MINERALS AND VITAMINS FOR DAIRY COWS

CIUM · PHOSPHORUS · MAGNE
IUM · SODIUM · CHLORINE · SUL
UR · COPPER · MOLYBDENUM ·
ANGANESE · IRON · SELENIUM
ODINE · COBALT · ZINC · FLUOR
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Minéraux et vitamines pour le bétail laitier.

Traditionally, dairymen have been concerned with the dry matter intake and especially the energy and protein content of the rations that they feed to lactating cows. As the efficiency in milk production has increased, greater attention has been paid to the mineral requirements of dairy cattle. Although the "more the better" rule applies to dry matter consumption, the same rule does not apply to minerals. Too much of one mineral can often disrupt the ability of an animal to absorb other minerals. The "availability" to the animal of minerals in a ration also differs. Availability refers to the ability of an animal to absorb the nutrients from the feedstuff that it consumes. Although the capability to digest protein or energy may vary from 50 to 80%, the ability to utilize the minerals in the ration may vary more widely, from 5 to 100%. The availability of a specific mineral depends on the ration, the chemical form of the mineral, the amount of companion minerals, and the age of the animal.

The growing interest in minerals is also related to the gradual disappearance of minor or trace elements from our soils as a result of intensive cropping. Trace minerals, such as selenium, copper, manganese, and zinc, are often in fairly short supply in certain soils and climatic zones. The usual fertilizer practices do not replace the trace elements that have been depleted by intensive cropping practices. Health problems related to mineral deficiencies are being encountered more often and over larger areas.

Furthermore, two major changes in management systems have contributed to the growing interest in the mineral requirements of dairy animals. First, the increasing reliance on a single forage, such as corn silage, requires a thorough knowledge of the mineral requirements of lactating cows. Second, the number of dairy cows housed indoors or on paved lots all year has increased. The incidental intake of soil and dust no longer contributes to the animals' intake of trace minerals. These animals depend on the dairyman and his feed supplier for all their nutrient requirements, including minerals.

Because the range of minerals in feedstuffs is wide (Table 1), the mineral content of the ration must be formulated from precise information. Forages should be carefully analyzed to identify deficiencies so that the correct mineral supplements are used. District agriculturists, servicemen for feed companies, and provincial extension offices provide assistance by sampling feeds, interpreting results, and recommending the amount and type of minerals required.

Dairy cattle need varying amounts of nearly all minerals. Most of these minerals are provided in natural feedstuffs (Table 1), but supplementation is always necessary for the major minerals calcium, phosphorus, and sodium chloride (common salt). Most forage-based rations provide enough potassium. Adding magnesium and sulfur to rations for dairy cows has become more frequent, particularly where a large part of the ration is corn silage.

Supplements of the trace elements iodine and cobalt are required for dairy cattle rations in nearly all parts of Canada. The addition of

Table 1. The average and range of content of minerals in feeds used on farms in the Fraser Valley

Kind of feed and number of analyses			Calcium	Phosphorus	Magnesium	Copper	Iron	Manganese	Zinc
			% of dry matter			mg/kg			
Alfalfa hay	52	Av.	1.4	0.2	0.3	8.2	156	32	19
		Range	0.8–1.8	0.1–0.4	0.15–0.4	5.0–11.6	58–625	11–80	11–92
Grass hay	98	Av.	0.6	0.3	0.2	5.9	175	97	19
		Range	0.1–1.5	0.1–0.4	0.01–0.3	1.5–10.6	52–1219	20–212	10–79
Grass silage	46	Av.	0.5	0.3	0.2	8.8	515	94	22
		Range	0.3–1.6	0.2–0.4	0.08–0.4	3.5–18.1	94–1644	22–188	9–39
Corn silage	35	Av.	0.3	0.2	0.2	10.1	274	39	24
		Range	0.1–1.5	0.1–0.3	0.09–0.2	2.5–22.5	68–1019	14–70	14–46
Grain mixture	70	Av.	0.9	0.6	0.2	11.1	201	60	68
(lactating cows)		Range	0.1–2.8	0.4–1.0	0.04–0.3	4.1–21.9	100–469	41–90	32–132

Data courtesy of R. G. Peterson, D. E. Waldern, P. E. Ewert, and C. J. Williams.

selenium, copper, manganese, and zinc is required in certain parts of the country.

