as possible, technical terms are defined in the vernacular in the text and are also defined in a glossary. Practical recommendations, it is hoped, will be readily understood.

I. The Ruminant Digestive Process

Structure and Function of the Digestive Tract

BEING RUMINANT ANIMALS, cattle have a unique four-compartment stomach. The first compartment, or rumen, is commonly called the paunch. Poorly developed and essentially non-functional at birth, it develops rapidly when calves are fed solid feeds such as hay and grain. When calves are 4 to 6 weeks old, the digestive processes in the rumen are similar to those of adult cattle.

The Rumen

The rumen functions principally as a combination holding-tank and fermentation vat for ingested feed. In adult cattle, its contents are normally equivalent to about 16% of body weight. Billions of microorganisms, principally bacteria and protozoa, inhabit the rumen contents where they multiply and grow while producing enzymes necessary for the digestion (or breakdown) and synthesis (manufacture) of nutrients for the use of the host animal. No enzymes are known to be secreted into the rumen, or any of the digestive tract prior to the true stomach. Only those produced by microorganisms are responsible for chemical changes occurring in the rumen.

An abundance of saliva, 110 to 130 pounds per day for adult cows, is secreted into the rumen during rumination. Although ruminant saliva contains no enzymes for partial breakdown of starch to sugars as in simple-stomach animals, it does contain both sodium bicarbonate and some urea. These two compounds neutralize the fatty acids produced in the rumen and maintain the pH of the rumen contents at approximately neutral (pH 6.8 to 7.0).

The end products of rumen fermentation are short-chain fatty acids, microbial protein, B-vitamins, vitamin K, and the gases methane and carbon dioxide. Gas production accounts for 13 to 15% of the carbon consumed. The fatty acids are absorbed through the rumen wall into the portal vein and pass directly to the liver.

The Reticulum

The reticulum is the second compartment of the ruminant stomach, and for all practical purposes it functions in conjunction with the rumen. It is much smaller and aids in the rumination (movement of feed), and particularly regurgitation, of the bolus of fibrous feeds up the esophagus to the mouth for chewing of the cud. The opening from the reticulum to the omasum is small and thus retains larger particles in the rumen-reticulum for regurgitation, chewing and more complete fermentation.

The Omasum

The omasum, the third stomach compartment, is characterized by many leaves or plies of tissue. Its primary function appears to be in the absorption of some water and perhaps some nutrients before passing the ingested feed material into the true stomach.

The Abomasum

The abomasum is the fourth compartment, or true stomach, and functions essentially the same as the non-ruminant stomach. It secrets hydrochloric acid and enzymes which break down starch and complex sugars to glucose. It also secretes other enzymes which induce hydrolysis (splitting by addition of water) of microbial protein to simpler protein fractions such as peptides and amino acids.

Upon leaving the abomasum, ingested matter enters the duodenum section of the small intestine where the process of digestion continues. The small intestine is about 130 feet long and 2 inches in diameter. In adult cattle, enzymes secreted by the pancreas enter the duodenum and continue the hydrolysis of protein to amino acids. Bile from the liver also enters the duodenum via the bile duct. Salts in the bile aid in the preparation of fats and fatty acids for absorption. Amino acids, fats, small amounts of glucose, vitamins and minerals are absorbed mainly from the small intestine and small amounts from the large intestine.

The Cecum

The cecum (blind gut) is similar to the human appendix. It is 20 to 30 inches long and 4 to 5 inches wide in the cow and located near the juncture of the small and large intestines. Its function in the fermentation of feed residues is similar to the rumen but is much less important in ruminants. In the horse, rabbit and other non-ruminant plant-eating animals, it is larger in proportion to other segments and plays a significant role in the digestion of fibrous feeds.

Chemical Components of Feeds

Feedstuffs such as hay, silage and grains are composed of chemical fractions which may be utilized as nutrients or converted to usable nutrients during the processes of digestion.

Nutrients are classified into carbohydrates, proteins, fats, vitamins, minerals and water. Feedstuffs vary considerably in their content of these components as shown by examples in Table 1.

Carbohydrates are compounds composed of carbon, hydrogen and oxygen. The more complex carbohydrates, (e.g., starch, cellulose and other fibrous materials) are formed in the plant by condensation or the chemical combining of simple sugars. Glucose is the most common simple sugar. Hydrolysis (splitting by the action of acids or enzymes) of starch, cellulose and similar complex carbohydrates results in glucose units. Glucose is the principal source of energy for most mammals but as explained later, is largely fermented to short-chain fatty acids* in the rumen. Sucrose (table sugar) is a disaccharide (2 sugars) composed of glucose and fructose. Fructose is converted to glucose in the digestive process before being absorbed into the blood stream.

Proteins are the second major class of nutrients in feedstuffs. Proteins contain nitrogen (N), carbon, hydrogen, oxygen and a small amount of sulfur and phosphorus. The crude protein content of feedstuffs is determined by measuring the amount of nitrogen released by chemical treatment of the material. Most proteins contain about 16% nitrogen, thus crude protein equals N% x 6.25. This procedure assumes that all of the nitrogen is contained in protein and, as the term implies, is only a crude determination of protein content without regard to protein quality.

True proteins are composed of smaller units called amino acids. Amino acids (containing N as ammonia) may be considered the "building blocks" from which proteins are formed in plants and animals. Of the 22 different known amino acids, only 10 are known to be essential in the diet of simple-stomach animals. These are methionine, arginine, threonine, tryptophane, histidine, isoleucine, leucine, lysine, valine and phenylala-

** See glossary at end for definition of scientific and technical terms.*

nine. All essential amino acids are synthesized from ammonia by rumen bacteria and protozoa, as discussed later. In addition to true protein, feedstuffs also contain non-protein-nitrogen in enzymes, amino acids, nitrate, nitrites, ammonia and urea.

Minerals and vitamins in feeds may be valuable in maintaining the rumen microbial population as well as in providing the nutrient requirements of the host.

Roughages

Roughages are high in fiber content compared to grains or concentrates. The crude fiber fraction is composed largely of cellulose or similar complex carbohydrates, which are partially digestible by rumen microorganisms. Lignin, which is undigestible, is also found in the crude fiber fraction upon chemical analysis. Lignin increases as forage plants mature, resulting in lower digestibility of the plant material. The corn plant is an exception, however. As the corn plant matures, starch is added to the kernels, resulting in a lower proportion of fiber and higher digestibility and energy value.

Immature hay crops, such as the pre-bud alfalfa shown in Table 1, may be very low in fiber and high in soluble carbohydrates and protein. Such feeds are highly digestible and may act more like concentrates than roughage in the rumen.

Concentrates

Grains and high-protein feeds are known as concentrates because of their high concentration of energy or protein. They are usually low in fiber, compared to roughages. Cereal grains have a high starch content as their main source of soluble carbohydrate and are rich in energy value. The oil meals, (e.g., cottonseed, linseed and soybean meal) are rich sources of protein and comparable to cereal grains in energy value.

Mill feeds, (e.g., wheat bran, middlings and brewer's grains) are intermediate in both fiber and energy values. Because feedstuffs vary so widely in nutrient value, several kinds of feeds may be necessary to balance a ration and provide all essential nutrients.

Energy Metabolism

Rumen Fermentation

Digestible carbohydrate, protein and fat are all energy sources yielding 4, 5 and 9 kcal/g (thousand calories per gram), respectively. Fat is multiplied by (9÷4), or 2.25, to adjust for this extra caloric density when computing total digestible nutrients (TDN). Protein yields about the same metabolizable energy as carbohydrate after subtracting the cost of secreting the excess nitrogen as urea.

TABLE 1—Chemical analysis of feedstuffs showing the variation in nutrient content of roughages and concentrates. (Data are for individual samples and are not necessarily averages.)

Feedstuff	Dry matter	Protein	Crude fiber	Soluble[1] carbohydrates	Fat[2] and wax	Minerals total	TDN[3]	ENE[4]
	%	% Dry matter						MCal/lb
Roughages:								
Alfalfa, Pre-bud, haylage	47	23.8	21	41	4.0	10.9	70	0.63
Alfalfa, 2nd cut, No. 1	90	17.8	31	42	2.7	6.8	59	0.47
Alfalfa-Brome hay, mature	88	15.9	41	36	1.8	6.0	57	0.45
Alfalfa hay stemmy	89	11.2	42	39	1.2	6.2	46	0.37
Timothy hay, avg.	89	7.0	33	50	2.5	5.5	54	0.41
Grass hay, mature, weathered	90	4.1	43	49	1.1	3.0	46	0.37
Corn silage, immature kernels in milk stage	21	8.4	32	53	3.1	4.3	63	0.54
Corn silage, dent stage	30	9.1	20	62	3.4	5.5	68	0.72
Concentrates								
Corn, shelled	87	9.9	3	79	5.1	3.6	93	0.94
Ear corn	86	8.6	9	77	3.7	1.5	85	0.84
Oats	90	13.3	12	65	5.1	4.4	78	0.79
Soybean meal 44%	90	51.2	5	33	4.1	6.2	87	0.88

[1]*Soluble carbohydrates-Nitrogen-free extract.*
[2]*Fat and wax-Ether extract.*
[3]*Total digestive nutrients.*
[4]*Estimated net energy in megacalories per pound of feed dry matter.*

The microbial population in the rumen converts digestible carbohydrate to about 65 molar % (units) acetic acid with two carbons (C2), 20 molar % propionic acid (C3) and 15% butyric acid (C4). These commonly used molar percentages of volatile fatty acids (VFA) overemphasize the nutritional importance of acetic acid because it is total calories of the acids that are burned for energy (Table 2).

About 22% of the carbohydrate calories are lost as methane gas and heat, and 4% are captured into the microbial cells which are later digested by the animal. This 22% loss is the cost for microbial digestion of cellulose and other complex carbohydrates which cannot be digested by the animal. This loss also occurs from ruminal digestion of protein and such carbohydrates as starch, which can be utilized more fully if they bypass the rumen and are absorbed from the intestine.

The retention of calories in useful products can be increased by inducing the rumen microbial population to form more propionic and butyric acids, with a consequent reduction in methane, acetic acid and energy for microbial growth including microbial synthesis of protein.

Feeding more grain, increasing total intake or making the rumen more acid with feeds such as silage (lactic acid) encourage formation of propionic and butyric acids; feeding alkalizing agents (sodium bicarbonate and magnesium oxide) has the opposite effect. Certain chlorinated hydrocarbons and unsaturated fats suppress methane formation, thus encouraging formation of propionic and butyric acids. More than 8% of any fat in the diet slows down ruminal fermentation and increases the amount of unfermented feed reaching the intestine. All of these techniques for decreasing the cost of ruminal fermentation tend to slow down cellulose digestion and microbial synthesis of protein and vitamins. The net benefits derived depend on the ration and the level of production.

Ruminal volatile fatty acid (VFA) production yields the calories required for maintenance, but as intake and production increase, more feed escapes ruminal fermentation, and intestinal digestion becomes more important. At high levels of production, one-half the feed may be digested in the intestines, and utilization of this portion of the feed presumably requires the same vitamin and amino acid supplementation as in non-ruminants. When complex carbohydrates of forage escape rumen fermentation, they can still be fermented to VFA's in the cecum, and these VFA's can account for 5% of the digestible energy.

Beet and citrus pulp are rich sources of pectic substances which are attacked by a different microbial population from those that attack forages with the yield of predominantly acetic acid. Corn cobs are a rich source of pentosans (polymerized five-carbon sugars) which likewise are fermented by a different microbial population. All these bacteria need an adaptation period.

Specific Effects of Rations

Rumen Fermentation

Certain feedstuffs and feeding practices will cause an increase in the rumen microbial population, resulting in the fermentation of a higher proportion of propionic acid and butyric acids and a lower proportion of acetic acid in the rumen.

This process utilizes energy more efficiently for milk production until an optimum balance may be exceeded. At that point, milk production declines, the percent of fat in the milk is depressed and the energy is shifted toward fattening of the animal. Continued long-term feeding of a milk-fat depressing ration may have detrimental effects on the

TABLE 2—Distribution of fermentation products.

	Volatile fatty acids			Methane	Carbon dioxide	Water
	Acetate CH_3-COOH	Propionate CH_3-CH_2-COOH	Butyrate CH_3-CH_2-CH_2-COOH	CH_4	CO_2	H_2O
Molar ratio	65	20	15	35	60	25
Weight %	38	14	13	5	26	4
kcal/g[1]	3.5	5	6	13.3	0	0
Caloric %	35	19	20	18 (waste)	(heat and bacteria)	

[1] *Thousand calories per gram.*

health of the cattle since fat cattle are likely to have a higher incidence of fatty livers, high free-fatty acid levels in the blood, and a higher incidence of ketosis. Mineral metabolism may also be disturbed. The health problems are most likely to occur at or near calving time when the stress on the animal is most severe.

Roughage for Rumination

Fibrous feeds aid in the rumination process by stimulating rumen movements, chewing of the cud and subsequent stimulation of salivary flow. Saliva contains sodium bicarbonate (baking soda) and a small amount of urea which aid in buffering the rumen contents to maintain a normal rumen pH.

Fiber action in the rumen is not completely understood but it is known that rations low in fiber or lacking the fibrous characteristics of roughage generally result in a low milk fat test. Rations lacking in fiber or bulk apparently contribute to the occurrence of displaced abomasum and other digestive disturbances.

Roughage Level

The proportion of roughage required in the ration depends on the fiber content and physical form of the ration. When baled hay is fed, 35 to 40% of the ration dry matter as hay may be sufficient to maintain normal rumen function and a normal fat test. This amounts to 1.25 to 1.50 pounds of hay or its equivalent as silage per 100 pounds of body weight of the cow to maintain normal rumination. Fifteen percent (15%) crude fiber in the total ration dry matter is the minimum acceptable level under these conditions.

Immature forages such as lush immature pasture, hay and haylage harvested prebud may be low in fiber and often contribute to a low milk-fat test. Again, fineness of chopping and level of concentrates fed play an integral part in determining the effect on rumen fermentation and milk and fat production.

Grinding of the roughage, grinding and pelleting, or chopping forage for silage too finely and feeding it as the only roughage will cause a drop in milk fat even though the ration contains 15% or more fiber. Thus, the physical form of the ration is important for maintaining optimum conditions in the rumen. Finely chopped feeds may pass out of the rumen too rapidly for sufficient fermentation to occur and fail to stimulate normal rumination.

Silages commonly contain lactic acid equivalent to 5 to 10% of their dry weight, and modern corn silage may contain half or more shelled corn on a dry weight basis. Feeding silages as the only forage with high levels of grain tends to reduce the rumen pH and thus encourages growth of lactic acid-producing bacteria and reduces the population of acetic acid-producing organisms. Lactic acid is converted to propionic acid and may contribute to a low milk-fat test problem under some conditions.

Dryer silages tend to contain less lactic acid and are less likely to contribute to a low test unless chopped too finely.

Feeding excessive amounts of grain will depress the appetite for roughage and result in a low milk-fat test. Excessive grain in relation to the amount of roughage and the fibrous character of the roughage are nearly always involved in low fat-test problems.

Heat-processed grains and pelleted grains will contribute to a low test at a lower level of grain feeding than do ground grains that have not been heated. Gelatinization of the starch occurs when some grains are heated to certain temperatures, and this starch is apparently converted to a higher proportion of propionic acid during fermentation in the rumen. Feeding heat-processed grains may increase feed efficiency and stimulate milk flow or fattening under some conditions, but the level of feeding without causing fat depression is more critical than otherwise.

Milk Fat Test

Low milk-fat test problems are corrected by: (1) Reducing the amount of grain fed and (2) increasing the amount of roughage consumed by cattle. Where silage or haylage is fed as the only roughage, feeding 5 to 10 pounds of long or baled hay per cow daily will normally help correct the problem.

Increasing the fiber content and bulkiness of the grain ration by substituting 10 to 20% of light feeds such as oats, ear corn, beet pulp or wheat bran may also help maintain a normal test where other factors in the ration are critical. Feeding concentrates and roughages more frequently or mixing roughages and concentrates may also be helpful.

Feeding buffering agents in the grain ration has been effective in preventing low milk-fat test when test-depressing rations were fed experimentally. Including 1 to 3% sodium bicarbonate and 0.5% (10 pounds per ton) magnesium oxide, or 10 to 15% delactosed whey in the grain ration may help prevent the low test. These compounds are less effective once the low test has occurred. Feeding more hay and less grain has been most effective in returning low test to normal under farm conditions.

Lactic Acidosis

Abrupt increases in the amount of concentrates fed to cattle cause a rapid drop in rumen pH and create a condition of lactic acidosis. Lactic acid-producing bacteria work faster and tolerate a greater acidity than other rumen bacteria. Feeding large amounts of fermentable carbohydrate thereby stimulates formation of D and L lactic acids, thus acidifying the rumen and favoring additional production of lactic acid (see Figure 1). Some antibiotics also favor lactic acid production. If the increase is not too severe the ruminal microorganisms will increase their conversion of lactic to other volatile fatty acids such as propionic, acetic and butyric acid, and the animal will recover. Drenching with about 1 pound of sodium bicarbonate alkalizes the ruminal contents and inhibits further production of lactic acid.

Accumulation in the blood of D-lactate, which animals cannot use, is eventually fatal in severe or acute cases of lactic acidosis.

Chronic ruminal acidity and lack of rumination associated with finely ground feeds or lack of roughage eventually causes rumenitis and ulceration or other ruminal changes which permit entry of pathogenic microorganisms and cause liver damage.

Grain should be increased only at the rate of 1 to 2 pounds per head daily unless the rumen is partially adapted to concentrate feeds.

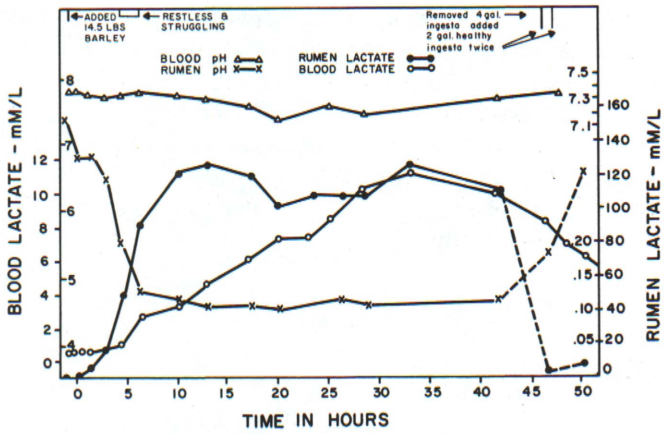


Figure 1. Lactic acidosis in a Holstein steer weighing 290 pounds (R. H. Dunlop).

Displaced Abomasum

Displaced abomasum (DA) is a disorder of cattle in which the abomasum (fourth or true stomach) becomes distended with gas, fluid or both and migrates to an abnormal position, most commonly to the left and upward, coming to rest between the rumen and the abdominal wall on the left side. About 86% of the cases occur in cows within two weeks after calving, although it occasionally occurs in bulls and heifers. Predisposing factors are pregnancy, the act of calving or the conditions associated with calving, although these probably are not the cause of DA. One out of eight cases involves a right abomasal displacement. The disorder is usually corrected by surgery.

Feeding a high proportion of concentrate (grain mix) in the ration of the dry cow and immediately after calving substantially increases the incidence of displaced abomasum. High levels of grain can slow down the action of the abomasum and can cause increased gas production in the abomasum. Experimentally, reduced abomasal contractions also occur when the volatile fatty acids produced in the rumen of cows fed high grain rations are injected into the abomasum of other cows. Increasing too rapidly the amount of grain fed can also produce an acid rumen and temporary off-feed conditions.

Experiments at Purdue University indicate that cows fed roughage consisting of half alfalfa-half corn silage and 25% of the daily ration as concentrates had no displaced abomasum. But when the concentrate was increased to 40%, DA occurred in 16% of the cows. Forty percent of the cows had DA when the ration contained 55 or 70% concentrate.

Modern corn silage normally contains one-half grain (dry basis) and must be considered a high-energy feed. Limiting corn silage to one-half or less of the ration dry matter should be a first step toward reducing the incidence of displaced abomasum and will reduce the energy intake to help avoid excessive fatness at calving.

In a California experiment, 11 cases of DA occurred in 46 cows fed a complete feed mixture, free choice, of 40% chopped alfalfa hay and 60% concentrates, beginning 4 weeks before calving. This concurs with on-farm observations that DA occurs in herds fed hay as well as those fed silage if an excess of concentrate is fed.

Forages that are chopped extremely fine and high moisture silages that are more acid than normal may also contribute to reduced motility and abomasal displacement.

Dry cows fed high energy rations tend to reduce feed intake quite dramatically a few days prior to calving. Since this reduced rumen volume, combined with the empty abdominal space after calving, provides more room for the abomasum and other organs to migrate, it may be a contributing factor to displacement.

Both hay and good quality haylage are normally bulky, fibrous and low in energy content and are the first choice as roughages for the dry cow to avoid post-calving disorders.

Other Disorders

Other post-calving disorders are partly related to the energy and fiber content of the ration of the dry cow and immediately after calving.

Metritis, Retained Placenta

Metritis (infected uterus) and retained placenta are observed frequently in herds that are excessively fat at calving time as a result of free choice feeding of high levels of grain or corn silage during the dry period.

In the Purdue experiments cited above, 9 of the 10 cows with displaced abomasum also had metritis and five of these cows had a retained placenta. All 9 of the cows with DA received 40% or more concentrate in their ration. Among the 33 cows that did not have a displaced abomasum, there were only 6 cases of metritis and 8 of retained placenta.

An experiment at Michigan State showed that feeding grain up to appetite, starting 3 weeks before calving, increased the incidence and severity of mastitis after calving, mammary edema and milk fever in heifers and cows compared to controls that were fed only hay.