Vitamin A and D supplements are required for lactating cows, particularly when the ration consists of stored feeds. Vitamins E and K may be helpful in alleviating certain diseases. Under intensive management systems it may be useful to provide the animals with B vitamins.

The mineral needs of dairy cows are related to level of milk production, age of the cow, rate of growth, pregnancy, and type of feeding system. Mineral imbalances and deficiencies often result in reduced feed intake, inefficient utilization, impaired digestibility, lower milk production, reproductive failures, and a decreased viability.

The first part of the publication concerns the requirements of lactating cows for the minerals that are needed in fairly large amounts, mainly for bone development and milk synthesis. The second part discusses the requirements for trace minerals. Appendix 1 gives the actual content of specific elements in various compounds used as mineral supplements.

MAJOR MINERALS

Calcium

Calcium is the most important mineral required by lactating cows. The normal formation and maintenance of a healthy bone structure depends on a regular supply of calcium in the ration. Each litre of milk contains an average of 1.2 g of calcium, which increases with increasing fat content of the milk. Dairy animals can utilize calcium from the bone for milk synthesis and then can replace this bone calcium when intakes exceed requirements.

The average availability of calcium is 45% and is more readily available to calves and heifers than to mature cows. The amount of dietary calcium that can be utilized by lactating cows depends on the type of ration fed, the supply of vitamin D, the age of the cow, the amount required, and the physiological state of the animal. Milk fever occurs at calving time because of the cow's inability to utilize dietary calcium or to mobilize bone calcium, or both, quickly enough to satisfy the need of increased milk production.

A mature dairy cow needs about 16 mg available calcium per kg of body weight for proper maintenance and a further 1.25 mg available calcium for each kilogram of milk (3.5% fat) produced. A 600 kg cow that produces 30 kg of milk requires a daily supply of 104 g of calcium. Assuming a dry matter intake of 3% of body weight, a 600 kg cow would consume 18 kg of dry matter, which would have to contain 0.58% calcium in order to provide 104 g of calcium (Table 2). An additional 15 g of calcium are needed daily during the last 3 months of pregnancy.

The percentage of calcium in the diet should range from 0.80% for very high producing cows and high-producing first-calf heifers to 0.40% for low-producing cows or during the latter one-third of lactation. The calcium content of rations can be increased by adding a mineral source such as dicalcium phosphate to the grain mixture or by feeding a forage such as alfalfa, which contains up to 1.75% calcium.

The level of calcium in the blood plasma normally ranges from 9 to 12 mg/100 mL. Plasma calcium drops at calving time or at times of dietary deficiency. Levels of 5–6 mg/100 mL in the plasma indicate an inadequate dietary supply or the beginning of milk fever, which is the principal health problem related to calcium deficiency. This problem usually occurs shortly before or immediately after calving and occurs most frequently in high-producing mature cows and in those breeds that produce milk with a high fat content.

The incidence of milk fever can be reduced by giving large doses of vitamin D prior to calving, by maintaining the Ca:P ratio in the ration near 1.7:1, and by insuring that during late lactation and dry period the cows are not fed an excess of calcium. Too much of this mineral lowers the ability of a cow to utilize dietary calcium or to mobilize calcium from the bone as required by the start of lactation. The incidence of milk fever has also been lowered in herds by reducing calcium in the rations of cows 14–21 days prepartum. This may be accomplished by removing legume hays from the ration or supplementing the grain mixture with monoammonium phosphate rather than dicalcium phosphate. As a general guideline for total rations fed to dairy cows, the Ca:P ratio should be 1.5–2.0 parts calcium to 1.0 part phosphorus. The daily calcium intake should be at least 0.35% but not more than 1.0% of the dry matter intake, and the daily phosphorus intake should be at least 0.30% but not more than 0.65% of the daily dry matter intake.

Table 2. Daily intake of calcium needed to satisfy the requirements of a 600 kg cow that produces milk containing 3.5% fat

Milk yield kg/day	Calcium g/day	Calcium in total ration %
15	62.9	0.35
20	76.7	0.42
25	90.5	0.50
30	104.4	0.58
35	118.2	0.66
40	132.1	0.74
45	155.9	0.81

Phosphorus

Phosphorus, like calcium, is important for milk production and normal bone growth and composition. Unlike calcium, phosphorus is important in maintaining an active population of microorganisms in the rumen.

Each kilogram of milk contains an average of 0.95 g of phosphorus. This quantity is slightly greater in early and late lactation but is not related to the percentage of fat in the milk. A 600 kg cow requires 30.6 g of dietary phosphorus per day and a further 1.7 g/kg of milk produced (Table 3). An additional 7 g of phosphorus is required daily during the last 100 days of gestation to provide for the needs of the developing fetus.

The amount of phosphorus that can be utilized from the ration depends on the availability of vitamin D. Too much calcium can cause an increased fecal loss of phosphorus, which raises the requirement for this element. The availability of phosphorus decreases with the maturity of the animal but usually ranges between 45 and 65%. Forages are generally low in phosphorus, grains are fairly high, and protein supplements, such as soybean meal and rapeseed meal, are the highest.

Phosphorus deficiency lowers the mineral content of bones, which become fragile. Feed intake is decreased in the phosphorus-deficient animal, which results in a drop in milk yield. Normally, inorganic blood phosphorus ranges from 4 to 6 mg/100 mL and decreases when phosphorus-deficient rations are fed. Symptoms of phosphorus deficiency are low feed intakes, depraved appetites, poor reproductive performances, and in severe cases, bone fractures.

Table 3. Daily intake of phosphorus necessary to satisfy the requirements of a 600 kg cow

Milk yield kg/day	Phosphorus g/day	Phosphorus in total ration %
15	56.1	0.31
20	64.6	0.36
25	72.0	0.40
30	82.6	0.46
35	90.1	0.50
40	108.6	0.60
45	117.1	0.65

Magnesium

Magnesium is also needed to build and maintain strong bones. Magnesium functions as the mineral component of enzymes, which maintain normal muscle tone, make use of dietary energy, and manufacture milk fat.

The amount of magnesium required by a dairy cow depends on the availability of magnesium in the ration, the amount of milk produced, and the amount of calcium and phosphorus in the ration. Each kilogram of milk contains an average of 135 mg of magnesium. The availability of magnesium may range from as low as 10% in lush, high-protein pastures to 35% in grains or supplemental sources of magnesium. High intakes of calcium and phosphorus reduce the availability of magnesium. Cereals are usually a good source, whereas corn silages are often a poor source of magnesium. Forages that contain more than 3% potassium are likely to interfere with the proper utilization of calcium and magnesium.

A milking cow requires 2.5 g of magnesium to maintain normal body functions and an extra 0.12 g/kg of milk produced. The amount of magnesium needed in the daily ration of a cow is difficult to predict because of the wide and often unknown differences in availability of magnesium in different feedstuffs. Table 4 illustrates the influence of availability on the dietary requirements for magnesium. The requirement for magnesium may be expressed as a percentage of the total

Table 4. Dietary requirements of cows for magnesium as influenced by milk production and availability of the magnesium

Availability of magnesium %	Milk yield kg/day		
	10	20	30
	Magnesium, g/day		
10	37	49	61
17	22	29	36
25	15	20	24

ration. Low-producing cows that consume feed with readily available magnesium need only 0.12% magnesium in the ration. However, high-yielding cows fed a ration where magnesium is of low availability need 0.38% magnesium in their feed.

When the supply of magnesium is adequate, 2.5 g of magnesium are excreted in the urine daily. If the supply is more than adequate, the excess is excreted in the urine and the concentration in the blood plasma stays normal at 2.0–3.5 mg/100 mL. If the amount of magnesium absorbed from the ration is inadequate, the total urinary loss may drop to 0.1 g/day. Blood plasma levels between 1.0 and 2.0 mg/100 mL are an indication of a deficiency, where milk production decreases and a disturbance of heart function is detectable. If plasma levels drop below 1.0 mg/100 mL, the animals will show extreme incoordination, will be unable to get up, and if not treated promptly may die within a few hours. Grass tetany (severe magnesium deficiency) occurs during cool weather in early spring or in the fall in cattle that graze rapidly growing lush pastures. When such a hazard is suspected the forage grasses should be analyzed. Forage containing less than 0.2% magnesium and more than 3% potassium and 4% nitrogen are especially apt to cause tetany. Cows that are pastured on such grasses should be given about 50 g of magnesium oxide per day starting 2 weeks before being put to pasture.