Fat Cow Syndrome

Fat cows, or those receiving high energy rations, apparently have low resistance to infections. There is some concern that deficiencies of vitamin A, D and E, selenium and other unidentified factors may increase susceptibility to these conditions by affecting the integrity of tissues, smooth muscle motility and contraction of the organs involved.

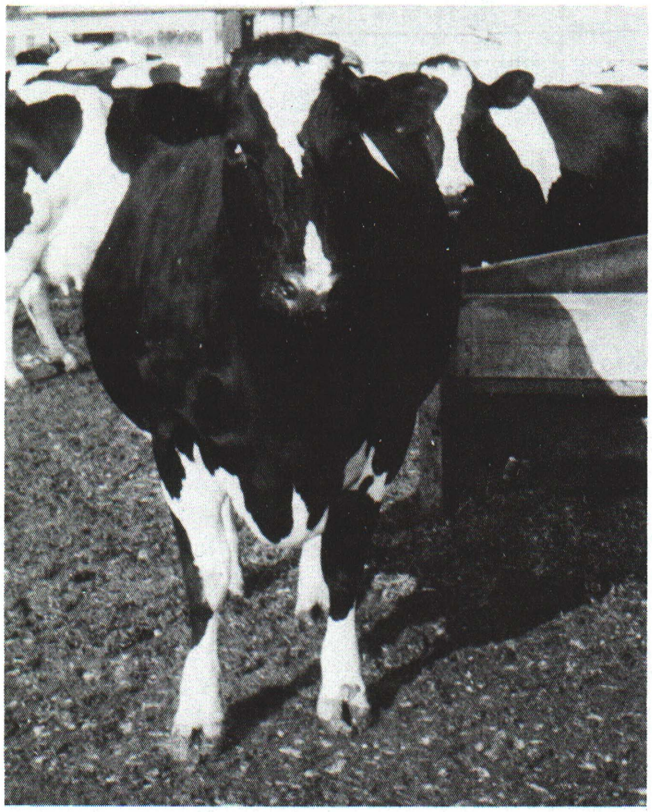
On post mortem examination, the liver of cows affected with the fat cow syndrome is so heavily infiltrated with fat that it is pale in color and often will float in water.

On-farm experiences, supported by the research cited above, strongly suggest the desirability of providing hay or otherwise nutritionally balanced low energy rations for the dry cow to prevent many post-calving disorders.

Utilization of Fermentation Products

Acetic acid (acetate) produced in the rumen is used principally by the mammary gland for energy, for synthesis of milk fat and milk proteins. Acetate is also used for energy in muscle tissue, and excesses may be deposited in adipose (fat stores) tissue as body fat. Some acetate is also converted to ketones in the liver.

Propionic acid is converted to glucose by the liver and reaches the other tissues in that form. Glucose derived from (1) dietary starch which bypasses the rumen, (2) propionic acid and (3) amino acids must be sufficient to form all of the milk lactose with at least 10% left over to meet the needs of the other tissues. Milk contains about 4.0% lactose and thus the glucose drain is heavy in early lactation.



The fat-cow syndrome — such cows are susceptible to calving difficulties and post calving disorders, such as milk fever, ketosis, and metritis. They also tend to have poor resistance to infectious diseases.

Ketosis

If the glucose needs are not met, excessive fat is mobilized from adipose tissue and converted to ketones in the liver and the cow gets ketosis (toxic levels of ketones in the blood). Any extra stress such as other disease or indigestion can trigger ketosis during early lactation. Fat cows are particularly more susceptible because fatness depresses appetite and the extra fat increases the potential for ketone production. Once started, ketosis also suppresses appetite, and the disease becomes self-accelerating until reduced milk production reduces the glucose drain, or the cow is weakened until death. About half of the cows in the high-producing herds go through borderline ketosis in early lactation and may recover without treatment or become clinical cases depending on other factors. About one-third of the cases are secondary to some other condition such as metritis or mastitis.

Prevention

Prevention of ketosis requires practices that stimulate the appetite or feed intake during the ketosis-susceptible period. Providing palatable feeds, frequent feeding and offering enough grain to meet energy requirements and increase the glucose supply are measures for preventing ketosis after calving. Feeding programs that tend to produce more ruminal propionic acid, and/or starch by-passing the rumen are desirable for cows susceptible to ketosis because they increase the supply of blood glucose, even though such rations may cause a lower milk fat test during that period. Limiting the energy intake of dry cows to avoid excessive fatness results in less ketosis and heartier appetites after calving.

NICOTINIC ACID

Nicotinic acid, a B-vitamin, administered intraruminally by capsule in therapeutic doses, suppresses fat mobilization and blood levels of free fatty acids and ketones. Wisconsin researchers have successfully treated cows with clinical and subclinical ketosis by administering nicotinic acid in four doses of 40 grams each at 2-hour intervals over a 6-hour period. The dosage is approximately 60 milligrams per kilogram of liveweight. After a 2-day lag there was a distinct improvement in milk production and appetite accompanied by increased blood glucose and decreased ketones and free fatty acids. Further research is needed to determine the mode of action and overall effects of nicotinic acid before being recommended for general use.

Other Treatments

Other treatments aimed at increasing blood glucose levels include feeding ¼ to ½ pound daily of sodium propionate and drenching with propylene glycol. Propylene glycol bypasses the rumen and is converted to glucose in the liver.

Feeding of sucrose (sugar and molasses) is essentially ineffective in preventing ketosis because it is fermented in the rumen to approximately equal parts of propionic and butyric acids. While the propionic acid is converted to glucose, the butyric is converted to ketones in the liver which offsets any benefits. Only the sugar that by-passes rumen fermentation by feeding 2 to 3 pounds daily is likely to be helpful.

Early detection of ketosis is essential in any control program. Since ketones usually appear in the milk before other symptoms occur, testing the milk for ketones during early lactation will facilitate early treatment. Typically, ketosis usually appears 10 days to 6 weeks after calving. The average time is about 3 weeks after calving. Other problems should be suspected when ketosis occurs outside of this period.

Nitrogen Metabolism

Nitrogen is consumed in two basic forms, pre-formed protein and non-protein nitrogen. Ammonia, which is derived from both forms is utilized by the microorganisms in the rumen for synthesis (manufacture) of microbial protein. The microbes (bacteria and protozoa) pass into the abomasum and small intestine where their proteins are hydrolyzed to amino acids and finally absorbed into the blood stream. This microbial protein contains all of the essential amino acids.

Microbial cell formation is equivalent to 12 to 15% of the material fermented in the rumen. The cell material contains about 65% crude protein of which 80% is digested, with only 15 to 20% passing into the feces. Thus, microbial protein digested by the animal is equivalent to 6 to 8% of the dry matter digested in the rumen.

Assuming a cow consumed 40 pounds of dry matter per day which is 65% digestible, then the digested dry matter is 26 pounds and 6 to 8% of that (1.6 to 2.1 pounds) is digested and absorbed protein from microbial sources.

Non-protein-nitrogen compounds such as urea, ammonia and nitrates may supply up to 20 to 30% of the total nitrogen in the ruminant diet.

[1]Ketotest, The Denver Chemical Manufac. Co., Stamford, Conn.

Synthesis of microbial protein is a major source of protein and accounts for about half the total protein utilized by high-producing cows.

Some of the factors influencing the conversion of dietary nitrogen to microbial protein are: (1) the time spent by feed particles in the rumen (the longer the time the greater the conversion); (2) the resistance of dietary nitrogen to ruminal degradation and release of ammonia; (3) availability of nitrogen (nitrogen must be present in adequate quantities); (4) energy available for rumen fermentation; and (5) presence of growth factors or other nutrients that specifically influence rumen bacteria and the population of rumen microbes. Some non-protein nitrogen normally occurs in all feeds and may comprise from 5 to 50% of the total nitrogen in alfalfa, grasses or corn silage.

Non-protein nitrogen such as urea, ammonia and nitrates can be advantageously added to the diet and may comprise 20 to 30% of the total dietary nitrogen. Excessive amounts of non-protein nitrogen may result in rumen ammonia concentrations higher than can be efficiently utilized by rumen microbes and result in high levels of ammonia in the blood. Small increases in blood ammonia are converted to urea in the liver and may increase the blood urea nitrogen (BUN) levels slightly until cleared from the blood by the kidneys and excreted in the urine. Excessively large doses of non-protein nitrogen may result in ammonia toxicity.

Amino acids absorbed in the blood stream are utilized for building body proteins (muscle, cell walls, hair and hoofs), for synthesis of milk proteins and of enzymes. Excessive protein is hydrolyzed to an energy fraction (the carbon chain) and urea which is either excreted by the kidneys or recycled into the rumen via the saliva. Normally about 15% of the total absorbed nitrogen is recycled into the rumen as urea through the saliva. This process serves as a very efficient protein-sparing mechanism when rations are low in protein.

Nitrates

Plants normally take up nitrogen from the soil in the form of nitrates. The nitrate (NO_3) is normally converted rapidly to ammonium ion (NH_4+) and then to amino acids for formation of plant proteins. When the amount of nitrate absorbed from the soil is greater than the amount the plant can convert to amino acids, some nitrate may accumulate, generally in the lower parts of the plant. Heavy application of nitrogen fertilizer or manure and severe drought or other factors which reduce plant metabolism will tend to cause some accumulation of nitrates.

Analysis of several hundred forage samples (mostly chopped corn, corn silage and alfalfa) indicates only about 3% of the samples contained more than 0.5% (½%) nitrate on a dry basis, even in drought years. Sixty percent contained less than 0.05% nitrate, 20% from 0.05 to 0.1%, 15% from 0.1 to 0.3% and 2% contained 0.3 to 0.5% nitrates. Occasionally plants will contain as much as 5% nitrates, dry basis. Pigweed, lambsquarter, ragweed and other weeds may accumulate very high levels of nitrate but generally comprise a small percent of the diet.

Safe Consumption Limits

Numerous studies indicate that cattle can safely consume nitrates equivalent to no more than 2% of the total dry matter of the ration, or approximately 20 grams of nitrate per 100 pounds of body weight. Some studies show no effect from even higher amounts when the nitrate intake was gradually increased over a period of weeks, allowing the cattle to become adapted to nitrates.

Since forages normally constitute only 40 to 60% of the total diet of lactating cattle, the nitrate content of forages must be in the order of 3 to 4% of the dry weight to be considered hazardous to the health of cattle under most conditions.

The nitrate content of feeds may be expressed on several different bases on laboratory reports and must be converted to nitrate ion (NO_3) to be meaningful. Table 3 shows the conversion factors for comparing nitrate when different methods of reporting are used.

TABLE 3—Conversion factors necessary for comparing nitrates using different methods of reporting.

Method of expression	Chemical designation	To convert to nitrate multiply by:
Nitrate	$-NO_3$	1.0
Nitrate-nitrogen	NO_3-N	4.4
Potassium nitrate	KNO_3	0.6
Sodium nitrate	$NaNO_3$	0.7

Nitrate levels in feed and water are frequently reported in parts per million (ppm). To convert ppm to percent, move the decimal point four places to the left or vice versa.

Example: 5500. ppm = 0.5500% or 0.55%
550. ppm = 0.0550% or 0.055%

Nitrates (NO_3) are normally reduced successively to nitrites (NO_2) to nitrous oxide (NO) and then to ammonia (NH_4) in the rumen The chemical process is as follows: $NO_3 + 10\ H^+ + \mathit{enzyme} \rightarrow NH_4^+$ 3 H_2O (water).

This reaction occurs much faster when grain is in the diet and when the rumen is adapted to the presence of nitrate.

The ammonia is utilized by bacteria and protozoa for synthesis of microbial protein as described earlier.

If the nitrate content is sufficiently high, and conversion to NH_4^+ is slow, then a major part of the NO_3 is reduced to NO_2 (nitrite), and some of the NO_2 and NO_3 may enter the blood stream. Nitrate is excreted in the urine but NO_2 may displace the oxygen from some of the hemoglobin of the blood resulting in methemoglobinemia. This reaction results in dark colored blood (black-coffee colored) when a substantial amount of methemoglobin is formed. If enough is formed, the animal will die from lack of oxygen. The brownish discoloration of blood is positive evidence of nitrate poisoning in a live animal, but not in a dead animal.

Animals can tolerate some methemoglobin in their blood without harm, and they possess an enzyme, methemoglobin reductase, for converting methemoglobin back to hemoglobin. Methemoglobin levels normally must approach 60 to 90% of the hemoglobin to be lethal. Cattle fed high levels of nitrates over a long period of time tend to adapt to the lower oxygen-carrying capacity of the blood by increasing the concentration of red cells (erythrocytes) in the blood.

Signs of Toxicity

Toxic levels of nitrates (over 2% of the diet) may result in peak levels of methemoglobin about 4 hours after feeding. Labored breathing, frothing at the mouth, and brownish to bluish-grey color of the non-pigmented skin and mucous membranes are symptoms of nitrate toxicity. Pregnant cows may abort when the oxygen-carrying capacity of the blood is seriously reduced.

Recent studies indicate that feeding high levels of nitrate has no effect on the vitamin A or thyroid status of cattle when adequate carotene, or vitamin A, and iodine are in the ration.

When feeds are known (by laboratory analysis) to contain high levels of nitrate, they can be fed in limited quantities or diluted with other ingredients to a safe level of 2% or less nitrate in the dry ration.

Nitrate-Urea Relationships

Both urea and nitrate (at least the small amount of nitrate normally contained in feeds) are degraded to ammonia in the rumen and utilized by microbes for formation of bacterial protein. Several experiments have attempted to determine the effects of feeding high levels of nitrate or nitrate-containing feeds when urea was contained in the diet.

Missouri researchers fed two lots of sudangrass hay containing 0.5% and 5.0% potassium nitrate to milking cows being fed a grain ration containing 2% urea fed at 80% and 110% of energy requirements. No differences were detected in milk production, and only slight, non-significant differences occurred in methemoglobin content of the blood. High nitrate feeding resulted in slightly higher blood-urea nitrogen (BUN) levels (14.7 vs 12.1 milligrams per 100 milliliters) and higher excretion of nitrate in the urine. Urinary nitrate was highest from cows fed the low energy-high nitrate ration. High nitrate-high energy resulted in slightly higher NPN in the milk than low energy-high nitrate.

These results indicate that feeding forage containing 5% KNO_3 (potassium nitrate with 3% NO_3) had little effect on blood and milk components and no effect on milk production. Any excess of protein in the diet will tend to increase BUN and urinary NPN levels.

Similarly, addition of 1% KNO_3 to a feedlot ration using urea with corn silage or shelled corn had no effect on animal performance, compared to soybean meal in Minnesota experiments.

The small amount of nitrate normally contained in forages and the considerable capacity of ruminants to utilize nitrates in the diet make nitrates of little significance in ruminant rations. Exceptions exist in rare occasions when the nitrate level may exceed 2% of the ration dry matter, and can cause acute toxicity symptoms.

Non-Protein-Nitrogen

As mentioned, rumen microorganisms use simple, nitrogenous compounds for building their body proteins. These proteins are digested and converted by the host animal to meat and milk. This action, coupled with the ability to digest plant structural material high in cellulose (indigestible to humans and other simple-stomach animals), gives the ruminant its unique capacity to convert otherwise unusable materials into high-quality human food.

Of the numerous non-protein-nitrogen (NPN) studies with ruminants, only a few have used high-producing dairy cows, which quantitatively require more protein and can derive the greatest potential savings from using NPN.

Urea

Urea is the most widely accepted NPN source, and its use for ruminants has rapidly increased. Although used successfully at low levels, it is unpalatable (has an undesirable taste) to cattle when used at concentrations greater than 1 to 1.5% of the grain ration.

Urea is highly soluble in water, and upon contact with the enzyme urease in the rumen, ammonia is released, which can then be incorporated into microbial protein. A decreased solubility and ammonia release rate may partially explain why pelleting urea and alfalfa meal (in Ohio studies), or combining with gelatinized starch, as reported by Kansas workers, gave improved results.

Corn silage is a convenient carrier for urea, distributing the intake over the entire day and allowing for more efficient use of the urea nitrogen compared to including the urea in concentrate, which is fed twice daily and consumed in relatively short periods. Up to 30% of the total nitrogen for high-producing cows can be provided from the urea added to corn silage; whereas in some experiments the limit was about 20% when all the urea was furnished through concentrate. Sorghum and small grain silages are also satisfactory vehicles for urea.

Another advantage for adding urea or other NPN sources to the silage is greater flexibility in feeding cows according to production. Low producers in the latter stages of lactation do not depend on high levels of grain to meet their protein requirement. Using corn silage as their main nutrient source when it contains adequate protein will reduce feed costs.

Urea-Treated Corn Silage

Experiments at Michigan State University and elsewhere have shown that urea added to corn silage at the time of ensiling is efficiently utilized as a nitrogen source for milk production. Normally corn silage (dry matter) contains 8 to 9% crude protein. Addition of 10 pounds of urea per ton of silage as ensiled increases the crude protein content to 12 to 13% of the dry matter so that approximately 30 to 40% of the total crude protein in urea-treated silage comes from added urea. Shelled corn, ear corn and other cereal grains are low in protein; therefore, additional protein must be provided by the concentrate to raise the protein content of the total ration to 14 to 15% of the dry matter consumed (12 to 13% protein air dry, 90% dry matter.) If urea has been added to corn silage to be fed as the main source of roughage, this additional protein should be provided from natural protein sources such as soybean meal or legume hay.

TABLE 4—Characteristics of corn silage and urea corn silage used in MSU feeding experiments.

Silage characteristics	No Urea	Urea 10 lb/ton	Urea 15 lb/ton
Dry matter recovered % [1]	98.0	97.8	94.8
Dry matter %	34.8	34.1	34.5
Crude protein % of dry matter	8.8	12.8	13.9
Ammonia-N (% of total N)	8.8	16.1	25.3
Urea-N (% of total N)	9.9	21.2	24.4
Urea + NH_3 (% of total N)	18.7	37.3	49.7
Silage pH	4.08	4.17	4.24

[1]*Percent of total dry matter ensiled in 12′ x 50′ concrete stave silos.*

TABLE 5—Feed consumption and performance of cows fed corn silage (low protein), urea-corn silage and corn silage-soybean meal rations.

Rations				
Roughage	Corn silage	Urea-corn silage	Urea corn silage	Corn silage
Concentrate	corn	corn	corn-soy	corn-soy
Protein, total ration %	8.5	10.5	12.5	13.6
Feed Intake				
Corn silage/day, lb	42.0	50.0	56.0	56.0
Corn silage dry matter/day, lb	14.5	16.8	19.1	19.7
Total dry matter/day, lb.	29.5	31.8	36.6	33.7
Crude protein intake, lb	2.4	3.6	5.3	6.0
Nitrogen excreted in milk + urine, % of intake	118.0	111.0	91.0	98.0
Performance				
Milk/cow daily, avg. lb	42.2	52.2	58.1	56.5
Persistency (% of pre-experimental production)	67.3	81.4	91.2	87.6
Body weight change/day, lb	− 1.1	− .2	+ .4	+1.1

Protein Deficiency and Performance

The importance of adequate crude protein in the ration and the benefits of using both urea and natural protein to supplement urea corn silage fed to high-producing cows are shown in Fig. 2, p. 16. Protein deficiency is more obvious in lactating cows than other cattle eating the same feed because of the higher protein requirement for milk production. Symptoms include low milk production, lack of appetite, and emaciation (severe loss of body weight).

In experiments at MSU, one group of cows producing an average of 65 pounds of milk per day was fed a low protein ration (8.8% protein) composed of only corn silage and shelled corn (minerals and vitamins were included in all rations, see Tables 4 and 5.) These cows declined very rapidly in feed consumption, milk production and body weight, and at the end of the 70-day experiment they averaged only 33 pounds of milk per day. Digestion and nitrogen balance studies show that the feed was poorly digested and the small reserves of body protein were soon depleted when cows were fed this protein-deficient ration.

A second similar group of cows was fed urea-treated corn silage (10 pounds urea per ton) and shelled corn. This ration contained about 10% protein, which was still deficient in terms of standards. Nevertheless, this group produced 10 pounds more milk per cow daily than those fed the control low-protein ration. These results clearly demonstrate that urea was efficiently utilized as a source of protein added to a low protein ration.

A third group fed a higher level of urea in corn silage (15 pounds urea per ton) and shelled corn, making the total ration 11% protein, produced only slightly better than those fed the lower level of urea in a 10% protein ration.This ration was still deficient in protein but indicated that the higher level of urea was not significantly beneficial. Data on this third group are not shown in Table 5.

A fourth group fed urea corn silage (10 pounds urea per ton) and a 12% protein grain ration composed of shelled corn and soybean meal (total ration dry matter 12.5% protein) produced nearly 6 pounds more milk per cow daily than those fed the 11% ration containing only urea. Milk production averaged 16 pounds more per cow daily than for the cows fed the unsupplemented low protein ration. In fact, cows fed the urea-corn silage and 12% corn-soy ration produced somewhat better than a similar group fed untreated corn silage and an 18% corn-soy ration.

Analysis of the data indicates that this difference in production occurred among the lower-producing cows in the groups. This suggests that the urea-corn silage provided protein from roughage more nearly adequate for the lower-producing cows than did the untreated silage since the protein intake of this group was reduced when the amount of grain fed was limited according to production requirements for energy.

The economic benefit of feeding urea-corn silage and the 12% corn-soy ration is revealed in the returns above feed cost from the above experiment. This group returned $2.32 per cow daily above feed cost compared to $2.10 for the group fed untreated silage and the 18% protein corn-soy ration, and $1.68 per cow daily from those fed the unsupplemented low-protein ration.

The main reason for using urea, or other non-protein nitrogen sources is to reduce feed cost and increase returns above feed cost. Low protein rations, such as corn silage and grass hay, require considerable protein supplementation and provide the greatest opportunity to increase returns by properly using urea and other non-protein nitrogen supplements.