Sodium and Chlorine

Common salt supplies the needs of the dairy animal for sodium and chlorine. Sodium and chlorine are present in the digestive fluids and the soft tissue of the dairy cow. They are actively involved in the movement of nutrients across cell walls and membranes.

Sodium and chlorine help to maintain the acid–base balance in the blood. The body requirements for chlorine are about one-half those for sodium. Salt stimulates the action of digestive enzymes and encourages secretion of saliva. Because feedstuffs do not contains adequate amounts of salt, supplementation is required. An inadequate supply of salt results in loss of appetite, body weight, and milk yield. Each kilogram of cow's milk contains 0.63 g of sodium and 1.15 g of chlorine.

An excess of potassium can aggravate a deficiency of sodium. This can occur when rations high in forage are fed. Pastures can contain up to 18 times as much potassium as sodium. In general, cattle on pasture consume more salt than those on dry feed.

Lactating cows that were deprived of sodium craved salt after 4 weeks and after 3 months they began to lick soil and chew on wood.

The dietary requirement for sodium is 0.18%, which is equivalent to 0.45% sodium chloride in total ration dry matter if sodium and chlorine in the ration are 100% available.

Sulfur

Sulfur is a necessary component of amino acids and certain vitamins and enzymes. Of all the minerals, sulfur is the most important for maintaining and supporting an active growth of rumen microflora.

The symptoms of sulfur deficiency are not specific and may be difficult to identify. Sulfur-deficient rations result in lower dry matter intake, loss of weight, weakness, and in extreme cases, death. At first there is a reduction in the total number of bacteria in the rumen as well as a change in the type of bacteria and a decrease in the amount of microbial protein synthesized.

A deficiency of sulfur in the ration results in low digestibility of cellulose. Ideal sulfur levels in the ration range from 0.16 to 0.24%. Sulfur deficiency results in reduced blood volume, reduced serum sulfate, increased plasma urea, and increased blood lactate and sugar.

TRACE MINERALS

Dairy cows require trace minerals, such as copper, iodine, zinc, manganese, cobalt, selenium, molybdenum, and fluorine, in very small amounts. These minerals function as catalysts for specific enzyme reactions, which are necessary for the well-being of the animal. For optimum performance these essential minerals must be present in sufficient but not excessive amounts. Two main problems have to be dealt with when assessing the requirements of dairy cows for trace minerals. First, all trace minerals are potentially toxic when fed in excessive amounts. The toxic level of a specific mineral depends on age, species, and perhaps breed of animal. Other factors are level of other minerals in the ration, interaction with other components in the ration, and the chemical form of the mineral. For optimum production, the intake of trace elements must be controlled to within fairly narrow limits. Second, the content of trace elements in feedstuffs can vary by factors of 10–100 depending on plant species, soil type, growing conditions, maturity, and area where the crop was grown.

Animals differ in their ability to withstand a lack or an excess of a given mineral. An exact minimum or maximum level of intake for a trace element cannot be stated with certainty because biological systems are constantly changing. The quantities suggested in the following pages are approximations. For specific estimations pay attention to the factors relevant to establishing the need for each element (Table 5).

Copper

Copper is important in the synthesis of hemoglobin and in the maintenance of connective tissue. Copper is stored in the liver and can readily be mobilized from this organ. If the copper level in the ration of yearlings falls below 5.0 mg/kg, and of heifers and cows below 2.5 mg/kg, the concentration of copper in blood plasma starts to decrease.

Only 5–10% of the copper in an ordinary ration is absorbed and retained in the body. This retention level is reduced by an abnormally high intake of either molybdenum or sulfur.

The suggested requirement for copper in cattle rations is 10 mg/kg. Young animals are most often affected by copper deficiency, and symptoms include scouring, unthriftiness, loss of coat color, and abnormalities in leg bones. Occasionally, cows become infertile. Australian cattle on low copper rations developed atrophy and fibrosis of the heart tissue, which resulted in sudden death.

In studies of pasture containing 7–10 mg of copper and 10–15 mg of molybdenum per kg of dry matter, young calves showed unthriftiness, loss of coat color, and swelling of joints. These conditions responded to copper supplementation.

Sulfur can also act as an antagonist of copper. Goats that received 10–15 mg of sulfur and 10 ppm of copper per kg of ration were depressed in growth.

Symptoms of acute copper toxicity include gastroenteritis, scouring, dehydration, and death. Chronic copper poisoning can be a problem in intensive lamb production where animals are kept indoors for fattening purposes. This is probably due to the greater availability of copper in grain rations and the very low molybdenum content of grains, 0.25–0.30 mg/kg. Cattle are not as sensitive as sheep to an excess of copper.

In order to prevent deficiency problems in areas where the forages contain less than 10 ppm of copper and where molybdenum and sulfur contents are relatively high, add copper to the ration. The ratio of copper to molybdenum should be higher than 4:1. If the copper content of the forage is below 6 ppm and its ratio to molybdenum is lower than 3:1, add 0.5–1 kg of copper sulfate to 100 kg of a mineral mixture or cobalt-iodized salt. This gives a mineral mix containing 0.12–0.25% copper. If forages contain 6–10 ppm, add 0.25–0.5 kg of copper sulfate to 100 kg of the mineral or salt mixture. This mix contains 0.06–0.12% copper.

Cows can safely consume feeds containing copper at 80 mg/kg without any harmful effects; however, most natural feedstuffs contain quantities well below this level. Symptoms of copper toxicity are reduced growth rate, decreased hemoglobin and hematocrit levels, and increased copper in the liver.

Molybdenum

Molybdenum is necessary in three main enzyme systems: those concerned with energy metabolism, growth, and the metabolism of iron. The minimum molybdenum requirement for ruminants is not known but is probably about 0.5 mg/kg. The toxicity of molybdenum is a more practical problem. When the Cu:Mo ratio is 1:2 or the molybdenum content of the feed is greater than 5 ppm, symptoms of copper deficiency, such as change in hair coat color and scours, may occur. These conditions can be prevented by the addition of copper to the ration or the feeding of rations with a lower level of molybdenum.

Manganese

Manganese is associated with growth, skeletal development, reproduction, and the function of the central nervous system. Its specific function is not known, but deficiencies have resulted in calves being born with weak front legs, and heifers and cows that exhibit quiet heats and poor reproductive performances. Rations high in calcium and low in phosphorus tend to increase the requirement of cattle for manganese. A level of 40–60 mg/kg in the forage portion of the ration is generally considered to be sufficient. If forages contain less than 40 mg/kg, add 1 kg of manganese sulfate to each 100 kg of mineral mixture. When forage contains less than 20 ppm, add 2 kg of manganese sulfate to 100 kg of mineral mixture. This mineral mixture contains 0.62% manganese.

Although little is known concerning the effects of too much manganese, do not feed more than 1000 mg/kg of ration.

Iron

Iron functions in the formation of hemoprotein enzymes and flavoprotein enzymes. Cattle fed normal rations are seldom deficient in this mineral. Milk is a fairly poor source of iron; it contains only 0.18–0.31 mg/kg. About 25% of the iron in milk is available to young calves. Calves fed only milk need a supplement of 30 mg of iron per day. Suggested dietary intake for mature ruminant animals is 30 mg/kg of dry matter. High levels of iron in the ration lower the copper and zinc levels in the liver. Cattle can safely consume rations containing iron at 500–1000 mg/kg, depending on its chemical form.

Selenium

Selenium is an essential mineral for livestock. It is a structural component of the enzyme glutathione peroxidase and its functions are associated with vitamin E, unsaturated lipids, and sulfur amino acids. Lactating cows require a minimum of 0.1 mg/kg of ration depending on the presence of other elements, such as sulfur or arsenic, which may interfere with the utilization of selenium. Although selenium toxicity is a problem in only one or two limited areas, the areas where animals may become deficient are numerous and of major economic importance. The amount of selenium in milk is low and is not affected by dietary intakes in the range of 0.15–3.0 ppm.