Urea in Concentrates

Urea can be included in grain rations to provide part of the nitrogen requirements for cattle. Many commercial protein supplements contain some urea. Urea is unpalatable to cattle when the concentration in the grain ration is too high, and for that reason may reduce grain consumption or increase the amount of time required for eating the grain. Grain rations containing more than 1.5% urea are generally less palatable than those containing less urea unless the urea taste is masked by adding molasses. Grain rations containing up to 2.0% urea (40 pounds/ton) can be satisfactorily utilized, providing the acceptability to cattle can be maintained. Palatability may become important even when as little as 1% urea is contained in the grain ration if fed in a milking parlor where eating time is limited.

Addition of 3 to 10% wet molasses or 2% dry molasses notably improves the palatability of urea.

Liquid protein supplements such as urea-molasses mixtures are available in some areas and can be used to replace natural protein supplements when the urea level is limited to about 1.5 to 2% of the grain ration, and such supplements are competitively priced. Blending liquid supplements with silage or grain is desirable so that the amount of urea fed can be controlled within the recommended limits.

Commercial Protein Supplements

The protein contributed by urea in commercial protein supplements is expressed on the feed registration tag as percent protein-equivalent from non-protein nitrogen (NPN). This can be converted to percent urea by dividing by 2.81. Protein-equivalent from NPN ÷ 2.81 = percent urea.

Protein supplements vary considerably in their urea content. Therefore, one should calculate the amount of urea added to a ration by commercial supplements to avoid an excessive amount. This is particularly important when urea corn silage is the main source of roughage. Also, where urea-corn silage is fed in limited quantities, a higher concentration of urea can be contained in the grain ration without exceeding the acceptable limits of urea.

Practical Limits

Animal performance may be less than desirable when the urea intake exceeds about 0.027 pounds of urea per 100 pounds of body weight. This amounts to approximately 0.8% of the total ration dry matter, or 0.35 pounds (160 grams) urea per day for a 1,200-pound cow. This is approximately 1 pound of protein-equivalent from urea.

The maximum amount of urea that can be contained in grain rations and remain within the above limitations is shown in Table 6. Note that urea should not be added to grain rations when corn silage containing 10 pounds of urea per ton is the only forage fed. When feeding other forages (hay or the equivalent amount of haylage, silage or other forages containing no urea), the intake of corn silage and urea is reduced proportionately; thus, urea can be included in the grain ration at the rate corresponding to the amount of such feeds fed as shown in Table 6.

Adapting to Urea

Cattle and the rumen microbes require about 3 weeks to get fully adapted to using urea. Start with a low level (about 1/3 of the final amount) and increase the urea content gradually in subsequent batches until the desired level is reached. Cattle may eat grain rations more slowly until they are accustomed to the urea.

Avoid Toxicity

Complete and thorough mixing of urea in the other ingredients is absolutely necessary to avoid accidents that cause fatal urea toxicity.

1. Never feed urea or a urea-containing protein supplement without diluting it by mixing completely in the grain ration or other feed. One-fourth pound of urea is enough to cause toxicity if cattle are not accustomed to urea or if it is the only feed consumed. Cattle can consume much larger amounts after they have become accustomed to it and are kept on a urea ration continuously. Cattle can lose their adaptation to urea within 3 to 4 days after urea is withdrawn.
2. Never feed a ration containing over 2% urea.

TABLE 6—Maximum urea allowable in grain rations for dairy cattle fed urea-corn silage and other forages.

Urea corn silage fed free-choice (10 lb urea added per ton silage)				Corn silage (no urea added) Other forages
	Maximum in grain ration			
Hay-Equivalent[1] of legume or grasses	Urea		Prot. Equiv.[2] from NPN	Maximum in grain ration
lb/day	%	lb/T	%	
0	0	0		1.5% urea
5	0.3	6	0.8	30 lb urea/ton
10	0.6	12	1.7	or
15	0.9	18	2.5	4.2% protein-equivalent
20	1.1	22	3.0	from non-protein-nitrogen
25	1.5	30	4.2	in grain ration

[1]Hay-equivalent = lb dry hay; 0.6 x pound 50% moisture haylage; or 0.33 x pound wilted silage fed. Table assumes urea corn silage consumption reduced as hay-equivalent from other forages is increased; and 1 pound grain fed per 3.0 pound milk.

[2]"Protein-Equivalent from Non-Protein-Nitrogen" contained in commercial supplements is given on the feed tag. To determine above figure, multiply percentage given on feed tag times 100 pound (cwt) of supplement added and divide by cwt total feed in batch.

Example: Supplement tag reads 23% protein-equivalent from NPN. Two hundred lb added per ton. 23 x 2 = 46 ÷ 20 cwt (1 ton) = 2.3% protein-equivalent from NPN in grain ration. Conclusions: From the table it is observed that if urea-corn silage is fed free choice, then 15 pounds of hay-equivalent per head daily from other forages should be fed. Otherwise, the amount of urea in the grain ration should be reduced.

[3]Cornage (30% moisture corn grain ensiled) with 10 pounds urea added per ton contains 0.7% urea or 2.0% protein-equivalent from NPN on a dry matter basis. Urea should not be included in cornage to be fed with urea corn silage unless 12 pounds or more hay-equivalent from other forages is also fed.

3. Beware of mixing urea with wet-corn or other ingredients that may cause the urea to "bunch-up" and fail to distribute evenly throughout the ration.

4. Don't try home-mixing unless you have satisfactory mixing equipment to insure uniform distribution.

5. Never leave urea or high urea supplements accessible to cattle or other livestock.

6. Premixing of the urea with a small amount (200 to 300 pounds) of ground dry grain before adding to the full batch of feed will help to insure uniform distribution of the urea.

Urea toxicity develops rapidly when cattle consume excessive amounts. The symptoms include uneasiness, muscle and skin tremors, excess salivation, labored breathing, incoordination (ataxia), bloat, tetany and death.

Antidote—Acetic acid as a 5% solution or as vinegar given orally (drench) is an effective cure if given before tetany develops. Approximately 1 gallon of vinegar is a readily available material for treating an adult cow. A second treatment may be necessary about 3 hours later.

Cattle Fertility and Urea

Research evidence indicates that the reproductive efficiency of cattle is not affected by feeding urea. A study of the length of calving interval (days from calving to calving) and the percent of cows sold because of sterility in Michigan DHIA herds for the 5-year period (1965-1969) shows that reproductive efficiency was not related to either the amount of urea fed or the length of time it was fed during that period. The data in Table 7 represent 85,281 calving intervals in 3,157 herd-year observations. Urea was fed in 54% of the cases. If conception rate, or fertility, was lower due to feeding urea, then the calving interval would have been longer or the percent of cows sold as sterile should have been higher in herds fed urea. Such differences did not occur. The data did show that calving interval was longer for the years 1967 and 1969 whether or not urea was fed. Experiments in other states offer no evidence that feeding urea at recommended levels causes poor reproductive performance in cattle.

Ammonia

Recent studies at Michigan State University with high-producing dairy cows, dairy heifers, beef cows and fattening steers have shown equal performance by cattle fed corn silage treated with ammonia compared to urea when the ration is properly balanced with additional protein from natural sources.

Because of relatively high concentrations of lactic and acetic acids in corn silage, ammonia added to silage is converted to the salts of these acids during fermentation, and the animal receives the ammonia in the salt form. Even with urea-treated silage, about 30 to 70% of the added urea nitrogen is hydrolyzed to ammonia during silage fermentation and is combined with the silage acids to form ammonium salts. The nitrogen (or crude protein) from ammonia must be limited to 20 to 30% of the protein in the total ration as with urea.

Biuret

This compound is formed through conjugation of two urea molecules with the removal of water. The rumen microbes must first hydrolyze biuret to urea and then urea to ammonia for incorporation into microbial protein. Adaptation to biuret requires a longer time than that needed for urea.

Biuret has advantages over urea since it is relatively non-toxic and apparently tasteless. It is also less soluble in water, and the rate of release of ammonia in the rumen is slower. Performance studies have shown it essentially equal to urea. Biuret can be used in rations for growing or fattening livestock but cannot be used in rations for milking cows until it is conclusively known that the compound does not appear in the milk and is cleared by the Food and Drug Administration.

TABLE 7—Average calving interval, percent cows sold as sterile, and milk production of herds fed various levels of urea compared to herds fed no urea. Michigan DHIA herds 1965-69.[1]

Measurement	Herds fed no urea	All herds fed urea (1-370 g)	Grams urea/head daily			
			1-60	61-120	121-180	184+
Number of observations	1,442	1,715	760	653	219	83.0
Calving interval, days	380.4	379.9	379.4	380.7	379.8	377.8
Adjusted calving interval, days	314.4	315.7	313.4	317.8	316.5	313.7
Cows sold sterile, %	2.15	2.4	2.4	2.4	2.6	1.7
Milk per cow, avg. lbs	13,046	12,895	12,747	12,952	13,146	13,136

[1] *W. L. Ryder, M.S. Thesis, 1970, MSU.*

II. Nutrient Requirements of Dairy Cattle

Energy and Protein

ENERGY AND PROTEIN are the two major nutrients in dairy cattle rations. Energy comprises 70 to 80% of the total nutrient requirement, and protein 10 to 15%, while minerals and vitamins comprise less than 10% of the total dietary requirement.

Likewise, energy and protein are the two nutrients most commonly lacking in adequate amounts, or deficient, in dairy cattle rations. The reasons are simple. Forages are generally the major feed for dairy cattle, and forages are usually low in energy content and vary considerably in their energy and protein content. Differences in forage species, stage of maturity when harvested and success or failure to preserve the nutrients during harvesting and storage will affect the energy and protein content of the forages; thus they require different supplementation to meet the requirements of cattle for growth, maintenance, production and reproduction.

The mineral and vitamin content of feeds may also vary considerably, but the levels required in the diet may be less critical, or the deficiency symptoms may be slower in developing and less obvious than when energy or protein are lacking. Body stores of energy and protein are generally depleted more quickly when lacking in the diet than stores of minerals and vitamins.

Measurement of Energy

The energy values of feedstuffs may be expressed in several ways. Total digestible nutrients (TDN) is most commonly used in this country. Digestible dry matter is the difference between the amount of feed dry matter consumed and the amount of dry matter that appears in the feces. TDN is essentially the same except that the chemical fractions of the feed and feces are analyzed and the digestibility (amount absorbed) determined for each fraction. Thus, TDN is equal to digestible crude fiber + digestible crude protein + digestible fat x 2.25 + digestible nitrogen-free extract (which represents the soluble carbohydrate).

TDN has been determined for thousands of feedstuffs, and from that standpoint, is the most reliable measure of feed value. However, TDN does not consider the quality of end products from the rumen fermentation, i.e. the proportions of various volatile fatty acids produced and their energy value and physiological functions. Fibrous feeds such as poor quality forages tend to produce more heat and lower energy organic acids when fermented in the rumen than do high-energy feeds; thus, digestibility (TDN) may overestimate the value of forages in the ration. Also, enzymes, urea and other compounds are secreted into the digestive tract from various organs and glands after having been assimilated. TDN values therefore are approximations of apparent digestibility and not true digestibility. In spite of these shortcomings, TDN values are useful in comparing the energy value of feedstuffs (Appendix Table 5) and for estimating the amount of various feeds needed to meet the energy requirements for various productive purposes (Appendix Tables 1, 2, 3 and 4).

Other measures of energy are "digestible energy," "metabolizable energy" and "net energy." Each of these is based on the caloric value of feeds when different body functions or losses have been subtracted. One calorie is the amount of heat required to raise the temperature of 1 gram (1 cubic centimeter) of water from 14.5° to 15.5°C. One kilocalorie = 1,000 calories and 1 magacalorie (MCal) = 1 million calories.

Figure 3 shows how each of these is derived and the average fraction that each represents of the total energy intake. Only about 18% (ranges from 0 to 35%) of the gross energy is converted to net energy available for production in the example of Figure 3. Although this is rather low efficiency, it should be recognized that half or more of the diet of cattle is usually composed of forages which have very little or no nutritional value to man unless fed to ruminants. Also, since the heat loss for maintenance is the largest single source of energy loss and is principally dependent on body size, the more milk a cow of given size produces the higher will be her net energy efficiency.

Feeding Standards

Daily requirements for TDN, net energy, protein, calcium and phosphorus for milking cows are given in Appendix Tables 1 and 3 and for youngstock and breeding bulls in Appendix Table 2.

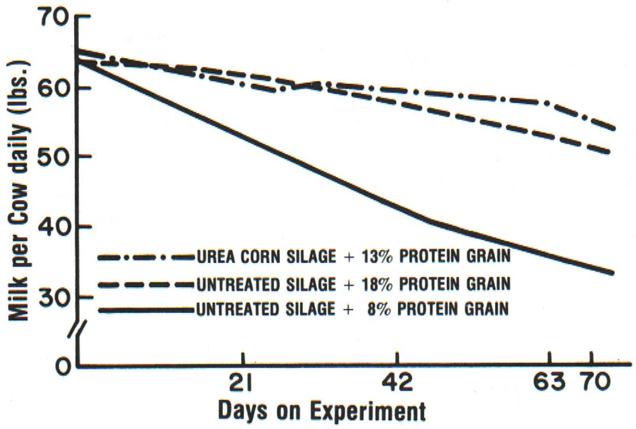
Maintenance requirements (Appendix Table 1) are based on body weight. Milk production requirements depending on the amount of milk produced, and its fat content are given in Appendix Table 3. The requirements for maintenance and milk production must be added together to determine the total daily requirements.

These amounts of energy and protein must be supplied in the daily ration to meet the requirements. If lesser amounts are provided, body reserves of fat and protein will be utilized until depleted, and milk production will decline more rapidly than necessary. Milk production normally declines 7 to 10% per month after the peak of lactation, which occurs 45 to 60 days after calving but somewhat earlier with first-calf heifers.

Exceptionally high producers (over 80 pounds of milk per day) may decline at a faster rate for 1 to 2 months after peak production. Inability of high producers to consume enough feed probably accounts for this rapid decline.

Insufficient energy intake during the breeding period not only limits milk production but may result in failure of open cows to show signs of estrus (heat) and may result in poor conception rates. Cows should be in positive energy balance,

Figure 2. Low protein rations depress milk production rapidly.



(gaining weight) for best reproductive efficiency. The desirable breeding period (60 to 90 days after calving) coincides with peak production, and most high-producing cows are deficient in energy intake during that time and are less likely to exhibit heat and conceive.

Limitations on the amount of non-protein nitrogen that can be used in the ration must be observed as discussed under the section on nitrogen metabolism.

The protein of silage (or hay) that has been overheated in storage may become insoluble and nondigestible. Crude protein analysis does not reflect this condition. A recent study of farm haylage samples indicates that one-third of the haylages were seriously damaged by heating in storage, averaging 37% of their protein unavailable for digestion. The average for all samples was about 20% unavailable protein, suggesting that methods for ensiling of haylage must be improved. Carmelization and browning of the forage is evidence of heat damage. Therefore, low production due to protein deficiency may result in some instances when heated forages are fed even though there appears to be adequate crude protein in the ration. Addition of 20 to 30% additional protein (2 to 4 pounds of soybean meal per cow daily) to the ration may be beneficial in such cases and will be reflected in milk production response within 3 to 7 days if needed in the ration.

Appetite for Dry Matter

Appetite of cattle is measured as the amount of dry matter consumed per 100 pounds of body weight daily and is frequently referred to as "dry matter intake." Appetite is influenced by the palatability and the quality of feed offered and rate

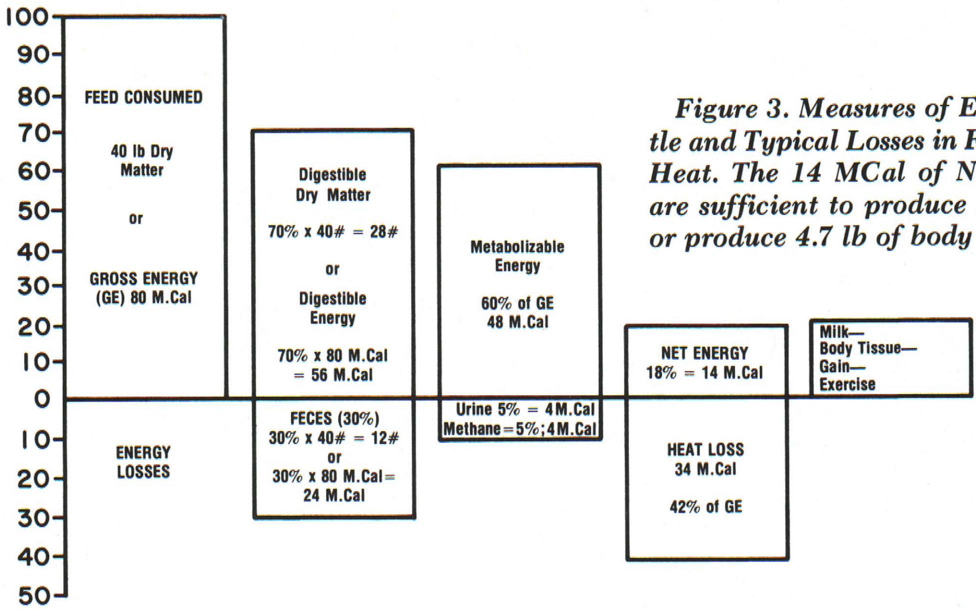


Figure 3. Measures of Energy Value of Feeds for Cattle and Typical Losses in Feces, Urine, Methane Gas and Heat. The 14 MCal of Net Energy in this illustration are sufficient to produce about 45 lb of 3.5% fat milk; or produce 4.7 lb of body weight gain.

TABLE 8—Average consumption of air dry feed (90% DM) at various stages of lactation and body weight.

Body weight	Stage of Lactation											Average
	1	2	3	4	5	6	7	8	9	10	Dry	
	lb.											lb.
800	25	31	32	31	31	30	28	28	27	25	23	31
1,000	32	39	41	39	38	38	36	35	34	32	30	35
1,200	38	47	49	47	46	45	43	42	40	38	35	42
1,400	42	52	54	52	51	50	47	47	45	42	39	47

Individual appetite, level of milk production and quality of feeds cause additional variation in feed consumption. Average figures are fairly reliable for estimating on a group basis but individuals will vary 5 to 7 pounds from the average. Data are based on feeding hay, medium level of corn silage and dry grain rations. Forage consumption may be 10 to 20% lower when high moisture silages are fed as the major forage.

of passage through the gastrointestinal tract. Low-quality forages and grains are generally poorly consumed by cattle. High-moisture silages tend to reduce dry-matter consumption. This appears to be caused by the products of the silage fermentation rather than the moisture content as such. Stage of lactation also affects appetite. During the first 2 to 4 weeks of lactation, appetite is low but gradually increases until it peaks at about the same time as peak milk production. Thereafter, appetite declines at a rate similar to the lactation curve and is only about 70% of peak appetite by the 10th month of lactation. Lack of protein, phosphorus, cobalt and several other minerals, as well as diseases, will cause a low appetite (anorexia).

Appetite for dry matter must be considered in formulating rations. For example, if forages are poorly consumed, then adjustments must be made in the amount of concentrates fed and perhaps in the protein content of the grain ration to balance requirements for energy and protein.

When the ration is completely composed of dry feeds, normal total dry matter intake approximates 3.0 pounds per 100 pounds body weight daily plus or minus 0.2 pounds dry matter per pound of milk above or below 40 pounds per day. When silage and other high-moisture feeds are the principal feed, total dry matter intake will average about 3.0 pounds per 100 pounds body weight daily and vary from 2.5 to 3.5 pounds. Consumption of good quality haylage (50% dry matter or more) is similar to that of dry hay of comparable quality. Forages are usually fed to cattle free choice, or in the amount they will readily consume in a given amount of time such as one day. Increasing the level of grain will tend to depress forage intake after peak appetite has been reached. When formulating rations, have a reasonably accurate estimate of forage intake in order to balance the ration with concentrates, protein and other nutrients.

Average consumption of air-dry feed at various stages of the lactation is shown in Table 8. Multiply the amounts by 0.90 to find dry-matter (DM) intake.

Formulating Grain Rations and Estimating Feeding Rate

Concentrates, or grain rations, should be formulated to supplement forages with the additional energy, protein and other nutrients needed to meet requirements for maintenance, milk production and growth. Forages vary considerably in energy and protein content, as shown in Appendix Table 5. Similarly, the kind, quality and amount of forages available for feeding on a given farm generally determine what forages will be fed. Therefore, it is desirable to estimate the forage contributions to a ration, then formulate a grain ration to balance the forages fed and determine an appropriate rate for the grain ration to be fed. This procedure requires the following steps:

Step 1—Determine the nutrient requirements for energy (TDN) or net energy (NE), protein, calcium and phosphorus.

Find maintenance requirements based on body weight in Appendix Table 1; requirements for milk production (by percent fat) in Appendix Table 3; requirements for growth of youngstock and breeding bulls in Appendix Table 2.

Select the values that correspond to your problem and arrange them in a table as shown in Illustration 1. **Note:** For calculation purposes, select a level of milk production that corresponds to the higher-producing cows in the herd or an expected level of production, usually 20 to 30 pounds above herd average.

Step 2—Determine the kind, amount and quality of forages being consumed. Accurate estimation of forage intake is necessary to form a sound basis for formulating the grain ration. Weigh the amount of each feed and deduct leftovers if necessary. Avoid overestimating forage intake (forage intake of 1.5 to 2.5 pounds dry matter per 100 body weight is normal).