Symptoms of selenium deficiency include calves born dead or unable to stand, and a high incidence of retained placenta in mature cows. Muscle degeneration, a condition known as white muscle disease, is the most frequent symptom in lambs and calves. Increasing the average daily intake of mature cows from 0.23 mg to 0.92 mg of selenium as selenite reduces the incidence of retained placenta. Cattle can consume up to 5 mg of selenium per kg of ration without harmful effects, but above that level symptoms of toxicity may appear. Selenium toxicity produces abnormal growth rate of hooves and impairs peripheral circulation.

Iodine

Iodine is a component of the hormone thyroxine, which in turn controls the rate of metabolism in animals. The birth of dead or weak goitrous calves indicates that there may have been an iodine deficiency in the ration of the pregnant cows.

Colostrum is rich in iodine but after a few days the concentration falls off rapidly. About 10% of the iodine consumed in the ration is excreted in the milk. The availability of iodine can be inhibited by goitrogenic substances, which are found in some feedstuffs. Iodine deficiency can occur in many parts of Canada. As a preventive measure, add potassium iodide to salt at the rate of 0.1%.

Normally, pregnant lactating cows need 0.8 mg of iodine per kg of dry matter. However, if the ration is known to contain goitrogens, add iodine at the rate of 2.0 mg/kg of dry matter. Toxicity may occur over a wide range of levels, but cattle can tolerate 50 mg/kg in the ration for a short time. Do not use large amounts of iodine to treat foot rot. Symptoms of iodine toxicity are reduced feed intake, excessive salivation, and bronchial congestion.

Cobalt

Cobalt is essential for the synthesis of vitamin B_{12} by rumen microorganisms. Lactating cows require 0.07–0.10 mg/kg of ration dry matter. Deficiency symptoms include loss of appetite, reduced milk production, rough hair coat, and eventually anemia. Mixing 40–50 g of cobalt carbonate with 100 kg of salt is an effective means of supplementation. Because cobalt is not easily stored, it has to be provided each day. The requirement for cobalt increases as the intake of digestible dry matter increases.

Symptoms of cobalt toxicity are reduced feed intake, anemia, lower packed-cell volume, and excess salivation. The maximum safe amount of cobalt is considered to be 20 mg/kg of dry matter.

Table 5. Minimum and maximum quantities of trace minerals required by mature ruminants to prevent deficiency and toxicity symptoms*

	Required level	Tolerated level
	mg/kg of total ration	
Cobalt	0.07-0.10	20
Copper	10	80
Fluorine	unknown	30-100
Iodine	0.8-2.0	20-50
Iron	30	400-1000
Manganese	40-60	1000
Molybdenum	0.5	5-50
Selenium	0.1-0.15	3-5
Zinc	50	500-1000

* Neathery, M. W. 1976. J. Anim. Sci. 43:328.

Zinc

Zinc is required for growth and for healthy skin. A deficiency can cause a thickening of the skin known as parakeratosis. Low levels of zinc in the ration may increase the incidence of foot rot in cattle. At parturition, plasma zinc levels have been observed to drop from 1.1 to 0.75 μg/mL, but the relevance of this drop to calving difficulties is unknown.

Milk contains 3–5 mg of zinc per kg. The concentration of zinc in the plasma of healthy cows ranges from 0.60 to 1.40 mg/L. When intake of zinc is lower than normal, plasma levels drop below 0.40 mg/L. Lactating cows need 50 mg of zinc per kg of dry matter intake. Too much zinc may cause a tie-up of copper or iron but rations containing 1000 mg of zinc per kg of dry matter have not caused any short-term harmful effects. A deficiency of zinc slows growth more in the male than in the female animal.

Fluorine

The minimum requirement for fluorine and symptoms of fluorine deficiency are unknown. However, fluorine toxicity caused by forage or water contaminated by industrial pollution has been recorded. For lactating cows, the tolerance level of soluble fluoride is probably 30–50 mg/kg of dry matter intake. Fluorine in the water is readily available and should be considered when calculating total intake. Symptoms of toxicity are severe reduction in feed intake, stiffness in legs, enlarged bones, and a rapid decline in health.

VITAMINS

Vitamin A

Vitamin A is required for maintaining healthy mucous membranes. Animals low in vitamin A are much more subject to infection because of keratinization of epithelial tissue and degeneration of the mucosa of the respiratory tract. Night blindness often occurs in mild cases. Vitamin A deficiency in pregnant animals produces a high incidence of retained placentas, shorter gestation periods, and birth of dead, uncoordinated, or blind calves.

The provitamin A, carotene, represents the most common dietary source for cattle. It is generally considered that 1.0 mg of carotene is equal to 400 IU of vitamin A. The maintenance requirement for vitamin A is 10.6 mg of carotene per 100 kg of liveweight. The vitamin is stored in the liver and is capable of maintaining an animal consuming a low vitamin A diet for some period of time. Blood plasma levels below 100 μg/100 mL indicate a deficiency. The amount of vitamin A needed for lactation is considered to be low and the total requirement of a lactating cow would be 13.0–15.0 mg of carotene per 100 kg of body weight. Under conditions of total confinement, or where cows are fed low quality hay or corn silage, the addition of vitamin A to the ration at the rate of 7000 IU/kg of grain mixture has proved beneficial.

Vitamin D

Vitamin D is necessary for the proper metabolism of calcium and phosphorus.

Vitamin D functions in three main ways.

- It increases the absorption of calcium and phosphorus from the gastrointestinal tract.
- It assists in the mineralization of bone.
- It regulates the urinary loss of calcium and phosphorus.

If vitamin D is not present in sufficient amounts, less than 20% of the calcium consumed will be absorbed. However, if an adequate supply of vitamin D is available, 50–60% of the calcium will be utilized. Vitamin D supplements may be necessary to coordinate the metabolism of minerals, particularly in animals suffering from a deficiency of phosphate.

Vitamin D also increases the absorption of phosphorus from the digestive tract. Apparently the synthesis of vitamin D in the skin, even with exposure to sunlight, is not sufficient to improve phosphorus absorption by dairy cows.

Massive doses of vitamin D ($10–30 \times 10^6$ IU) given 24–48 hr before calving improves the utilization of calcium and phosphorus when these elements are supplied at normal levels. The protection against milk fever reaches a peak after 3 days. The need to predict the calving date within narrow limits is the main objection to this method of prevention. Vitamin D supplements may improve fertility even in cows that get plenty of sunlight. A highly productive animal could suffer a temporary, inadequate supply of vitamin D during the peak of lactation. This would influence both the metabolism of calcium and phosphorus and reduce fertility.

Injections of 50 000–250 000 IU of vitamin D_3 are recommended for the treatment of rickets in calves, and injections of 500 000–1 000 000 IU of vitamin D are recommended for the treatment of osteomalacia (weak bones) in adult ruminants.

Dairy cattle should be fed vitamin D at 4000–7000 IU daily depending on the level of milk production. If a cow produces 30 kg of milk and is fed a grain mixture at the rate of 1.0 kg for every 3.0 kg of the milk produced, then a grain mixture containing 600 IU of vitamin D per kg should be sufficient.

Vitamin E

The metabolic role of vitamin E is similar to that of selenium. Green forages and cereal grains are fairly good sources of vitamin E, but the amount that mature animals need is not known. However, muscular dystrophy responds to vitamin E supplementation in young calves and lambs. The vitamin E requirement of immature ruminants is greatly increased by a lack of selenium in the ration. The use of vitamin E supplement delays the development of an oxidized flavor in milk. Although this vitamin is required for proper reproduction in rats, no conclusive evidence is available for ruminants. Vitamin E should be given along with vitamins A and D to cattle on silage feeding systems or to cattle that are maintained on stored feeds throughout the year. The addition of vitamin E at 15 IU/kg of grain mixture may contribute to the well-being of dairy cows.

Method of Mineral Supplementation

Cattle do not regulate their intake of minerals according to their needs. The intake seems to be related to taste and appetite. The free-choice system of supplying minerals to lactating cows is impractical because of the large individual variations among the animals in any one herd. Cows need a supplemental form of minerals fed on a regular daily basis. For heifers or dry cows not fed grain mixtures, provide mineral mixtures free-choice. The proper supplements for cows cost between 60¢ and $4 per cow per month.