Step 3—Calculate the amount of energy (TDN or NE), protein, calcium and phosphorus provided by each of the forages consumed. Values for each of these nutrients that correspond to your forages are given in Appendix Table 5. **Multiply:** pounds of feed x nutrient content = pounds of TDN, megacalories of NE and pounds of protein, calcium and phosphorus. Record these values in your table as "Nutrients Provided by Forages." **Note:** When working with low-quality forages, net energy (NE) will provide the best estimate of energy value.

Step 4—Subtract: nutrient requirements minus nutrients provided by forages = deficiency (or surplus). Deficiencies must be provided by the grain ration.

Step 5—Determine the amount of grain ration that must be fed to meet energy requirements. Energy deficiency (TDN or NE) divided by energy concentration of grain ration (% TDN or MCal. NE per pound = pounds of grain ration required to meet requirements). Divide by 0.75 for heavy grain rations containing mostly shelled corn, barley or wheat. Divide by 0.70 for lighter grain rations containing mostly ear corn, oats or mill feeds.

To determine the amount of grain ration for cows milking at other levels of production: Divide pounds of grain (determined above) by pounds of milk (determined in Step 1 above). The result is pound of grain per pound of milk. Multiply this figure x pound of milk for cows milking at other levels.

Step 6—Determine percent protein required in grain ration. Divide protein deficiency (lb) by pound of grain required (from Step 5) and multiply result x 100 = % protein. Use the same procedure to determine percent calcium, phosphorus or other nutrients required in grain ration.

Step 7—Formulate a grain ration to meet above requirements and feed at the appropriate rate.

Illustration 1 — Calculation procedures for balancing rations. Example: 1300 pound cows, ration balanced for 70 pounds of 4.0% milk per day. Forages fed are 10 pounds average quality alfalfa-brome hay and 45 pounds corn silage (without urea) 32% dry matter.

Nutrient requirements:	Weight lb.	TDN[1] lb.	NE[2] Mcal	Protein lb.	Ca lb.	P lb.
Maintenance	1300	9.2	10.3	1.6	0.048	0.037
Milk (70 lb., 4% fat)		23.1	23.1	5.4	0.189	0.140
Gestation (open)			(Use pregnancy allowances for maintenance last 2 to 3 months of pregnancy)			
Total nutrients required		32.3	33.4	7.0	0.237	0.177
Nutrients provided by forages						
Alfalfa-brome hay, lb.		10	10	10	10	10
Nutrients/lb.		0.50	0.45	0.15	0.012	0.0025
Nutrients from alfalfa-brome		5.0	4.5	1.50	0.120	0.025
Corn silage, lb.		40	40	40	40	40
Nutrients/lb.		0.22	0.24	0.029	0.0009	0.0007
Nutrients from corn silage		8.8	9.6	1.16	0.036	0.028
Total nutrients from forages (hay plus corn silage)		13.8	14.1	2.66	0.156	0.053
Deficiency (or surplus): total nutrients required — nutrients from forages: (Needed from grain ration)		18.5	19.3	4.34	0.081	0.124

Grain needed to provide energy: (19.3 ÷ .75 Mcal/lb. grain = 25.7 lb. grain ration).

Protein percent needed in grain ration: (4.34 lb. protein ÷ 25.7 lb. grain) x 100 = 16.9% protein.

Calcium percent needed in grain ration: (.081 lb. Ca ÷ 24.1) x 100 = 0.32% Ca.
Phosphorus percent needed in grain ration: (.124 lb. P ÷ 24.1) x 100 = 0.48% P.

Feeding rate: 25.7 ÷ 70 lb. milk = .36 lb. grain per pound milk.

Example: Cow producing 40 lb. milk x .36 = 14 lb. grain per day.
Cow producing 80 lb. milk x .36 = 28 lb. grain per day.

[1] Total digestible nutrients
[2] Net energy, megacalories

Minerals

DAIRY CATTLE REQUIRE calcium, phosphorus, potassium, iodine, magnesium, sodium, manganese, iron, copper, cobalt, zinc, chlorine, sulfur and selenium in sufficient quantities to maintain normal health. Other minerals such as chromium, silicon, fluorine and molybdenum are essential for mammals, but their role in cattle nutrition is not well known. Some of these are also toxic. The requirement for minerals is higher during lactation because all are secreted in milk and some are needed for milk secretion.

Most minerals are normally contained in sufficient concentrations in forages and grains to satisfy the requirements of cattle when fed normal proportions of forages and grains. Exceptions occur when soils are deficient in certain minerals, when severe weather conditions affect the uptake of minerals by plants, or when many of the leaves of forages are lost during harvesting or rain has leached the minerals from the forage. Also, an excess of some minerals may interfere with absorption or utilization of others. For instance, excess potassium in the soil tends to reduce the calcium and magnesium content of forages as well as their absorption from the intestine, and high levels of molybdenum increase the requirement for copper in the diet. The latter condition is not known to be prevalent in Michigan.

The minimum daily requirements for each of the important minerals and the deficiency symptoms are given in Table 10. Calcium, phosphorus, salt, (sodium chloride), iodine and cobalt are most likely to be of concern in Michigan feedstuffs.

Calcium (Ca)

Cattle require approximately 0.25% calcium in the total ration (air dry) to meet requirements for growth and maintenance. The daily requirement for lactating cows is 10 to 15 grams plus 1.0 gram per pound of milk produced daily so that a cow producing 60 pounds of milk has a daily requirement of 70 to 75 grams of calcium. Rations for high-producing milking cows should contain a minimum of 0.7% calcium in the total ration (air dry) to meet requirements and allow for variations in feed consumption. This amounts to 3.0 grams of calcium per pound of air dry feed.

High-producing cows utilize dietary calcium very efficiently, and they will also withdraw calcium from the bone temporarily while producing at a high level without harmful effects. Bone calcium is replenished when production subsides. Therefore, short-term (2 to 3 months) dietary calcium deficiencies are normal for high-producing cows.

Legume forages normally are rich in calcium. Grass hays are medium to low while corn and sorghum silages are too low in calcium content. Cereal grains contain very little calcium as shown in Appendix Table 5.

Selection of a mineral supplement should be based largely on the species of forages fed and their calcium content in order to balance the total ration to meet dietary requirements without providing a large excess of calcium.

Phosphorus deficiency in the ration of cattle. Note the "postiness" of legs, stiff joints and poor body condition — breeding difficulties may also result.

Phosphorus (P)

Cattle require approximately 0.25% phosphorus in the ration for growth, maintenance and lactation up to about 60 pounds of milk per day. The requirement for milk production is 10 to 15 grams per head daily for maintenance plus 0.75 to 1.0 grams per pound of milk produced daily. Allowing 0.30 to 0.40% phosphorus in the total air dry ration is adequate to meet production requirements for high-producing cows.

TABLE 10—Nutrient requirements and deficiency symptoms. (See pp 15-32 for further information.)

Nutrient	Function	Daily Requirement	Deficiency Symptoms
ENERGY (glucose, fats, fatty acids)	Muscle — nerve activity, growth, fattening, milk secretion.	Variable with body size, rate of growth, milk production and milk fat % (see Nutrient Requirement Appendix Tables 1-4.)	Low milk production; slow growth rate; poor body condition; silent estrus (heat); lowered protein content of milk. Excess energy relative to requirement: fattening; high blood fat levels; fatty liver; tendency for depressed appetite and ketosis post calving; unsaturated fats in tissue and fat deposits; tendency toward low resistence to infectious diseases, retained placenta and metritis; sudden increase causes lactic acidosis, death.
FIBER	Stimulates rumination and secretion of saliva, helps maintain rumen pH near neutral ±6.8; partially fermented to short-chain fatty acids for energy and synthesis of milk fat.	Minimum 15% of ration dry matter for lactating cows; higher with finely chopped feeds.	Rumenitis; founder; rumen stasis; tendency toward displaced abomasum post-calving; low milk fat test; higher unsaturated fats in tissue fats; may contribute to poor muscle contractility.
PROTEIN	Cell formation, muscle, hair, blood proteins, enzymes. Milk protein secretion	11 to 15% of ration dry matter depending on age and rate of production, proportional to energy intake	Emaciation (poor body condition); retarded growth; low milk production; reduced digestion of feed; poor conversion of feed to growth, fat or milk; lower blood protein and possibly immune fractions; underdeveloped reproductive organs possibly due to retarded growth.

Mineral and vitamin requirements and deficiency symptoms

Nutrient	Function	Daily Requirement	Deficiency Symptoms
SALT (Na) Sodium and (Cl) chloride	Acid-base balance; nerve and muscle action; water retention; hydrochloric acid.	2-3 grams/cwt/day Estimate 0.18% sodium or 0.45% salt (NaCl) in dry ration.	Lack of appetite; unthrifty, low production; craving for salt; appetite for soil, clothing; licking objects; drinking urine from other cows during urination.
CALCIUM (Ca)	Skeletal growth and milk production; muscle quiescence.	Maintenance 10-15 grams/day plus 1 gram per pound milk; 0.5% to 0.8% in dry ration for lactation; 0.3% for dry cows.	Bones and teeth easily broken; low calcium content in bones.
PHOSPHORUS (P)	Energy metabolism; skeletal growth; milk production.	Maintenance 10-15 gram +0.75 gram/pound milk; 0.25-0.4% in dry ration.	Lack of appetite; irregular estrus (heat periods); depraved appetite for bones, wood, bark, etc.
MAGNESIUM (Mg)	Muscle irritability, electrolyte balance, enzymes.	Calves: 0.4-0.6 grams/cwt/day; or 0.15 to 0.22% in the dry ration of milking cows.	Grass tetany (or grass staggers); twitching of the skin; staggering or unsteady on feet; down; common with cattle grazing rapidly growing, succulent pasture, or similar green chop and occasionally stored feeds; may be aggravated by high N and potassium levels in feeds.
POTASSIUM (K)	Acid-base balance in intracellular fluid; osmotic pressure activates enzymes, heart, muscle tone.	0.6% of dry ration for growth of lambs; 0.8% suggested for cattle, ± 1.0% for high producing cows.	Overall muscle weakness; loss of appetite; poor intestinal tone with intestinal distension; cardiac and respiratory muscle weakness and failure.
IODINE (I)	Thyroxine synthesis; metabolic rate.	0.1 ppm in dry ration (for non-lactation 2 miligrams/ head daily); 0.8 ppm for pregnancy or 8 to 12 mg; more may be required when soybean meal or other goitrogenic feeds are fed heavily.	Goiterous (big neck) calves frequently dead or hairless; failure to show estrus; high incidence of retained placentas in mature cows.
VITAMIN A	Growth, differentiation and health of epithelial tissue, especially of eyes, alimentary tract and respiratory mucosa.	3,000 IU/hundredweight/day or 6 milligram carotene per hundredweight per day; no lactation requirement except for health of animal—50,000 IU/cow/day generally recommended.	Night blindness; bulging and watery eyes; muscle incoordination; bronchitis and coughing may progress to pneumonia; chronic symptoms; roughened haircoat; emaciated, hairless or blind calves if dam deficient; edema or swelling of the brisket and forelegs (anasarca); abortions pre-term; young calves weakness at birth; susceptible to pneumonia and digestive infections; watering of the eyes, cloudiness of the cornea, protrusion or "bulging" of the eye followed by permanent blindness and death.

(Continued next page)

TABLE 10—Nutrient reqirements and deficiency symptoms. (Continued)

Nutrient	Function	Daily Requirement	Deficiency Symptoms
B VITAMINS		Synthesized by organisms in normal functioning rumen to meet requirement; calves to weaning: contained in milk.	Deficiency symptoms produced only with abnormal restricted diets; may occur in calves with prolonged severe scours or fed artificial milk diets.
Thiamin B_1.	Co-enzyme in CHO metabolism, carboxylases; alfa-keto acid and pentose metabolism.	Prevented by 0.65 milligram thiamine-HCl per kilogram of liquid diet or 0.065 milligram per kilogram live weight.	Polioencephalomalacia; necrosis in the gray matter of the brain; muscular incoordination tremor, grinding of the teeth, convulsions; high blood and urine lactate and pyruvate.
Niacin, nicotin or nicotinamide.	Co-enzymes I and II oxidation-reduction of all major nutrients.	Energy metabolism, enzymes.	Dermatitis and necrotic lesions in mouth, pellagra.
Riboflavin B_2	Hydrogen transfer in metabolism.	Calves <.75 milligram per kilogram liveweight or 0.65 ppm in liquid diet	Lesions around the corner of the mouth, eyes and nose; damp haircoat; loss of hair; copious salivation and lacramation.
Biotin.	Enzyme system, synthesis of aspartate, oxidation of pyruvate, synthesis of unsaturated fatty acids.	0.01 milligram per kilogram liquid diet; 1.0 microgram per kilogram body weight.	Paralysis of hind quarters.
Pantothenic acid.	Co-enzyme A, metabolism of carbohydrates, fats, amino acid .	<1.3 milligram per kilogram liquid diet.	Lack of growth and emaciation; scaly dermatitis around eyes and muzzle; susceptible to respiratory infection.
Folic acid.	Not fully known; co-enzyme in formation of nucleoproteins and hemoglobin.	0.39 milligram per kilogram liquid diet prevented symptoms.	Lack of growth and emaciation; leukopenia (low WBC)
Vitamin B_{12}. (cobalamin)	Energy metabolism, maturation of red blood cells.	0.34– .68 microgram (μg) per kilogram liveweight.	Lack of growth and emaciation (see Cobalt).
Pyridoxine (B_6).	Amino acid metabolism, coenzymes.	<0.065 milligram per kilogram weight.	Lack of appetite; epileptiform fits; demyelination of peripheral nerves.
Choline.	Labile methyl groups; nerve function and fat metabolism.	260 milligram per kilogram liquid diet promoted recovery.	Extreme weakness, labored breathing within 6—8 days.
VITAMIN C (Ascorbic Acid)	Structure of intercellular material all tissues.	Synthesized in tissue of calves and adult bovines.	Other species-scurvy; loosening of teeth; subepithelial hemorrhage and other problems related to faulty collagen formation.
VITAMIN D	Absorption of Ca and P; reduced excretion of P; mobilization of Ca and P from skeleton.	300—400 IU/cwt/day; D2 or D3; 5000-20,000 IU/head/day.	Rickets; enlarged joints; wobbly gait; lack of appetite; stiff legs; arched back; swelling of pasterns; lameness; calves deficient in Ca, P or vitamin D.
VITAMIN E (Alpha tocopherol)	Antioxidant; protection of vitamin A; muscle integrity; carotene, ascorbic acid, fats.	Calves: less than 40 milligram per day. Adults not established 1—2 grams (1,000-2,000 units) fed to cattle prevents oxidized flavor in milk having high copper content. Poultry 2 milligram/pound feed	Nutritional muscular dystrophy; white muscle disease in calves, stiff lamb disease-stiff legs; sudden death from heart muscle degeneration; heart, diaphram and intercostal muscles show light streaking.
VITAMIN K (fat soluble)	Prothrombin formation, blood clotting.	None, synthesized in gut; vegetative material cows milk.	Hemorrhage.
SELENIUM (Se)	Muscle integrity.	Uncertain: 0.1-0.2 ppm.	Nutritional muscular dystrophy; high calf and lamb mortality; retained placentas increased, liver and pancreatic necrosis (degeneration) in pigs; toxic above 3 ppm.
SULFUR (S)	Synthesis of S-amino acids. Co enzyme A.	0.2% in dry ration 1 S to 10 parts N in high NPN rations	Lowered production; poor nitrogen utilization; cellulose digestion and conversion of lactate to propionate.
FLUORINE (F)		Small amount appears to prevent dental cavities.	Toxic above 10 ppm; deformed teeth and bones.
MANGANESE (Mn)	Growth, enzymes.	Cows: 40 ppm in dry ration for normal reproduction and offspring. Normal growth at lower levels. Poultry 25 ppm.	Newborn: deformed bones, enlarged joints, stiffness, twisted legs, shorter humeri (foreleg), general physical weakness; deficiency could occur in cattle fed high grain low roughage rations where symptoms could be ataxia (uncoordinated movements).

(Continued next page)

TABLE 10—Nutrient requirements and deficiency symptoms. (Continued)

Nutrient	Function	Daily Requirement	Deficiency Symptoms
IRON (Fe)	Formation of hemoglobin.	Growth, 150 milligram/cwt/day for growth, 100 ppm in adult ration; 2 grams per day	Anemia particularly in calves maintained on milk; seldom in adult cattle.
COPPER (Cu)	Respiratory pigments of blood, some enzymes.	10 ppm dry ration. Increases with high molybdenum intake.	"Coast disease" or "Salt sick" (in Florida); anemia, stillbirth of young; loss of wool in sheep; incoordination of hind legs; sudden death in cows due to heart degeneration; baby pig "thump", Cu and iron deficient.
COBALT (Co)	Microbial synthesis of vitamin B_{12} in rumen	0.1 ppm in dry ration (2 milligram/day)	Loss of appetite; anemia, emaciation; low appetite for grain; calves unthrifty, poor appetite, first to exhibit symptoms because low vitamin B_{12} content of milk.
ZINC (Zn)	Enzyme systems.	Calves: 9 ppm in ration adequate for normal growth and appearance; above 50 ppm may be desirable for lactation and wound healing; NRC-40 ppm.	Itch, hair slicking, stiff gait, swelling of hocks and knees, soft swelling above rear feet, rough and thickened skin, dermatitis between rear legs and behind elbows; undersize testicles in bull calves and low fertility in cows have been attributed to zinc deficiency.

Forages normally contain about 0.25% phosphorus (air dry) which is similar for all species. The phosphorus content varies, however, depending on the available phosphorus in the soil and damage from lack of leaves. Cereal grains normally contain about 0.3% phosphorus, while oil meals and wheat bran contain greater amounts of phosphorus (about 0.6%). Supplemental phosphorus should generally be provided for lactating dairy cattle since forages are frequently low in phosphorus content. Addition of 4 to 5 pounds of phosphorus per ton of grain ration is recommended to avoid phosphorus deficiency. Dicalcium phosphate contains about 20% phosphorus; thus, addition of 20 pounds per ton of grain ration furnishes 4.0 pounds of supplemental phosphorus. The percent phosphorus and calcium contained in commercial supplements varies considerably and must be considered when balancing rations.

Calcium, Phosphorus and Milk Fever

Feeding excessive amounts of calcium in the ration of dry cows tends to increase the incidence of milk fever (parturient paresis) at calving.

Reducing the calcium level in the ration of the dry cow to deficiency levels (1 gram per 100 lb. body weight) while maintaining adequate levels of phosphorus for a period of two to four weeks before calving has been shown to be an effective method of preventing milk fever in susceptible cows.

The low intake of dietary calcium is believed to stimulate the secretion of parathyroid hormone (PTH). This hormone stimulates the transformation of vitamin D to an active form called 1,25-dihydroxy vitamin D_3.

At the initiation of lactation the sudden heavy drain on blood calcium and developing hypocalcium is offset by secretion of PTH which stimulates synthesis of the "active" vitamin D_3 increasing intestinal absorption of calcium, and mobilizing calcium stored in the bone.

Excessive calcium in the diet of the dry cow depresses synthesis of the "active" vitamin D thus the homeostatic mechanism for controlling blood calcium cannot respond rapidly enough at parturition to prevent the developing hypocalcemia (low blood calcium) and when the hypocalcemia becomes severe enough (5 mg Ca/100 ml serum) the paralysis of milk fever develops.

Some evidence suggests that milk fever can be partially prevented by supplementing high calcium forages (such as alfalfa) in the dry cow diet with a no-calcium, high phosphorus supplement such as monosodium phosphate. Excessive phosphorus may also depress blood calcium prepartum thus engaging the hemostatic mechanism at the initiation of lactation as described above. However, the low calcium dry cow diet is believed to be most dependable for preventing milk fever.

Grass hay, corn silage and hay or silage from cereal grains are low in calcium and desirable feeds for dry cows to prevent milk fever. Corn silage should be limited to the amount needed to meet energy requirements.

Alfalfa and other legumes should be limited and high calcium mineral supplements avoided in the dry cow ration for two weeks before calving to prevent milk fever.

At calving the ration must contain 0.5 to 0.7% calcium and throughout lactation to meet the high calcium requirements for milk production.

Salt (NaCl)

Most feeds are low in sodium and sometimes low in chlorine; thus it becomes necessary to provide supplementary salt (sodium chloride) for cattle in all cases. The recommended allowance for salt is 1 ounce per day for dry and pregnant cows and 2 to 3 ounces for lactating cows. Expressing this another way, 1 pound of salt is sufficient daily for 16 dry pregnant cows, but sufficient for only 5 to 8 milking cows.

The total ration should contain about 0.3% salt. Including 1% salt in the grain ration (20 pounds per ton) is the best way to insure an adequate intake for high-producing cows receiving grain. When the drinking water is salty, cattle may consume little additional salt, and salt additions may not be required.

Cattle will consume more salt as loose salt than from salt blocks. However, experiments indicate that they get enough salt from blocks when they have free access to the blocks.

Magnesium (Mg)

A condition known as grass tetany (or grass staggers) sometimes occurs when cattle are grazing rapidly growing, succulent pasture or are being fed similar green chop, and occasionally when fed stored feeds. Symptoms are similar to milk fever but may occur in cattle of any age or stage of lactation. Cattle exhibit symptoms of twitching of the skin, staggering or are unsteady on their feet and may go down, unable to rise. Lack of magnesium decreases cellulose digestion and may contribute to a low milk-fat test. Feeding one to three ounces of magnesium oxide (MgO) per head daily in grain or as 1/3 of the salt corrects the problem. Drenching of seriously affected cattle, or intravenous injection by a veterinarian of calcium gluconate containing magnesium may be necessary. Forages containing less than 0.2% magnesium may cause grass tetany especially when fertilized with high amounts of nitrogen and potassium. Rations fed to dairy cattle should contain a minimum of 0.15 to 0.2% magnesium.

Potassium (K)

Potassium is essential for maintaining acid-base balance and osmotic pressure in intracellular fluids and electrolyte balance, and it helps control nerve and muscle excitability. It acts as a co-factor in several enzyme systems.

Potassium is required in the largest quantities in the diet of all of the mineral elements. The requirement is probably increased by high lactation since potassium is secreted in the milk in fairly uniform concentrations. The minimum practical requirement for lactating cows is approximately 1% of the ration dry matter.

Forages normally contain adequate amounts of potassium such as 1.8 to 2.5%. However, forages grown on soils low in potash frequently contain less than 1.2 potassium, and a deficiency could occur if fed with cereal grains (0.35% K) as one-half or more of the ration. Approximately 15% of Michigan hay crop forages and many corn silages fall in this category. The requirement for fattening cattle and for growth appears to be above 0.7% of the ration dry matter.

Symptoms of potassium deficiency are a marked decrease in appetite, pica (craving for unnatural materials), loss of hair glossiness, decreased pliability of hide, lower blood plasma and milk potassium and higher hematocrit readings.

Deficiency can be corrected by feeding potassium chloride (KCl) commonly known as muriate of potash. Including 1% KCl in the grain ration or mixing half and half with salt provides supplemental potassium when deficiency is suspected.

Trace Minerals

Most trace minerals are normally contained in adequate quantities in forages and concentrates. However, analysis of some 1,500 Michigan forage samples indicates that about 15% of the samples are deficient in one or more of the essential trace elements including iron, manganese, zinc, cobalt and iodine. The levels required in the ration and deficiency symptoms are shown in Table 10. The symptoms may vary with age and species of animal and degree of deficiency. Iodine and cobalt are commonly low in feeds grown on Michigan soils and are discussed further below.

Iodine (I)

The iodine requirement is estimated to be about 2 milligrams per head daily for non-lactating cows

Goiter in the calf resulting from a lack of iodine in the ration of the dam prior to calving. Photo courtesy of R. W. Hemkin, Maryland Agricultural Experiment Station.

and 2 to 14 milligrams for lactating cows. The requirement is increased during pregnancy and by lactation, since iodine is secreted in the milk.

Commercially available trace mineralized (TM) salt contains 0.005 to 0.013% iodine, and special mineral supplements may contain more. Each should be fed according to the manufacturer's recommendations, which usually amounts to 1 or 2% of the grain mixture. When only 10 pounds of grain is fed and the TM salt contains only 0.005% iodine, then milking cows may not receive sufficient iodine. Dairymen and feed suppliers need to be more conscious of the iodine content of their supplements so that the milking cows will receive sufficient iodine (i.e. around 10 milligrams/cow/day). The iodine intake from grain containing 1% TM salt at two different levels of iodine is shown in Table 9. Most commercial protein supplements and mineral supplements also contain iodine and may correct the deficiencies in some situations.

TABLE 9—Iodine intake when grain contains 1% salt having two different iodine levels.

Grain fed daily	Salt fed daily	Iodine fed if salt contains 0.005% I.	0.011% I.
lb	lb	mg	mg
1	0.01 (.16 oz)	0.2	0.5
10	0.10 (1.6 oz)	2.2	5.0
20	0.20 (3.2 oz)	4.5	10.0
None	0.06 (1.0 oz)	1.4	3.1
	0.125 (2.0 oz)	2.8	6.2
	0.187 (3.0 oz)	3.2	9.3

Calculation of iodine intake: 1% T.M. (iodinated) salt =0.01 pound or 4.5 grams salt per pound feed. 4.54 g x 0.011% I =0.000499 gram or 0.5 mg I per pound feed. 10 pound feed = 5.0 milligrams I, etc.

Where calves have been born with goiter (big neck) or sometimes weak or dead and maybe hairless, it may be advisable to feed lactating and pregnant cows more iodized salt or a salt with a higher iodine content. Since iodine is used in the synthesis of thyroxine (a hormone which controls metabolic rate and affects other hormone systems) cows deficient in iodine fail to exhibit heat periods (estrus) and produce less milk.

Soybean meal is mildly goitrogenic*, and when fed heavily in supplementing all-corn silage rations, an iodine deficiency and goiter may result. In such cases, 20 to 30 milligrams of iodine daily may be required. To avoid iodine deficiency in such cases, it may be necessary to feed a commercial mineral supplement or a special iodine supplement which also contains trace mineral salt.

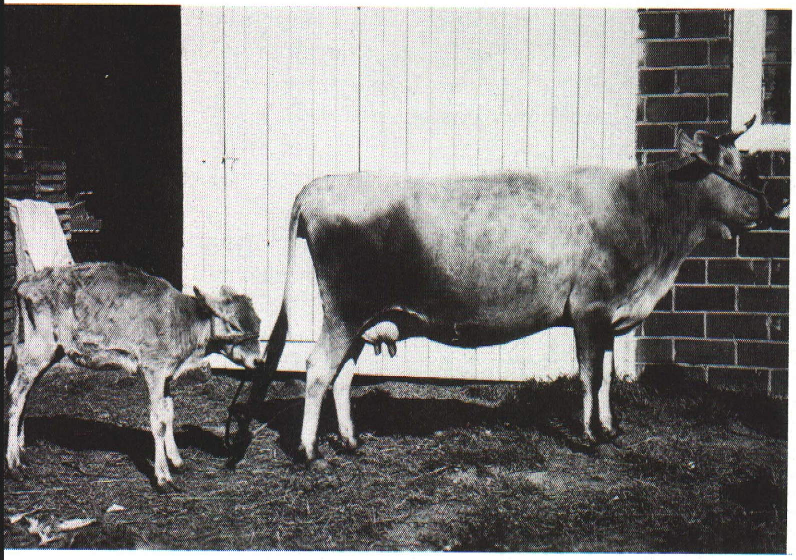
Common salt can be iodized by mixing 1/3 ounce (about 10 grams) of potassium iodide (KI) with 100 pounds of salt. The resulting mixture will contain 0.016% iodine. Less than a one-month supply should be prepared at one time since KI volatilizes slowly when exposed to air.

Cobalt (Co)

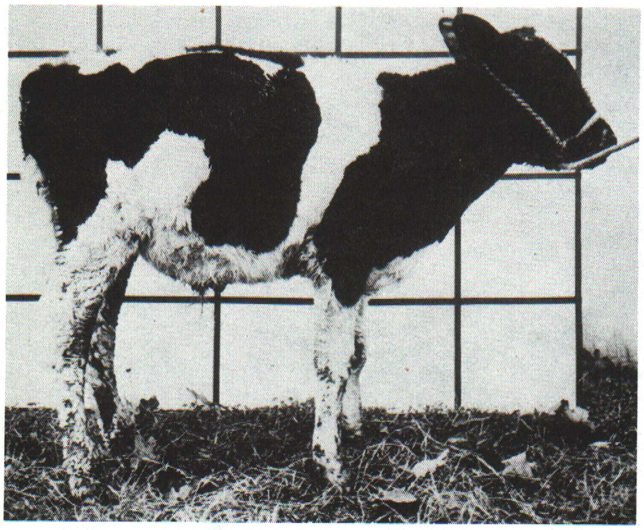
Colbalt is essential for the synthesis of vitamin B_{12} by rumen microorganisms. Calves fed milk from cows eating a cobalt-deficient diet develop deficiency symptoms. The symptoms are not specific and can be found in other deficiency diseases. They include loss of appetite, listlessness, retarded growth or loss of weight, anemia, pale mucous membranes, muscular incoordination, a stumbling gait, rough hair coat, decline in milk production and high calf mortality. A sub-clinical deficiency may interfere with milk production and is difficult to diagnose.

The minimum cobalt requirement is unknown, but rations that provide 0.07 to 0.1 ppm (parts per million) appear adequate to relieve deficiency symptoms. Mixing 1 ounce of cobalt sulfate or 3/4 ounce of cobalt carbonate with 100 pounds of salt is a satisfactory means of providing supplemental cobalt. Most trace mineralized salts and mineral supplements contain sufficient cobalt.

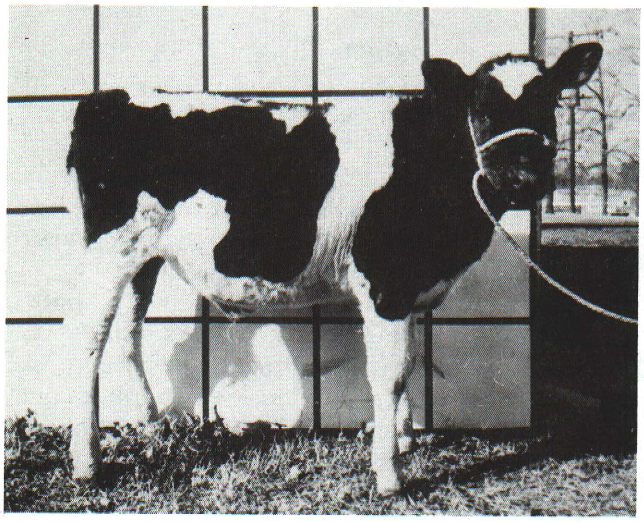
Feeds produced in much of Northern Michigan and some areas of Southern Michigan are known to be low in cobalt.



Cobalt deficiency in the ration of the cow causes low levels of Vitamin B_{12} in the milk. The calf fed the milk fails to eat and grow normally. A similar emaciated condition of adult cattle develops when fed cobalt deficient rations, although other deficiencies can cause a similar condition. (C. F. Huffman, Michigan Agricultural Experiment Station.)



(Above) Calf showing loss of hair on legs and severe scaliness, cracking and thickening of the skin as a result of zinc deficiency. (Below) The same calf after receiving supplemental zinc. (Miller et al., Georgia Agricultural Experiment Station.



Manganese (Mn)

Manganese deficiency has been shown to cause irregularity or absence of the estrus cycle (heat periods) in rats and heifers and a marked delay in the opening of the vaginal orifice. Resorption of fetuses, birth of dead or weak offspring, poor udder development and almost complete absence of milk secretion have also been attributed to manganese deficiency.

Calves born to manganese-deficient cows have exhibited deformed legs (enlarged joints, stiffness, twisted legs and over-knuckling, weak and shortened bones of the foreleg) lowered serum alkaline phosphatase and poor growth.

The minimum suggested requirement for cattle is 20 parts per million (ppm or milligrams per kilogram) of dry feed.

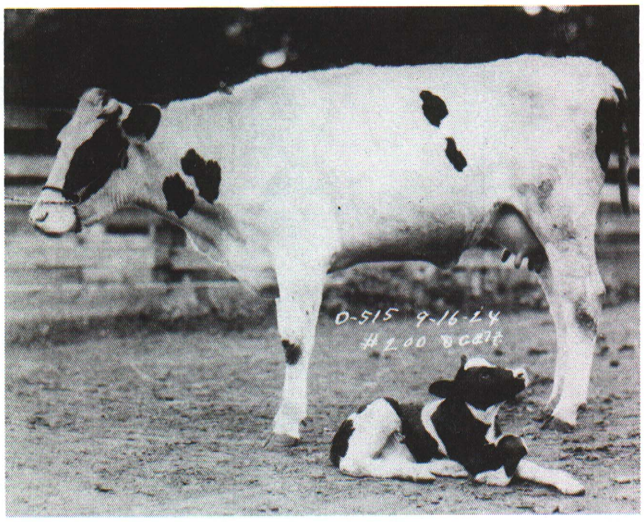
Michigan hay crop forages average about 36 ppm but range from 11 to 300 ppm. About 15% of the forages contain less than 20 ppm. Cereal grains contain only about 5 ppm. Therefore, rations containing considerable amounts of grain can be deficient in manganese unless supplemented with trace mineral salt or mineral supplements containing manganese. The requirement is increased with high intakes of calcium and phosphorus.

Zinc (Zn)

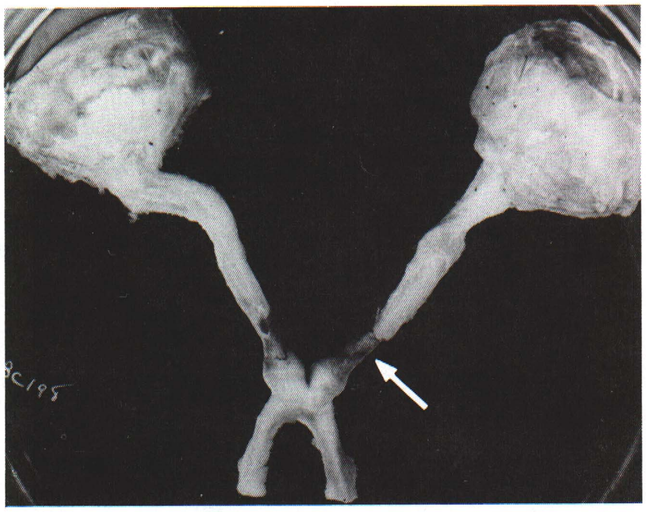
Zinc deficiency in calves can lead to decreased weight gains, lower feed efficiency and listlessness, followed by the development of swollen feet with open scaly lesions, alopecia (loss of hair in patches) and parakeratosis (a general scaly dermatitis) that is most severe on the legs, neck, head and around the nostrils. Wounds may fail to heal normally. In experiments, bull calves fed zinc-deficient rations showed a reduction in size of testicles at 21 weeks of age, but the symptoms disappeared by 64 weeks of age. In contrast, zinc deficiency in rats caused severe atrophy of the testes but no reversal effects were noted when adequate zinc was fed later.

Zinc deficiency has been reported as a cause of poor fertility in cows, but the effects on reproduction have not been adequately studied. Milk production improved substantially when a corn silage ration containing 15 ppm zinc was supplemented with 40 ppm zinc.

The estimated zinc requirement for dairy cattle is 40 ppm in the ration dry matter. The minimum requirement has not been adequately established. There is some evidence that the requirement may be substantially higher on some natural diets than on purified diets used in experiments. Michigan hay crop forages average about 30 ppm of zinc but range from 12 to 100 ppm. Cereal grains average 18 to 20 ppm. Supplementation appears to be necessary in most cases to avoid zinc deficiency.



Vitamin A deficiency in the ration of the dam caused this calf to be born blind and weak.



Vitamin A deficiency causes constriction of the optic foramen (opening) in the skull which pinches the optic nerve (arrow) causing permanent blindness. Nightblindness or inability to see in dim light is usually the first clinical sign of Vitamin A deficiency in cattle.

Vitamins

Carotene and Vitamin A

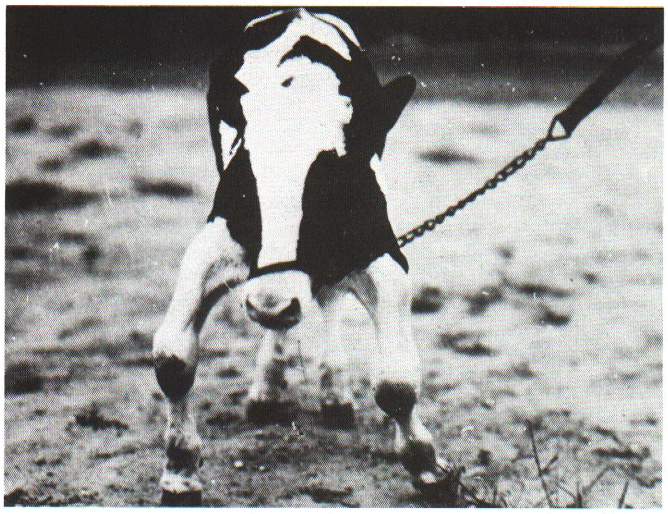
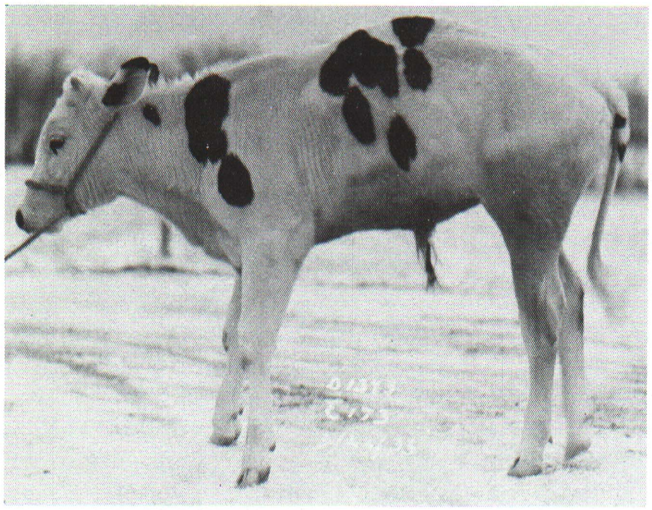
Carotene is an orange pigment occurring in most green and/or orange-colored plants. It is converted to vitamin A in the intestinal wall and/or liver by a specific enzyme. Adults absorb less than 10% of their dietary carotene and 10 to 30% of dietary vitamin A. The newborn can absorb and store 90% of the vitamin A in colostrum.

Vitamin A is carried in the blood by a specific carrier, lipoprotein. It is also re-excreted via the bile, and some constant recycling thus occurs. Vitamin A and carotene are stored in the liver. Concentration in the liver can be reduced one half every 28 to 56 days when dietary sources become nil. Several forms of vitamin A and its metabolites have been described.

Vitamin A has several distinct functions in the body, and different forms of vitamin A have different functions. All forms are eventually degraded to inactive metabolites and excreted in the urine and feces and as CO_2.

Vitamin A is a part of the visual pigment (rhodopsin) where it is attached to the amino acid lysine, in opsin, a protein of the retina and undergoes changes when excited by light. Protein synthesis in intestinal cells and muscles is decreased in vitamin A deficient animals. Vitamin A is necessary for proper reproduction in males and females and influences synthesis of certain hormones. It also has some specific effect on preventing abnormalities in the uterus of pregnant animals and in the testes. Deficient cows may abort during the last quarter of pregnancy.

A reduced rate of growth in vitamin A deficient animals is probably due to secondary effects because vitamin A deficient germ-free rats continue to grow and live for 9 months, but die in 1

Rickets in the calf caused by a lack of Vitamin D in the feed ration. Stiffness of joints, arched back and easily broken bones are typical symptoms of rickets.

month when transferred to a conventional environment. The synonym of "anti-infective vitamin" for vitamin A is probably justified.

Vitamin A also plays a role in mucus formation, bone formation, sulfate incorporation, glycogen synthesis, salivary secretions, epithelial cell integrity and integrity of cell membranes and lysosomes. Excess vitamin A causes cell disintegration similar to vitamin A deficiency.

Requirements vary with the criteria used for adequacy. The more liberal allowances for gestation and lactation are 8 to 20 milligrams per hundredweight (mg/cwt) or about 120 milligrams carotene per cow per day. This is equivalent to 36,000 to 48,000 International Units (IU) of vitamin A (1 milligram carotene is approximately equal to 300-400 IU vitamin A).

Intakes of 640 IU per pound of feed are sufficient for fattening beef steers. This corresponds to 20,000 to 25,000 IU per animal per day. Deficiency symptoms should not occur on intakes ¼ to ½ that level. Trials with milking cows show no advantage in calving interval or milk production with daily supplements of 25,000 IU of vitamin A to normal corn silage-alfalfa hay rations.

Corn silage contains 3 to 9 and hays 6 to 20, milligrams carotene per pound. Assuming values of 6 and 9, then 20 and 13 pounds respectively would furnish the needed 120 milligrams per day. Silage from frozen corn may contain much less or no carotene. Hay that is over 1 year old or excessively weathered or haylage overheated in storage may contain no carotene. Yellow shelled corn contains about 2.2 milligrams of carotene per pound. Corn stored for 2 years contains only 1.1 milligrams per pound, or less.

When cows are fed rations without carotene such as corn cob, bleached hay, overheated silage or straw with or without grain for 60 to 120 days, vitamin A deficiency may occur. Calves are born with no store of vitamin A and must receive colostrum or other sources of vitamin A to avoid deficiency symptoms (slow growth, weakness, increased susceptibility to infection, diarrhea and night blindness).

Calves require a minimum of 3.6 milligrams of carotene or 725 IU vitamin A per 100 pounds live weight for maximum growth and maintenance of normal spinal fluid pressure. Much higher levels (±5,000 IU vitamin A per day) are the usually quoted allowances.

Vitamin D

The best known end effect of vitamin D is proper calcification of the organic matrix of bone although there is no evidence that vitamin D actually participates in that process.

Lack of vitamin D results in low levels of blood Ca and P, high levels of blood phosphatase, reduced growth and anorexia (lack of appetite), deformed and weak bones, high levels of urinary amino acids and phosphorus.

Sunshine (ultraviolet light) converts provitamin D found in skin and dead plant tissue into vitamin D. The placental and mammary transfer is small, but newborn calves and lambs normally contain sufficient vitamin D for the first 4 to 6 weeks of life. Cattle or calves kept in dark quarters and fed rations devoid of vitamin D (grains, beet pulp, citrus pulp, corn cobs or poor roughages) will develop vitamin D deficiency symptoms in 2 to 5 months.

If dietary levels of Ca and P are adequate, the vitamin D requirement is small. The daily dietary requirement is about 200 IU for calves, but about 400 IU per 100 pounds of body weight is the recommended level so that cows need about 4,000 to 5,000 IU/day. Like vitamin A, excess vitamin D is toxic. As little as 5 to 100 times the daily requirement has produced excess calcification. Most silages and hays contain over 100 IU per pound. Intake from these sources plus sunshine should provide dairy cattle with sufficient vitamin D. However, vitamin D deficiency in calves (rickets) occurs occasionally under farm conditions.

Vitamin D is readily absorbed into the blood, bound to an alpha-2-globulin and carried to and stored in the liver. The liver converts vitamin D to 25-hydroxycholecalciferol and the kidney converts this to 1, 25-dihydroxycholecalciferol. This active vitamin D metabolite is then transported to the bone and intestine by the same blood alpha-2-globulin. In these organs, 1,25-dihydroxycholecalciferol acts on the cell nucleus material to initiate mechanisms so the cell can make a specific protein necessary for calcium transport through that cell. The result is increased calcium and phosphorus levels in plasma and presumably in cells responsible for bone formation.

Vitamin E

Alpha-tocopherol (vitamin E) and other tocopherols are biological antioxidants in plants and animals. Recent evidence indicates that alpha-tocopherol has other specific functions in hydrogen transfer, control of unsaturated fatty acid oxidation, membrane stability and pancreatic function.

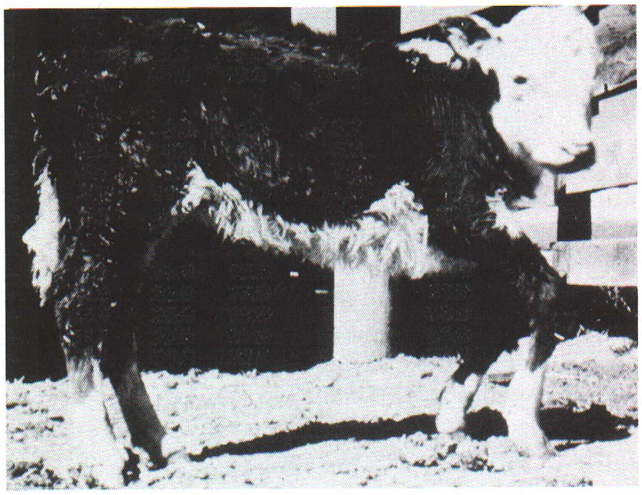
The usual symptoms in cattle due to lack of vitamin E are muscular dystrophy (white muscle disease) and heart muscle lesions. These can be produced in calves or lambs by feeding diets high in unsaturated fats to the young or the female. Calves with this deficiency have muscular weakness, drink milk slowly, fail to stand and show a shivering-like action of their muscles.

The requirement for cattle is not known, but calves require less than 40 milligrams per day. Corn silage contains ±0.4 mg alpha-tocopherol per pound, hays 5 to 20, green feeds 10 to 15 and corn 2 to 9 mg alpha-tocopherol per pound. Artificially dried corn contains very little tocopherol. Cows fed on low tocopherol rations for several years showed no symptoms except unexpected death and heart lesions. Cows fed normal rations have adequate plasma and liver levels. Claims have been made for increased beef gains with tocopherol supplementation. Many ration variables might influence the tocopherol status, and supplemental vitamin E may be necessary to prevent deficiency symptoms under some conditions.

Selenium and vitamin E have some synergistic as well as independent actions that have not been adequately explained. Selenium deficiency has been shown to result in liver necrosis (deterioration) and a high death loss in baby pigs. Deficient calves and lambs develop nutritional muscular dystrophy which is not corrected by vitamin E supplementation.

Effects on cattle are not as well known. However, under some conditions an injectable mixture of selenium and vitamin E has been effective in preventing the birth of dead or weak calves and reducing the incidence of retained placentas in cows. Linseed meal and wheat bran from the Western wheat regions are good sources of selenium. Including 10 to 20% of these ingredients in the grain ration may be desirable under some conditions. Selenium is toxic at relatively low levels, and for that reason selenium salts have not been permitted for use as feeding ingredients by the Food and Drug Administration.

Feeding vitamin E (1,000 to 2,000 IU) or 1 to 2 grams of d-alpha tocopherol has been effective in



White muscle disease caused by either Vitamin E or selenium deficiency.

preventing oxidized flavor in milk (cardboard flavor) which probably is caused by an excessive amount of copper or other oxidizing agents in the feed and milk.

Vitamin K

The only well-defined function of vitamin K in higher animals is the maintenance of normal blood plasma levels of four proteins (prothrombin, factors VII, IX and X) necessary for proper blood coagulation. Those proteins are made in the liver, and the level of these factors in plasma and liver is related to the vitamin K status of the animal.

Vitamin K functions in the final synthesis of these very labile (reactive) proteins (half-life less than 6 hours) and not in their degradation. This function of vitamin K can be completely blocked by dicoumarol, warfarin and similar compounds. Vitamin K may be involved in energy transfer mechanisms, membrane structures and pancreatic function.

Ruminal and intestinal bacteria make considerable quantities of compounds having vitamin K activity. Variations in production and absorption as influenced by diet have not been studied. Vitamin K occurs in usual feeds, and animal requirements are not known.

Hemorrhages throughout the body of animals consuming moldy sweet clover hay or corn infested with the toxins from certain strains of Fusarium mold are the only characterized symptoms of vitamin K deficiency noted in farm animals. Increasing the level of vitamin K to about 4 grams or more per ton of feed is suggested under these conditions.

Vitamin B Complex

The suckling ruminant depends on milk for its supply of B vitamins, but the animal with a functioning rumen is largely independent of a dietary source of the "B" vitamins. A requirement of thiamine, riboflavin, pyridoxine, folic acid, nicotinamide, biotin, pantothenate and vitamin B_{12} has been found. These are all made in the normal adult rumen. Variations in synthesis due to changes in diet are uncharacterized. Calculations based on rate of synthesis and lack of effects when supplements are fed indicate that rumen synthesis is sufficient. However, B vitamin supplementation or therapy is desirable in convalescent cattle when feed consumption and rumen synthesis commonly are abnormal. B-vitamins are water soluble and readily excreted via the kidney, resulting in practically no reserve supply or storage

Mineral Supplementation

Natural feeds such as forages and grains are the primary source of most minerals. Since forages vary considerably in their mineral content, and grains are low in some minerals, a mineral supplement is usually desirable to insure an adequate concentration of minerals in the ration.

The calcium and phosphorus content of the common mineral ingredients used in commercial supplements are shown in Appendix Table 6. These ingredients are combined in various proportions to formulate commercial mineral supplements or may be included in commercial protein concentrates to provide a completely fortified ration when mixed with farm grains according to directions.

Dicalcium phosphate, steamed bonemeal, and limestone are available from most elevators and feed suppliers for ration supplementation.

Mineral supplements should be selected to balance the ration with elements that may be lacking in natural feeds.

Illustration 2 shows the average concentration of mineral elements in typical alfalfa-bromegrass mixtures and shelled corn and the total concentrations provided by a ration of 50% alfalfa-bromegrass and 50% shelled corn.

Note that the phosphorus content is approximately adequate but borderline in the total ration. About one-half of the forages contain less than 0.27% P; thus they commonly require supplemental phosphorus. The calcium content is more than adequate with this amount of alfalfa in the ration. Monosodium phosphate or a low calcium mineral supplement could be used in this case. When corn silage is the principal forage, supplemental calcium is required. The magnesium content is normally adequate but is occasionally low when the magnesium content of forages is low. Fertilization with high levels of potassium depresses the magnesium content of alfalfa below required levels when the soil is low in magnesium.

Sodium, chlorine, cobalt and iodine are all low or borderline in relation to requirements.

Addition of 1% dicalcium phosphate, and 1% trace mineralized salt to the grain ration usually provides adequate quantities of all of these

Illustration 2. Nutrient requirements in relation to normal concentrations in alfalfa-brome and shelled corn rations. Illustration of deficiencies and supplementation.

Nutrient	Concentration required in total ration (DM basis)	Normal concentrations in Mich. feeds		Normal daily intake from 24 lb hay plus 24 lb corn	Normal concentrations total ration without supplement	Supplemented with 1% TM salt and 1% dical phosphate in grain ration (3.5 oz each)	
		Alfalfa-brome mixture	Shelled corn			Amount furnished	Resulting concen. in total ration DM basis
	%	%	%	lb	%	lb	%
TDN % dry matter	68	60	80	30.8	70	—	—
Net energy Mcal/lb	0.68-0.8	0.52	0.96	32.1	0.78	—	—
Crude protein	13-18	16	8.7	5.4	13.2	—	—
Crude fiber	15-20	31	2.0	7.3	17.8	—	—
Calcium	0.5-0.8	1.1	0.02	0.246	0.60	0.058	0.74
Phosphorus	0.3-0.4	0.27	0.27	0.119	0.29	0.044	0.40
Potassium	0.7	1.9	0.29	0.482	1.2	—	1.17
Magnesium	0.15-0.22	0.22	0.10	0.070	0.17	—	0.17
Sodium	0.11	0.03	0.01	0.009	0.03*	0.088	0.24
Chlorine	0.18	0.23	0.04	0.060	0.146*	0.132	0.47
Sulfur	0.15-0.20	0.28	0.12	0.642	0.156	—	0.15
	ppm†	ppm	ppm	mg	ppm	mg	ppm
Iodine	0.2-0.4	+.1	0.07	3.7	0.18*	11.0	0.79
Manganese	40	36	5.3	423.0	21.0	500.0	46.0
Copper	10	12	4.0	160.0	8.6	45.0	11.0
Cobalt	0.1	0.14	0.005	1.45	0.08	11.0	0.67
Zinc	40	27	12.0	390.0	19.5	300.0	34.5
Iron	100	225	20.0	2450.0	122.0	225.0	134.0

**Indicates deficiency exists without supplementation. Feeds containing less than average concentrations could cause deficiencies of several nutrients under some conditions.*

†ppm = parts per million or mg/kg; therefore, $\frac{\text{PPM x lb feed}}{2.2}$ *=ppm in feed.*

minerals. Similar results could be obtained by using a commercial mineral supplement containing these trace elements with common salt. However, the salt must be provided from one source or another.

While certain supplemented minerals are necessary as indicated above, there is no need to provide supplemental minerals from several sources.

Specific recommendations for supplementing alfalfa-grass and corn silage combinations are shown in the feeding programs in Rations 1, 2 and 3 (pages 31, 32).

Water Requirements

Cattle should have clean, fresh drinking water available at all times. Lack of water or water of poor drinking quality can seriously restrict milk production. Cattle normally consume 3 to 5 pounds of water for each pound of dry feed—100 to 210 pounds or 12 to 30 gallons per head daily. Lactating cows require more water because of the large amount secreted in milk, which contains about 87% water. They will consume about 3 to 5 pounds of water per pound of milk produced. This amount will vary, depending on the moisture content of the feed, the availability of salt, the balance of the ration and palatability of the water. Hard water, containing calcium and magnesium carbonates, had no effect on water consumption or performance of cattle at least up to about 500 ppm or 30 grains of hardness. Softening such water by ionic exchange methods has no effect on consumption or performance of cattle. Water with extremely high levels of all minerals, however, may be unpalatable and finally toxic.

Practical experience and limited research indicate that chickens, swine, cattle and sheep can survive and remain in good health on saline waters containing up to 15,000 ppm of minerals such as the bicarbonates, chlorides and sulphates of sodium and calcium and up to 10,000 ppm for the corresponding salts of potassium and magnesium. The limits of tolerance to alkaline waters, those containing sodium and calcium carbonates, is around 5,000 ppm.

During adjustment to highly mineralized waters, the feed and water intakes, rates of growth and production are depressed. Water begins to decrease in palatability when the total amount of minerals exceeds 500 to 1,000 ppm, depending on the nature of the minerals as indicated above. Nitrates may be contained in well water principally from contamination by seepage of ground water. The U.S. Public Health Service Drinking Water Standards include a limiting value of 45 ppm nitrates as NO_3, for human consumption. The Michigan Department of Health cautions against using water containing above 10 ppm.

The acceptable level of nitrates in water for ruminants has not been determined. However, it is known that ruminants can safely use feeds containing up to 2% of the total ration dry matter intake. This level of intake is equivalent to 6,000 to 7,000 ppm of NO_3 in the drinking water. The small amounts such as 40 to 50 ppm occasionally found in farm water, probably are of no significance to the health of cattle or sheep.

Pre-Balanced Hay–Corn Silage Rations

The feeding program shown in Rations 1, 2 and 3 are balanced for three different qualities of hay (or haylage) and normal consumption of corn silage with or without urea.

The tables present information on the amount of grain ration to be fed daily, the percent protein required in the grain ration, the percent of 44% protein supplement (such as soybean meal) needed in the grain ration and the kind and amount of mineral supplement needed in the grain ration.

To find this information for a given situation, simply estimate the quality of hay or haylage being fed which most nearly corresponds to Ration 1, 2 or 3. Then estimate the amount of hay, haylage (or both) being fed as pounds of hay-equivalent per head daily. Find this figure in the top line of the table. All figures in that column (below the amount of hay fed) pertain to that feeding program (See Ration Tables 1, 2 and 3).

To convert haylage or silage to hay-equivalent, multiply the wet weight by the factor shown below:

Feed	Moisture %	Dry Matter %	Factor (multiply by)	= Hay equivalent
Hay	10-12	88-90		1.0
Haylage	40	60	0.66	1.0
Haylage	50	50	0.55	
Haylage	60	40	0.44	
Wilted silage	65	35	0.41	
or				
Corn silage	70	30	0.33	(or divide weight by 3)
Direct cut silage	75	25	0.28	

Ration Rx 1 — Feeding programs for excellent quality alfalfa (18.4% protein) and corn silage. Balanced for 60 lb. milk per day (1300 lb. cows)

Forage per cow per day					10# urea (4.5# N)/ton in corn silage		
Hay, lb.	26	20	15	10	10	5	0
or							
Haylage, lb.	(46)	(35)	(26)	(18)	(18)	(9)	0
Corn silage, lb.	0	30	40	50	50	56	65
Concentrate mix							
Shelled corn	895	795	732	677	813	626	566
Soybean meal	89	185	248	300	161	200	254
Oats	—	—	—	—	—	150	150
TM salt	6	7	7	7	7	7	6
Dical phosphate	10	12	12	12	14	13	12
Limestone	—	—	—	5	5	5	10
Batch, lb.	1000	1000	1000	1000	1000	1000	1000
Protein %	12.2	15.7	17.4	20.0	14.8	16.5	19.1
Protein, % of total ration DM	14.3	14.3	14.7	15.2	15.3	15.7	16.2
Concentrate/cow/day							
For 60 lb. milk, lb.	23	18	18	18	18	19	20

Ration Rx 2. Feeding programs for average quality alfalfa-grass hay or haylage (15% protein, dry basis) and corn silage.

						Urea corn silage 10#urea/ton	
Forage per cow per day							
Hay, lb.	26	20	15	10	5	10	5
or							
Haylage (50% DM), lb.	(46)	(35)	(26)	(18)	(9)	(18)	(9)
Corn silage (32% DM), lb.	0	20	37	47	56	50	55
Concentrate mix							
Shelled corn	895	845	766	700	633	788	613
Soybean meal	91	139	217	280	343	191	212
Oats	—	—	—	—	—	—	150
TM salt	5	6	7	7	7	7	6
Dical phosphate	9	10	11	11	11	13	12
Limestone	—	—	—	2	6	2	6
Batch, lb.	1000	1000	1000	1000	1000	1000	1000
Protein, % (87% DM)	12.2	13.9	16.5	19.1	20.9	15.7	16.5
Protein, % of total ration DM	14.3	14.6	15.7	15.2	15.7	15.2	15.6
Concentrate/cow/day For 60 lb. milk, lb.	26	22	20	20	20	20	20

Cows producing above 60 lb. milk per day may need additional protein.
High moisture corn, or ground ear corn can be substituted for shelled corn.

Ration Rx 3. Feeding programs for low quality grass hay (10% protein dry basis) and corn silage.

					Urea corn silage 10# urea/ton	
Forage per cow per day						
Hay	21	15	10	5	10	5
or						
Haylage (50% DM), lb.						
Corn silage (32%DM), lb.	0	32	43	54	42	63
Concentrate mix						
Shelled corn, lb.	797	708	665	617	614	590
Soybean meal, lb.	184	268	319	355	210	232
Oats	—	—	—	—	150	150
TM salt	5	6	6	6	6	6
Dical phosphate	7	9	9	10	10	11
Limestone	8	9	10	12	10	11
Batch, lb.	1000	1000	1000	1000	1000	1000
Protein, % (87% DM)	15.7	15.7	20.0	21.7	16.5	17.4
Protein, % of total ration DM	14.3	14.5	15.1	15.6	15.0	15.6
Concentrate/cow/day For 60 lb. milk, lb.	29	22	21	20	22	21

III. Poisonous Plants and Compounds

OCCASIONALLY, CATTLE CONSUME poisonous (toxic) substances that are contained in the feed or may be accidentally available in their surroundings. Heavy metals, certain pesticides and herbicides, some molds and poisonous plants are either toxic to livestock or may contaminate the meat and milk products. Dairymen must be alert to these possibilities in order to prevent heavy economic losses.

Poisonous Plants

Several hundred plants are known to be toxic to livestock under some conditions. Fortunately, cattle that are fed adequate amounts of other feeds will seldom eat enough of a poisonous plant to do any harm. However, where feed is scarce, cattle will eat whatever is available and may consume enough toxic compounds to produce harmful or fatal effects. The occurrence of plant poisoning is rare in Michigan.

Alkaloids (alkali-like basic nitrogen-containing ring-structured organic compounds) generally affect the nervous system or cause liver damage. Symptoms may be different for different alkaloids.

Some typical plants that contain alkaloids are hemlock, poison hemlock, Indian tobacco, tobacco, prickly poppy, poppy, dutchman's breeches, bloodroot, ergot (on rye), lupine, tomato and potato plants, nightshade, staggergrass and larkspur.

Glycosides such as prussic acid are composed of a sugar molecule attached to a toxic compound such as hydrocyanic acid. These compounds can be metabolized by rumen microbes; thus fairly high concentrations in the feed are required to produce toxic effects. Sorghums and their hybrid crosses are known to contain fairly high levels of hydrocyanic acid under some conditions. Ordinarily they present no problem when fed to cattle under Michigan conditions, although occasionally prussic acid poisoning is suspected. Prussic acid poisoning is not easily produced experimentally even when frosted sorghum or sudangrass is fed to cattle.

Coumarin, a natural substance in sweet clover, is changed to dicoumarol by a white mold in poor storage conditions. Dicoumarol antagonizes the vitamin K and prevents blood clotting, causing hemorrhage and death in cattle.

Oxalates such as oxalic acid contained in some plants may cause depletion of blood calcium, resulting in nervous symptoms, reduced blood coagulability and acute nephritis (inflammation) of the kidney. Toxicity is less likely with ruminants than with other species because the rumen destroys large quantities of oxalate. Also, the problem is less likely to occur when the diet contains adequate amounts of calcium. Some plants that contain large amounts of oxalate are beet and mangold (tops), halogeton, sorrel, purslain, rhubarb, dock, Russian thistle and greasewood. None of these is normally fed in large amounts to cattle.

Resins in some plants directly irritate nervous or muscle tissue. Resin content of plants varies widely. Plants known to contain toxic levels are milkweed, marshuane, water hemlock, laurel and Labrador tea.

Plants may contain any number of toxic substances. Fortunately, most feedstuffs commonly used for cattle seldom contain enough toxic plants to be harmful.

HEAVY METALS

(Lead, Mercury, Arsenic)

Cattle or calves commonly contract lead poisoning as a result of licking fences or buildings painted with lead-containing paint. Old paint pails, old batteries and lead arsenate are other sources of lead poisoning. Lead, arsenic and mercury are toxic and cause coagulation of blood and tissue proteins particularly in the gut, liver, kidney and brain. Toxicity symptoms include neuromuscular incoordination, convulsions and death and are similar for all heavy metals.

The main source of mercury poisoning is from feeding grain seed treated with methyl mercury for control of fungi such as rust and smut. Dry cell batteries are another source. The meat from livestock contaminated with mercury must not be used for human consumption.

MOLDY FEEDS (Mycotoxins)

Mold that develops on feedstuffs in the field or in storage must be considered a hazard to livestock. Although many kinds of molds are not toxic to cattle, some are very toxic.

Aflatoxins

Aflatoxins are toxic chemicals produced by the fungus Aspergillis flavis and certain other molds. They may be found in grains stored under poor conditions of high moisture and little ventilation, but these or other mold toxins may also be found in standing grain during a wet harvest season.

Calves fed aflatoxin develop pale livers, typical of fatty liver degeneration, greatly enlarged adrenal glands and enlarged bile ducts. In tests, significant increases occurred in a serum alkaline phosphatase enzyme at dose levels of 0.01 milligrams of aflatoxin B_1 per kilogram of body weight and above. Calves refused to eat grain containing aflatoxin B_1 until it was mixed with other palatable feeds, but even then with reluctance. Little is known about the levels in feed that are toxic to adult cattle, although cattle apparently can tolerate more than simple-stomach animals and developing young stock.

Aflatoxins produce a "green-gold" fluorescence when examined under long ultraviolet light. Once detected in the feed, the concentration can be determined chemically. Recent evidence indicates that treating moldy feeds with ammonia (0.5%) destroys the aflatoxin.

F-2 Estrogenic Factor

Fusarium graminearum (Gibberella zeae), a fungus that grows in cribbed corn exposed to the weather, and *Fusarium maniliforme*, which affects corn ears while growing in the field, produce a toxin that has estrogenic effects on livestock. Reported effects include abortions, and/or infertility in dairy cows and sows; shrunken testes in young male pigs; vulvovaginitis, prolapse of the vagina, and fetal resorption in sows, and a drop in milk production in dairy cattle. Massive internal hemorrhages have also been reported to cause death of cattle fed feed heavily infested with another mold toxin called T-2. Bloody urine and feces may be evidence of T-2 toxicity.

Many other species of molds may produce toxicities in the young, more sensitive species such as ducklings. In general, ruminants appear to be less susceptible than other species.

There are no safe guidelines for feeding moldy grain. The feeder must proceed cautiously, recognizing that toxicities can occur. In such cases the moldy feed must be withdrawn immediately and veterinary assistance found promptly. Extensive dilution of somewhat moldy feeds by mixing with other sound feed may help to reduce the economic loss when a considerable amount of the feed supply has been infested with molds.

Early planting to allow harvesting in better weather and proper drying and storage are the safest way to avoid mold development.

PESTICIDES

Occasionally cattle have become contaminated with chlorinated hydrocarbon compounds such as DDT, dieldrin, heptachlor, PCB's or plasticizers, etc. These types of compounds are fat-soluble and thus are collected in the body fat deposits and excreted in the milk. Once an animal is contaminated, elimination of pesticides via milk and feces is a slow process. Dairymen must be very cautious about feeds that could be contaminated with insecticides either by direct application or by drift from aerial application. Avoid using any chlorinated hydrocarbon as an insecticide on or around dairy cattle.

Since these compounds have largely been banned from use in agriculture, there is a shift to the use of carbamate or organic phosphate insecticides. These so-called bio-degradable pesticides will present new problems. First, organic phosphate insecticides such as methylparathion are much more toxic than most of the hard pesticides. Consequently, the risk of acute poisoning to humans and livestock is much greater. Secondly, the bio-degradables are not completely broken down in the environment.

Herbicides improperly used on livestock farms can present serious problems. Although herbicides are not generally considered to be as poisonous to livestock as insecticides, they can interfere with reproduction. It is known that 2,4,5,T and possibly 2,4,D cause birth deformities in animals. In some instances, dairymen have suspected that triazine caused abortion and stillbirths in cows. Although extensive data on the effects of herbicides on reproduction in dairy cattle is lacking, it appears herbicides can cause reproductive problems in cattle.

APPENDIX TABLE 1—Daily Nutrient Requirements of Lactating Dairy Cattle

Body weight	Dry feed	Protein Total	Protein Digestible	Energy NE lactating cows	TDN	Ca	P	Carotene	Vitamin A
lb.	lb.	lb.	lb.	MCal.[a]	lb.	gm.	gm.	mg.	1000 IU
Maintenance of Mature Lactating Cows[b]									
770	11.0	1.0	.48	6.9	6.2	14	11	37	15
880	12.1	1.1	.54	7.6	6.8	17	13	42	17
990	13.2	1.3	.60	8.3	7.5	18	14	48	19
1100	14.3	1.4	.66	9.0	8.1	20	15	53	21
1210	15.4	1.5	.71	9.6	8.8	21	16	58	23
1320	16.5	1.6	.76	10.3	9.2	22	17	64	26
1430	17.6	1.7	.80	10.9	9.9	23	18	69	28
1540	18.7	1.8	.86	11.6	10.5	25	19	74	30
1650	19.8	1.9	.90	12.2	11.0	26	20	79	32
1760	20.9	2.0	.95	12.8	11.7	27	21	85	34
Maintenance and Pregnancy (Last two months of gestation)									
770		1.25	.70	8.7	7.9	21	16	67	27
880		1.43	.78	9.7	8.8	23	18	76	30
990		1.60	.88	10.7	9.7	26	20	86	34
1100		1.7	.95	11.6	10.6	29	22	95	38
1210		1.9	1.02	12.6	11.4	31	24	105	42
1320		2.00	1.10	13.5	12.3	34	26	114	46
1430		2.11	1.17	14.4	13.2	36	28	124	50
1540		2.2	1.22	15.3	13.9	39	30	133	53
1650		2.4	1.31	16.2	14.7	42	32	143	57
1760		2.5	1.39	17.0	15.6	44	34	152	61
Milk Production (Nutrients required per lb. of milk)[c]						g./lb.			
2.5		.066-.072	.042	0.27	0.255	1.09	.77		
3.0		.070-.077	.045	0.29	0.280	1.14	.82		
3.5		.074-.082	.048	0.31	0.305	1.18	.86		
4.0		.078-.087	.051	0.33	0.330	1.23	.91		
4.5		.082-.092	.054	0.35	0.355	1.27	.96		
5.0		.086-.098	.056	0.38	0.380	1.32	1.0		
5.5		.090-.103	.058	0.40	0.405	1.36	1.04		
6.0		.094-.108	.060	0.42	0.430	1.40	1.09		

a) The energy requirements for maintenance, reproduction, and milk production of lactating cows are expressed in terms of NE lactating cows.

b) Protein allowances recomended by the 1971 National Research Council are as follows: pounds total protein/pound milk: 3.0% = .070; 3.5%= .074; 4.0% = .078; 4.5%= .082; 5.0% = .086; 5.5% = .090; 6.0% = .094 lb protein/pound milk. These may be desirable for extremely high producing cows. Maintenance of lactating cows = 0.085 MCal NE lactating cows/kg. ¾. To allow for growth, add 20% to the maintenance allowance during the first lactation and 10% during the second lactation.

c) The energy requirement is presented as the actual amount required with no adjustment to compensate for any reduction in feed value at high levels of feed intake.

APPENDIX TABLE 2—Daily Nutrient Requirements for Growing Dairy Cattle

Body weight	Age	Daily gain	Dry feed	Protein Total	Protein Digestible	Energy NE_m	Energy NE_{gain}	TDN	Ca	P	Carotene	Vitamin A	Vitamin D
lb.	week	lb.	lb.	lb.	lb.	MCal.	MCal.	lb.	gm.	gm.	mg.	1000 IU	IU
Growing Heifers (Large Breeds)													
88		0.4	1.1[a]	0.24	0.22	0.9	0.4	1.1	2.2	1.7	4.2	1.7	265
100		0.6	1.3[a]	0.3	0.26	1.1	0.5	1.3	3.2	2.5	4.8	1.9	300
121	5[b]	0.9	2.6	0.4	0.32	1.3	0.6	2.0	4.5	3.5	5.8	2.3	360
65	10	1.65	4.6	0.7	0.54	1.5	0.9	3.3	9.1	7.0	7.9	3.2	495
220	15	1.6	6.4	0.8	0.57	2.0	1.1	4.4	10.9	8.4	11.0	4.0	660
330	24	1.6	9.0	1.0	0.65	3.1	1.5	5.9	15.0	12.0	16.0	6.0	990
440	34	1.6	11.7	1.1	0.73	4.1	1.8	7.5	18.0	14.0	21.0	8.0	1320
550	43	1.6	14.3	1.2	0.80	4.8	2.2	8.8	21.0	16.0	26.0	10.0	--
660	53	1.6	16.5	1.4	0.87	5.6	2.5	9.9	24.0	18.0	32.0	13.0	--
770	62	1.6	18.5	1.6	0.95	6.2	2.8	10.8	25.0	19.0	37.0	15.0	--
880	72	1.6	20.5	1.8	1.02	6.9	3.1	11.4	26.0	20.0	42.0	17.0	--
990	82	1.5	20.9	1.9	1.09	7.5	3.1	11.7	27.0	21.0	48.0	19.0	--
1100	93	1.3	20.9	2.0	1.11	8.1	2.9	11.7	27.0	21.0	53.0	21.0	--
1210	107	0.9	19.6	2.0	1.04	8.7	2.0	11.0	26.0	20.0	58.0	23.0	--
1320	133	0.3	18.9	1.8	0.89	9.3	0.7	9.5	24.0	18.0	64.0	26.0	--

Table continued on next page

APPENDIX TABLE 2—Daily Nutrient Requirements for Growing Dairy Cattle (Continued)

Body weight	Age	Daily gain	Dry feed	Protein		Energy		TDN	Ca	P	Carotene	Vitamin A	Vitamin D
				Total	Digestible	NE_m	NE_{gain}						
lb.	week	lb.	lb.	lb.	lb.	MCal.	MCal.	lb.	gm.	gm.	mg.	1000 IU	IU
Growing Heifers (Small Breeds)													
44		0.2	0.6[a]	0.15	0.13	0.6	0.2	0.7	1.1	0.8	2.1	0.8	130
55		0.3	0.9[a]	0.2	0.18	0.8	0.3	0.9	1.5	1.1	2.6	1.0	165
77	5[b]	0.66	1.8	0.3	0.24	0.9	0.5	1.3	3.2	2.5	3.7	1.5	230
110	10	1.1	2.6	0.5	0.35	1.0	0.9	2.0	4.9	3.8	5.3	2.1	330
165	17	1.2	3.7	0.6	0.42	1.5	1.0	2.6	7.0	5.4	7.9	3.2	495
220	23	1.2	5.3	0.7	0.46	2.1	1.1	3.5	9.0	7.0	11.0	4.0	660
330	36	1.2	7.9	0.9	0.54	3.7	1.3	5.0	12.0	9.0	16.0	6.0	990
440	49	1.2	10.5	1.0	0.62	4.1	1.6	6.4	15.0	11.0	21.0	8.0	1320
550	62	1.2	13.4	1.2	0.70	4.8	1.9	7.7	17.0	13.0	26.0	10.0	--
660	76	1.2	15.0	1.3	0.73	5.6	2.0	8.4	19.0	14.0	32.0	13.0	--
770	93	0.8	14.5	1.3	0.70	6.2	1.5	8.1	19.0	14.0	37.0	15.0	--
880	121	0.3	14.1	1.2	0.64	6.9	0.7	7.9	19.0	14.0	42.0	17.0	--
990	192	0.1	13.4	1.3	0.64	7.5	0.5	7.5	19.0	14.0	48.0	19.0	--
Growing Bulls (Large Breeds)													
88		0.4	1.1[a]	0.24	0.22	0.9	0.4	1.1	2.2	1.7	4.2	1.7	265
100		0.6	1.3[a]	0.3	0.26	1.1	0.5	1.3	3.2	2.5	4.8	1.9	300
121	5[b]	0.9	2.6	0.4	0.40	1.3	0.6	2.0	4.5	3.5	5.8	2.3	360
165	9	1.8	4.6	0.7	0.56	1.6	1.0	3.3	9.7	7.5	7.9	3.2	495
220	13	2.2	7.0	1.0	0.70	2.1	1.3	4.8	13.0	10.0	11.0	4.0	660
330	20	2.2	10.0	1.1	0.78	3.2	1.8	6.6	18.0	14.0	16.0	6.0	990
440	27	2.2	13.0	1.3	0.86	4.5	2.2	8.4	21.0	16.0	21.0	8.0	1320
550	34	2.2	16.0	1.5	0.95	6.0	2.7	9.9	24.0	18.0	26.0	10.0	--
660	41	2.2	19.1	1.6	1.02	7.2	3.0	11.4	27.0	20.0	32.0	13.0	--
770	49	2.2	22.4	1.8	1.10	8.1	3.4	13.0	29.0	22.0	37.0	15.0	--
880	56	2.2	26.0	2.0	1.19	9.0	3.8	14.5	30.0	23.0	42.0	17.0	--
990	63	2.2	27.5	2.3	1.30	9.8	4.1	15.4	30.0	23.0	48.0	19.0	--
1100	70	2.0	28.6	2.4	1.34	10.6	4.0	16.0	30.0	23.0	53.0	21.0	--
1210	79	1.8	30.4	2.5	1.38	11.4	3.8	16.9	30.0	23.0	58.0	23.0	--
1320	88	1.5	30.4	2.6	1.39	12.1	3.5	16.9	30.0	23.0	64.0	26.0	--
1430	99	1.3	30.0	2.7	1.40	12.9	3.2	16.7	30.0	23.0	69.0	28.0	--
1540	112	1.1	29.5	2.7	1.39	13.6	2.8	16.5	30.0	23.0	74.0	30.0	--
1650	128	0.9	39.0	2.7	1.36	14.4	2.3	16.3	30.0	23.0	79.0	32.0	--
1760		0.7	27.9	2.6	1.25	15.1	1.4	15.6	30.0	23.0	85.0	34.0	--
1870		0.2	26.6	2.3	1.12	15.7	0.6	15.0	30.0	23.0	90.0	36.0	--
Growing Bulls (Small Breeds)													
44		0.2	0.6[a]	0.15	0.13	0.5	0.2	0.7	1.1	0.8	2.1	0.8	130
55		0.3	0.9[a]	0.2	0.18	0.6	0.3	0.9	1.5	1.1	2.6	1.0	165
77	4[b]	0.6	1.8	0.3	0.24	0.7	0.5	1.3	3.2	2.5	3.7	1.5	230
110	8	1.4	3.1	0.6	0.44	1.0	1.1	2.2	6.5	5.0	5.3	2.1	330
165	13	1.6	4.4	0.8	0.53	1.5	1.3	3.1	8.4	6.5	7.9	3.2	495
220	18	1.6	6.2	0.9	0.56	2.1	1.6	4.2	11.0	8.0	11.0	4.0	660
330	28	1.6	9.5	1.0	0.65	3.1	1.9	5.9	15.0	11.0	16.0	6.0	990
440	37	1.6	12.5	1.2	0.73	4.5	2.3	7.5	18.0	14.0	21.0	8.0	1320
550	47	1.6	15.4	1.3	0.80	6.0	2.7	8.8	21.0	16.0	26.0	10.0	--
660	56	1.6	18.0	1.5	0.87	7.2	3.1	10.1	23.0	17.0	32.0	13.0	--
770	66	1.6	20.5	1.7	0.95	8.1	3.4	11.4	24.0	18.0	37.0	15.0	--
880	76	1.5	22.4	1.8	1.00	8.9	3.6	12.5	25.0	19.0	42.0	17.0	--
990	88	1.3	22.9	1.9	1.02	9.8	3.3	12.8	26.0	20.0	48.0	19.0	--
1100	106	0.9	22.0	1.9	1.01	10.6	2.3	12.3	26.0	20.0	53.0	21.0	--
1210	134	0.5	22.0	1.9	0.92	11.4	1.4	12.3	25.0	19.0	58.0	23.0	--
1320		0.2	21.5	1.8	0.85	12.1	0.6	12.1	24.0	18.0	64.0	26.0	--
Veal Calves													
77		1.2	1.5[a]	0.34	0.30	1.0	0.8	1.5	3.0	2.3	3.7	1.5	230
88		1.8	2.4[a]	0.53	0.45	1.5	1.4	2.4	4.8	3.7	5.3	2.1	330
165		2.2	3.1[a]	0.68	0.57	1.9	1.8	3.1	7.9	5.9	7.9	3.2	495
220		2.5	3.7[a]	0.82	0.70	2.3	2.2	3.7	11.1	8.0	11.0	4.0	660
330		2.9	5.3[a]	1.06	0.90	3.0	3.0	5.3	16.0	11.0	16.0	6.0	990
Maintenance of Mature Breeding Bulls													
1100		--	18.3	1.4	0.66	9.5	--	10.1	20.0	15.0	53.0	21.0	--
1320		--	21.1	1.6	0.76	10.8	--	11.9	22.0	17.0	64.0	26.0	--
1540		--	24.0	1.8	0.86	12.3	--	13.4	25.0	19.0	74.0	30.0	--
1760		--	26.4	2.0		13.9	--	14.7	27.0	21.0	85.0	34.0	--
1980		--	28.8	2.2	0.95	15.2	--	16.1	30.0	23.0	95.0	38.0	--
2200		--	31.0	2.4	1.1	16.9	--	17.4	32.0	25.0	106.0	42.0	--
2420		--	33.2	2.5	1.20	18.2	--	18.5	35.0	27.0	117.0	47.0	--
2640		--	35.4	2.7	1.28	19.5	--	19.8	38.0	29.0	127.0	51.0	--
2860		--	37.6	2.9	1.35	20.7	--	21.1	40.0	31.0	138.0	55.0	--
3080		--	39.8	3.0	1.43	21.9	--	22.2	43.0	33.0	148.0	59.0	--

[a]Based on milk replacer. NE_m=Net energy for maintenance.
[b]Weeks of age. NE_{gain}=Net energy for growth or fattening.
Adapted from Table 1, Nutrient Requirements of Dairy Cattle, 4th revised edition, 1971. National Academy of Sciences.

APPENDIX TABLE 3—Nutrient Allowances for Milk Production: Add to Maintenance

Milk Fat:	3.0%				3.5%				4.0%				4.5%+			
	Protein		Energy		Protein		Energy		Protein		Energy		Protein		Energy	
Milk produced daily	DP	TCP	TDN	NEL	DP	TCP	TDN	NEL	DP	TCP	TDN	NEL	DP	TCP	TDN	NEL
lb.	lb.	lb.	lb.	MCal.	lb.	lb.	lb.	MCal.	lb.	lb.	lb.	MCal.	lb.	lb.	lb.	Mcal.
1	.045	.07	.28	.29	.048	.074	.3	.315	.051	.078	.32	.334	.054	.082	.35	.357
5	.20	.35	1.4	1.4	.20	.37	1.5	1.6	.25	.39	1.6	1.7	.27	.40	1.6	1.8
10	.45	.70	2.8	2.9	.48	.74	3.0	3.1	.51	.78	3.2	3.3	.54	.80	3.3	3.6
15	.67	1.0	4.2	4.3	.72	1.1	4.5	4.7	.76	1.2	4.8	5.0	.81	1.2	4.9	5.3
20	.90	1.4	5.6	5.8	.96	1.5	6.0	6.3	1.0	1.5	6.4	6.7	1.1	1.6	6.6	7.1
25	1.1	1.7	7.0	7.2	1.2	1.8	7.5	7.8	1.3	1.9	8.0	8.3	1.3	2.0	8.2	8.9
30	1.3	2.1	8.4	8.7	1.4	2.2	9.0	9.4	1.5	2.3	9.6	10.0	1.6	2.5	9.9	10.7
35	1.6	2.4	9.8	10.2	1.7	2.6	10.5	10.9	1.8	2.7	11.2	11.7	1.9	2.9	11.5	12.5
40	1.8	2.8	10.2	11.7	1.9	3.0	12.0	12.5	2.0	3.1	12.8	13.4	2.1	3.3	13.2	14.3
45	2.0	3.1	11.6	13.1	2.1	3.3	13.5	14.0	2.3	3.5	14.4	15.1	2.4	3.7	14.8	16.1
50	2.2	3.5	13.0	14.6	2.4	3.7	15.0	15.6	2.5	3.9	16.0	16.8	2.7	4.1	16.5	17.8
55	2.5	3.8	14.4	16.0	2.6	4.0	16.5	17.1	2.8	4.3	17.6	18.5	3.0	4.5	18.1	19.6
60	2.7	4.2	15.8	17.5	2.9	4.4	18.0	18.7	3.0	4.7	19.2	20.1	3.2	4.9	19.8	21.4
65	2.9	4.5	17.2	18.9	3.1	4.8	19.5	20.3	3.3	5.0	20.8	21.8	3.5	5.3	21.4	23.2
70	3.1	4.9	18.6	20.4	3.3	5.2	21.0	21.8	3.6	5.5	22.4	23.5	3.8	5.7	23.1	25.0
75	3.3	5.2	20.0	21.8	3.6	5.5	22.5	23.4	3.8	5.8	24.0	25.1	4.0	6.1	24.7	26.8
80	3.6	5.6	21.4	23.3	3.8	5.9	24.0	25.0	4.1	6.2	25.6	26.8	4.3	6.5	26.4	28.6
85	3.8	5.9	22.8	24.7	4.0	6.3	25.5	26.5	4.3	6.6	27.2	28.5	4.6	7.0	28.0	30.3
90	4.0	6.3	24.2	26.2	4.3	6.6	27.0	28.1	4.6	7.0	28.8	30.2	4.9	7.4	29.7	32.1
95	4.3	6.6	25.6	27.6	4.5	7.0	28.5	29.7	4.8	7.4	30.4	31.8	5.1	7.8	31.3	33.9
100	4.5	7.0	27.0	29.0	4.8	7.4	30.0	31.3	5.1	7.8	32.0	33.4	5.4	8.2	32.9	35.7

Milk Fat:			5.0%				5.5%				6.0%			
			Protein		Energy		Protein		Energy		Protein		Energy	
Milk produced daily	Ca	P	DP	TCP	TDN	NEL	DP	TCP	NEL	TDN	DP	TCP	TDN	NEL
lb.	gm.	gm.	lb.	lb.	lb.	MCal.	lb.	lb.	MCal.	lb.	lb.	lb.	lb.	MCal.
1	1.3	1.0	.056	.086	.38	.38	.058	.090	.40	.40	.06	.094	.43	.42
5	7	5	.28	.43	1.9	1.9	.3	.45	2.0	2.0	.3	.5	2.2	2.1
10	13	10	.56	.86	3.8	3.8	.6	.90	4.0	4.0	.6	.9	4.3	4.2
15	20	15	.84	1.3	5.7	5.7	.9	1.3	6.0	6.0	.9	1.4	6.3	6.3
20	26	20	1.1	1.7	7.6	7.6	1.1	1.8	8.0	8.0	1.2	1.9	8.6	8.4
25	32	25	1.4	2.1	9.5	9.5	1.4	2.2	10.0	10.0	1.5	2.3	10.7	10.5
30	40	30	1.7	2.6	11.4	11.4	1.7	2.7	12.0	12.0	1.8	2.8	12.9	12.6
35	45	35	2.0	3.0	13.3	13.3	2.0	3.1	14.0	14.0	2.1	3.3	15.1	14.7
40	52	40	2.2	3.4	15.2	15.2	2.3	3.6	16.0	16.0	2.4	3.7	17.2	16.8
45	58	45	2.5	3.8	17.1	17.1	2.6	4.0	18.8	18.0	2.7	4.2	19.3	18.9
50	65	50	2.8	4.3	19.0	19.0	2.9	4.5	20.0	20.0	3.0	4.7	21.5	21.0
55	71	55	3.0	4.7	20.9	20.9	3.2	4.9	22.0	22.0	3.3	5.1	23.6	23.1
60	78	60	3.3	5.1	22.8	22.8	3.5	5.4	24.0	24.0	3.6	5.6	25.8	25.2
65	85	65	3.6	5.6	24.7	24.7	3.7	5.8	26.0	26.0	3.9	6.1	27.9	27.3
70	91	70	3.9	6.0	26.6	26.6	4.0	6.3	28.0	28.0	4.2	6.6	30.1	29.4
75	97	75	4.2	6.4	28.5	28.5	4.3	6.7	30.0	30.0	4.5	7.0	32.2	31.5
80	104	80	4.5	6.9	30.4	30.4	4.6	7.2	32.0	32.0	4.8	7.5	34.4	33.6
85	110	85	4.7	7.3	32.3	32.3	4.9	7.6	34.0	34.0	5.1	8.0	36.5	35.7
90	117	90	5.0	7.7	34.2	34.2	5.2	8.1	36.0	36.0	5.4	8.5	38.7	37.8
95	123	95	5.3	8.1	36.1	36.1	5.5	8.5	38.0	38.0	5.7	8.9	40.8	39.9
100	130	100	5.6	8.6	38.0	38.0	5.8	9.0	40.0	40.0	6.0	9.4	43.0	42.0

DP=Digestible protein; TCP= total crude protein; TDN=total digestible nutrients.
Ca=calcium
P=Phosphorus
NEL=Net energy for lactation in mega calories or therms
Calculated from Table 2, Nutrient Requirements for Dairy Cattle,National Academy of Sciences, 4th Revised Edition, 1971, Washington, D.C.

SOURCE: National Academy of Sciences, Nutrient Requirements of Dairy Cattle, Fourth Revised Edition, 1971. 201 Constitution Avenue, Washington, D.C. 20418. Members of the Subcommittee on Dairy Cattle Nutrition are: J. K. Loosli, Chairman; E. E. Bartley, W. P. Flatt, N. L. Jacobson, C. H. Noller and M. Ronning. Data presented in Tables 1, 2 and 3 were converted from the metric system to the English system for practical application in the feed industry. Modification consists of eliminating values for digestible energy and metabolizable energy from Tables 1 and 2 and changing the minimum magnesium levels in rations for lactation cows (Table 3) from 0.1% to 0.15–.20%, and suggestion of a minimum Ca:P ratio. Table 3 was also condensed to avoid repetition.

APPENDIX TABLE 4—Nutrient Content of Rations for Dairy Cattle

Nutrients	Concentration in dry matter											
	Heifer Grower Ration		Dry Cow Ration		Lactating Cows						Mature Bull Ration	
					44 lb.		44-66 lb.		66 lb.			
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Protein, %	10.0		8.5		14-16						7.7	
Digestible, %	6.2		5.1		10.5-12.3						3.6	
Energy, Mcal./lb.												
Digestible (DE)	1.3		1.0		1.2-3.1						1.1	
Metabolizable (ME)	1.1		0.9		0.9-1.1						0.9	
NE_m	0.4		0.5								0.54	
NE_{gain}	0.2											
$NE_{lactation}$					.6- .8		.73		.82			
TDN, %	66.0		53.0		60-70		65		70		56.0	
Ether extract, %	2.0		2.0		2.0		2.0		2.0		2.0	
Crude fiber, %	15.0		15.0		17.0		15.0		15.0		15.0	
Calcium, %	.34		.34		.4- .5		.47		.53		.24	
Ca:P ratio	2.3				2.0-4.0							
Phosphorus, %	.26		.26		.3- .4		.35		.39		.18	
Magnesium, %	.08		.15		.15- .2		0.2		0.2		.15	
Potassium, %	.70		.70		0.8		0.8		0.8		0.8	
Sodium, %	.10		.10		.18		.18		.18		.10	
Sodium chloride, %	.25		.25		.45		.45		.45		.25	
Sulfur, %	.20		.20		.20		.20		.20		.20	
Iron, ppm.	100.0		100.0		100.0		100.0		100.0		100.0	
Cobalt, ppm.	0.1	10	0.1	10	0.1	10	0.1	10	0.1		0.1	10
Copper, ppm.	10.0	100	10.0	100	10.0	100	10.0	100	10.0	100	10.0	100
Manganese, ppm.	40.0		40.0		40.0		40.0		40.0		40.0	
Zinc, ppm.	40.0	500	40.0	1000	40.0	1000	40.0	1000	40.0	1000	40.0	1000
Iodine, ppm.	0.1		0.6		0.6		0.6		0.6		0.1	
Molybdenum, ppm.		6		6		6		6		6		6
Fluorine, ppm.		30		30		30		30		30		30
Selenium, ppm.	0.1	5	0.1	5	0.1	5	0.1	5	0.1	5	0.1	5
Carotene, ppm.	4.0		8.0		8.0		8.0		8 0		8.0	
Vit. A equiv., IU/lb.	680		1455		1455		1455		1455		1455	
Vit. D, IU/lb.	114		136		136		136		136		136	

Modification of Table 3, National Academy of Sciences, Nutrient Requirements for Dairy Cattle, 4th ed., 1971.

APPENDIX TABLE 5—Nutrient values of common feedstuffs, as fed basis*.

Feedstuff	Dry matter	Protein	Digestible protein	Crude fiber	TDN**	Net Energy	Calcium	Phos-phorus
	%	%	%	%	%	MCal/lb	%	%
				Roughages				
Alfalfa hay-bud-1/10 bloom	90	17.5	12.8	23	53	.50	1.61	.27
Haylage	50	9.7	7.1	13	29	.27		
Haylage	40	7.7	5.7	10	23	.22		
Silage, wilted	30	5.8	4.3	8	17	.16		
Pasture	20	4.6	2.8	5	15	.11		
Alfalfa hay-½ bloom (average)	90	15.0	10.2	30	50	.45	1.50	.27
Haylage	50	8.3	5.7	17	28	.26		
Haylage	40	6.7	4.5	13	22	.21		
Silage, wilted	30	5.0	3.4	11	17	.15		
Alfalfa hay, full bloom-seed	90	13.0	9.3	32	47	.42	1.13	.20
Haylage	50	7.1	5.2	18	25	.23		
Haylage	40	5.7	4.1	14	20	.18		
Silage	30	4.3	3.1	10	15	.13	.35	.07
Alfalfa, ½ grass, mid bloom (average)	90	12.0	7.7	30	50	.48	.80	.20
Alfalfa hay, stemmy (over 34% fiber)	90	12.0	8.2	36	46	.33	1.07	.20
Barley hay	90	8.0	4.5	25	50	.39	.26	.23
Barley silage	30	2.6	3.1	11	16	.13	.11	.07
Barley straw	90	3.7	0.7	38	42	.22	.33	.10
Bean pods, field, dry	92	7.1	3.5	35	49	.24	.78	.10
Birdsfoot trefoil hay, early bloom	92	14.2	9.9	27	55	.45	1.60	.20
Bromegrass hay, average	90	10.4	5.3	31	49	.38	.42	.20

Table continued on next page

APPENDIX TABLE 5—Nutrient values of common feedstuffs, as fed basis* (Continued)

Feedstuff	Dry matter	Protein	Digestible protein	Crude fiber	TDN**	Net Energy	Calcium	Phos-phorus
	%	%	%	%	%	MCal/lb	%	%
Bromegrass hay, flower stage	90	8.8	4.5	28	52	.50	.33	.28
Bromegrass hay, mature	90	5.9	2.1	32	46	.40	.26	.23
Clover, red, average	88	12.0	7.2	27	52	.41	1.28	.20
Clover, red, leafy	88	13.5	9.2	23	53	.45	1.47	.20
Clover, red, stemmy	88	10.4	5.8	34	49	.36	1.12	.20
Clover and Timothy (30-50% clover)	88	8.6	4.7	30	50	.41	.70	.23
Beet tops, sugar	18	2.7	1.7	9	10	.09	.18	.04
Mixed hay, good, less than 30% legume	88	8.4	4.5	31	48	.37	.59	.18
Oat hay	88	8.2	4.9	28	47	.37	.21	.19
Oat straw	90	4.1	0.7	36	45	.32	.24	.09
Oat silage, early flower, wilted	30	4.2	2.9	10	18	.18	.07	.06
Oat silage, dough stage, direct cut	30	3.6	2.5	10	16	.14	.07	.06
Orchardgrass hay, good	88	8.1	4.2	30	50	.45		
Pea and oat hay						.40		
Corn cobs, ground	90	2.3	0.0	32	46	.40	.11	.04
Corn fodder, green, in tassel	15	1.6	1.0	4	10	.09	.07	.06
Corn fodder, dent, dough to glazing	27	2.1	1.2	6	19	.15	.08	.07
Corn silage, early dough	28	2.4	1.3	6	20	.22	.09	.07
Corn silage, late dough	32	2.6	1.4	7	22	.24	.10	.06
Corn silage with 10 pounds urea/T or NH_3	32	4.3	2.6	7	22	.24	.10	.06
Corn stover, ears removed, dry	90	5.9	2.1	31	52	.27	.54	.09
Quackgrass hay	89	6.9	2.5	35	40	.35	.30	.18
Reed canary grass, hay	90	9.8	5.0	29	45	.40	.33	.16
Rye hay	91	6.7	2.4	36	43	.38	.21	.18
Soybean hay, good	88	14.6	9.8	27	49	.45	1.10	.22
Soybean hay, in bloom or before	88	16.7	12.0	21	52	.50	1.29	.34
Soybean straw	89	3.9	1.1	41	39	.18	—	—
Sundangrass hay, average	89	8.8	4.3	28	49	.38	.36	.27
Timothy hay, all analysis	89	6.6	3.0	30	49	.36	.35	.14
Timothy hay, before bloom	89	9.7	6.1	28	49	.44	.60	.20
Timothy hay, late seed	89	5.3	1.9	31	42	.27	.20	.15
Timothy and clover hay, ¼ clover	89	7.9	4.0	30	50	.39	.58	.20
Vetch and oat hay, ½ vetch	88	11.9	8.4	27	50	.39	.76	.27
Wheat hay	90	6.1	3.3	26	47	.35	.14	.18
Wheat straw	93	3.9	0.3	37	41	.10	.15	.07
Concentrates								
Barley (excluding Pacific Coast)	89.4	12.7	10.0	5	77.7	.77	.06	.40
Beans, field or navy	90.0	22.9	20.2	4	78.8	.77	.15	.57
Beet, pulp, dried	90.8	9.1	4.3	20	68.2	.70	.68	.10
Beet pulp, molasses, dried	92.0	8.1	6.0	15	72.3	.76	.56	.08
Beet pulp, wet	11.6	1.5	0.8	4	8.8	.07	.09	.01
Blood meal	90.5	79.9	56.7	1	58.9	.80	.28	.22
Blood flour	90.8	82.2	78.9	1	81.2	.80	.45	.37
Bone meal, steamed	95.2	12.1	—	—	—	—	28.98	13.59
Brewers dried grains	92.4	25.9	20.7	14	66.0		.27	.50
Brewers grains, wet	23.7	5.7	4.2	4	16.1	.16	.07	.12
Buttermilk, dried	92.5	32.0	28.8	0	83.0	.88	1.34	.94
Corn and cob meal	86.1	7.4	5.4	9	73.2	.73	.04	.22
Corn and cob meal, 30% moisture	70.0	6.0	4.8	6	60.0	.60	—	—
Corn, yellow dent No. 2	85.0	8.7	6.7	2	80.1	.80	.02	.27
Corn, shelled, 30% moisture	70.0	7.1	5.6	2	66.0	.70	—	.33
Corn distillers dried grains	92.3	27.1	19.8	13	82.7	.90	.09	.37
Corn distillers, dried grains with solubles	91.9	27.2	19.9	9	81.0	.96	.17	.68
Corn distillers dried solubles	93.1	26.9	21.3	4	80.2	.96	.35	1.37
Corn gluten feed	90.4	25.3	21.8	7	75.4	.88	.46	.77
Corn gluten meal	90.7	42.9	36.5	4	79.9	.85	.16	.40
Cottonseed meal, expeller	92.7	41.4	34.4	10	73.4	.83	.18	1.15
Cottonseed meal, solvent	91.4	41.6	34.5	11	66.1	.77	.15	1.10
Fish meal, menhaden	92.2	61.3	49.7	1	67.0	.71	5.49	2.81
Hominy feed, white	89.8	11.1	7.9	4	82.9	.84	.02	.58
Hominy feed, yellow	90.7	11.1	7.9	4	83.7	.84	.05	.52
Linseed meal, expeller	90.9	35.3	30.7	9	76.3	.77	.44	.89
Linseed meal, solvent	90.9	35.1	29.5	9	71.0	.72	.40	.83

Table continued on next page

APPENDIX TABLE 5—Nutrient values of common feedstuffs, as fed basis* (Continued)

Feedstuff	Dry matter	Protein	Digestible protein	Crude fiber	TDN**	Net Energy	Calcium	Phos-phorus
	%	%	%	%	%	MCal/lb	%	%
Meat scrap	93.5	53.4	43.8	2	65.4	.67	7.90	4.03
Meat scrap, 50% protein	94.0	50.6	41.5	2	62.2	.65	10.57	5.07
Milk, cow's	12.8	3.5	3.3	0	16.3	.20	.12	.10
Molasses, beet	76.0	6.7	3.5	0	59.6	.71	.16	.03
Molasses, cane	74.5	3.2	0	0	54.9	.71	.89	.08
Molasses, cane, dried	96.1	10.3	—	0	62.6	.75	—	—
Oats	90.2	12.0	8.3	11	70.1	.72	.09	.33
Oats, light weight	91.2	9.0	7.0	15	59.8	.60	—	—
Oats, rolled (oatmeal)	90.8	16.1	14.5	3	91.4	.91	.07	.46
Oyster shell, ground	99.6	1.0	—	—	—	—	38.05	.07
Potato meal, dried	90.3	5.9	2.1	2	65.1	.70	.07	.20
Rape seed	90.5	20.4	17.3	7	117.1	.77	—	—
Rye grain	89.5	12.6	10.0	3	76.5	.70	.10	.33
Rye middlings	89.8	17.1	13.0	6	71.4	.77	.06	.63
Skim milk, dried	93.9	33.5	30.2	0	80.3	.88	1.26	1.03
Sorghum, Kafir, ground	89.8	11.0	8.9	2	81.6	.72	.03	.31
Sorghum, milo	89.0	10.9	8.5	2	79.4	.77	.03	.28
Sorghum, milo, head chops	89.6	9.2	7.0	12	74.3	.63	.14	.26
Soybeans	90.0	37.9	33.7	5	87.6	.88	.25	.59
Soybean meal, 50% protein	91.7	50.4	46.4	3	79.4	.80	.27	.63
Soybean meal, solvent, 44% protein	90.3	45.8	42.1	6	77.2	.80	.32	.67
Sunflower oil meal	94.3	49.5	45.0	5	70.8	.67	.15	.14
Tankage, digester	92.1	59.8	50.8	2	66.1	.66	5.94	3.17
Tankage, digester, with bone	94.1	49.6	42.2	3	64.7	.62	10.97	5.14
Wheat, hard, winter	89.4	13.5	11.3	3	79.6	.80	.05	.42
Wheat, hard, spring	90.1	15.8	13.3	3	80.7	.80	.04	.40
Wheat, soft, winter	89.2	10.2	8.6	2	80.1	.80	.04	.29
Wheat bran	89.1	16.0	13.0	10	65.9	.67	.14	1.17
Wheat flour middlings	89.8	18.4	16.2	4	78.2	.75	.11	.76
Wheat germ oil meal	89.7	27.3	22.9	3	84.1	.83	.07	1.06
Wheat screenings, good grade	90.4	13.9	10.0	4	68.7	.58	.44	.39
Wheat standard middlings	89.7	17.2	14.3	8	76.9	.77	.15	.91
Whey, cheddar cheese	6.9	0.9	0.8	0	6.5	.065	.05	.04
Whey, dried	93.5	13.1	11.8	0	78.4	.78	.87	.79
Yeast, brewers dried	93.4	44.6	38.4	3	72.4	.65	.13	1.43
Yeast, torula, dried	93.3	48.3	41.5	3	69.9	.59	.57	1.68

**To obtain values on a dry matter basis, divide nutrient percentage by dry matter content (as a decimal equivalent). E.G., Yeast = 48.3 (% Protein) ÷ .933 (dry matter) = 51.8.*
***In calculating the values for total digestible nutrients, no digestion coefficients for a few feedstuffs were available, or the data were inadequate. In those instances the digestion coefficients for comparable feedstuffs were used.*

APPENDIX TABLE 6—Composition of calcium and phosphorus supplements.

Mineral supplement	Calcium		Phosphorus		Fluorine
	%	gm/lb	%	gm/lb	%
Bone meal, raw, feeding	22.7	103	10.1	46	0.030
Bone meal, special steamed	28.7	130	13.9	63	—
Bone meal, steamed	30.0	136	13.9	63	0.037
Defluorinated phosphate rock a[1]	21.0	95	9.0	41	0.150 or less
Defluorinated phosphate rock b[1]	29.0	132	13.0	59	0.150
Defluorinated superphosphate	28.3	128	12.3	56	0.150
Dicalcium phosphate	22.0	100	20.5	93	0.050
Disodium phosphate	—	—	8.6	39	—
Limestone (high calcium)	38.3	174	—	—	—
Monocalcium phosphate	16.0	72	24.0	109	0.050
Monosodium phosphate	—	—	22.4	102	—
Oyster shell flour	36.9	167	—	—	—
Spent bone black	22.0	100	13.1	59	—

[1]Because of the limited number of products on the market, figures are given for two types of defluorinated rock which are being produced for livestock feeding.

Glossary

Abomasum—The fourth or "true" stomach of the ruminant; similar to the stomach of simple-stomach animals.

Acetic acid—an organic acid composed of two carbons; fermented in the rumen and used as a source of energy; the acid of vinegar.

Acidosis—Abnormal accumulation of acid in the blood.

Amino Acids—The basic structural chemical units from which proteins are composed.

Bolus—A small wad of food either swallowed or regurgitated for chewing by the cow; a cow's cud.

BUN—Abbreviation for "blood urea nitrogen"; the amount of nitrogen contained in the blood in the form of urea in milligrams per 100 milliliters blood.

Butyric acid—A fatty acid composed of four carbons; one of the three main acids fermented in the rumen and used for energy and milk-fat synthesis.

Calorie—The amount of heat required to raise the temperature of 1 gram of water from 14.5 to 15.5° centigrade; an expression of the potential energy value of food when used in the body.

Co-factor—A substance needed to assist a chemical reaction, or enzyme activity; several mineral elements are co-factors in certain reactions.

Enzyme—A specific compound necessary to assist certain chemical reactions.

Estrogenic—A compound that has an effect on the body similar to estrogen, a hormone produced by the ovaries.

Fatty acids—Part of the structural unit from which fats are composed. True fats are composed of three fatty acids combined with glycerol. There are numerous fatty acids classified according to number of carbons they contain and other properties; acetic is the smallest.

Goitrogenic—A substance that is believed to cause or increase the likelihood of goiter.

Gram—A unit of weight in the metric system; 453.59 grams equal one pound.

Growth factors—Vitamins, minerals, or unknown substances that enhance the growth of microorganisms in the rumen.

Ketones—A class of lipids; intermediate products in the utilization of fats such as acetone, acetoacetic acid, and betahydroxy butyric acid.

Ketosis—A condition caused by an accumulation of ketones in the blood; sometimes called acetonemia.

Kilocalorie — A measure of energy (heat) equivalent to 1000 calories.

Kilogram—A unit of weight in the metric system equal to 1000 grams; equivalent to 2.2 pounds.

Lipids—A broad class of compounds including fats, waxes, and many compounds soluble in ether.

Megacalories—abbreviated MCal; a measure of heat equivalent to one million calories.

Milligram—abbreviated mg; one thousand milligrams equals 1 gram; metric measure.

Milliliter—abbreviated ml; a measure of volume equivalent to one cubic centimeter; 1 ml of water equals one gram by weight; 1000 ml equals one liter.

Molar unit—a single molecule of a substance, such as one molecule of acetic acid ($COOHCH_3$).

Net energy—The amount of energy in calories available for milk production, fattening or work after substracting all losses that occur in digestion and metabolism from gross energy intake.

Nitrogen-free extract (NFE)—a chemical fraction of a feedstuff remaining after subtracting crude protein, crude fiber, ether extract, and ash; generally regarded as the soluble carbohydrate fraction.

Non-protein nitrogen—any nitrogen-containing compound that is not true protein; peptides, amino acids, nitrates, urea and ammonia are nonprotein nitrogen compounds.

Omasum—The third stomach of a ruminant, sometimes called many-plies.

Peptide—An aggregation of amino acids but smaller than a complete protein; a partially degraded protein.

Plasma—The fluid part of blood as opposed to the cells, fat globules and other substances suspended in it.

pH—A measure of the acidity (or alkalinity) of a solution, based on hydrogen ion concentration; pH 7.0 is neutral, below 7.0 is acid, above 7.0 is alkaline.

Propionic acid—A volatile fattly acid (VFA) composed of three carbons; fermented in the rumen; converted to glucose in the liver.

Protein—true proteins are nitrogen-containing compounds containing specific amino acids. Crude protein is estimated as nitrogen X 6.25.

Protein fractions—may be amino acids or peptides.

Protozoa—Microorganisms in the ruminant stomach which form protein; larger than bacteria; help in the digestion of foods.

Provitamin—A substance from which a vitamin is formed, e.g., carotene is provitamin A.

Synergistic—Two compounds working together whose total effect is greater than the sum of the effect of the two compounds taken independently.

Tocopherols—A group of compounds that provide vitamin E; 1 milligram of dl-alpha-tocopheryl acetate equals one international unit (IU) vitamin E.

Trace mineral—Abbreviated TM; a mineral element found in extremely small (or trace) concentrations.

Volatile fatty acids—Abbreviated VFA; The Short chain fatty acids: acetic, propionic, and butyric are volatile in steam and are commonly referred to as VFA's. Combined, they comprise about 95% of the fatty acids fermented in the rumen.