In attempting to identify a problem that appears related to a mineral deficiency, the sampling of certain materials provides the greatest information (Table 6).

In a herd problem, where analysis of blood is recommended sample at least 25% of the animals at least four times during their production cycle. To properly assess the composition of a pasture during the growing season, sample each field in the spring, summer, and autumn. Crops should be sampled at the growth stage and in the form in which they are fed. It is important to know the actual intake of dry matter of each ration component in order to assess the amount of a mineral consumed (Appendix 2).

Various factors influence the amount of a mineral element that may be required or tolerated in the ration of a dairy cow. The stating of exact values that satisfy all conditions is impossible, and hence it is important that the figures quoted in this bulletin not be used in specific cases for regulatory or legal purposes. The data presented are to be used as guidelines by the feed manufacturer, feed advisory services, and farmers in formulating rations to satisfy the mineral requirements of the average dairy herd.

Table 6. Material to be analyzed for determining mineral deficiencies

Mineral	Material
MAJOR	
Calcium	ration, plasma
Phosphorus	ration
Magnesium	ration, plasma, urine
Sodium	ration, saliva
TRACE	
Copper	liver, plasma
Manganese	ration
Iodine	milk
Cobalt	pasture, soil
Zinc	ration, plasma
Nitrogen	ration
Potassium	ration (forage), saliva

APPENDIX 1

Actual content of specific elements, in g/kg, in various compounds used as mineral supplements

Mineral supplement	Mg	Ca	P	Na	Cl	Cu	Co	I	Zn	Mn
Calcium phosphate $CaHPO_4.2H_2O$		220	170							
Decalcified bone meal	10	300	130							
Calcium carbonate $CaCO_3$		360								
Monosodium phosphate $NaH_2PO_4.2H_2O$			190	150						
Magnesium sulfate $MgSO_4.7H_2O$	90									
Magnesium oxide MgO	500									
Iodized salt				390	590			0.04		
Copper sulfate $CuSO_4.5H_2O$						240				
Cobalt sulfate $CoSO_4.7H_2O$							200			
Manganese sulfate $MnSO_4.H_2O$										220
Zinc oxide ZnO									750	

APPENDIX 2

The ratio of Ca:P in the total ration of lactating cows ranges from 1.5 to 2.0 parts calcium to 1.0 part phosphorus. Most of the daily requirement for calcium, phosphorus, and magnesium comes from the regular feedstuffs. However, variable amounts of each mineral have to be added, depending on the feeding system.

Let us consider three feeding systems and the quantities of supplemental minerals necessary for a 600 kg cow producing 25 kg of milk daily.

1) Pasture + grain — summer feeding program
2) Corn silage + grain — winter feeding program
3) Grass silage + hay + grain — winter feeding program

1) Assume that the cow consumes 7 kg of low-protein grain mixture and 16 kg of pasture dry matter. This ration provides the animal with 65 g of calcium, 70 g of phosphorus, and 42 g of magnesium. To meet requirements the animal needs an additional 26 g of calcium and 5 g of phosphorus. If tricalcium phosphate is added to the grain mixture at the rate of 1%, the cow will receive an additional 25 g of calcium and 11 g of phosphorus in the daily ration.
2) Corn silage plus a high-protein grain mixture provides 45.4 g of calcium, 49.9 g of phosphorus, and 24 g of magnesium. To meet its requirements the cow needs another 45.8 g of calcium, 25.3 g of phosphorus, and 1 g of magnesium. Add tricalcium phosphate at 2%, plus 1.0 kg of magnesium oxide per ton of grain mixture.
3) A daily winter feeding program consisting of 7.0 kg of a low-protein grain, 8.0 kg of alfalfa hay, and 8.0 kg of grass silage provides 236 g of calcium, 64 g of phosphorus, and 56 g of magnesium. The cow needs a further 10 g of phosphorus, which could be provided by the addition of 1% monosodium phosphate to the grain mixture.

Factors that influence these calculations:

Wide ranges in availability of each element.

Wide ranges in quantity of the ration components.

Variations in ration intake.

It is therefore necessary to treat each feeding system individually on the basis of accurate sampling and analysis of the feed for mineral content, production level, and the approximate dry matter intake of the animals.

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2,5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre