Champion Feed Services Ltd.

Vitamins For Feedlot Cattle

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Take home message

- ✓ Diets for feedlot cattle require supplementation with vitamins A and E.
- ✓ Vitamin E improves immunity of cattle that are immune-suppressed due to stress. High levels of vitamin E (400-800 IU/day for the first 30 days in the feedlot) may reduce the incidence of respiratory disease and improve performance.
- ✓ Vitamin E supplementation at 500 IU/day for the last 100 days on feed increases vitamin E concentration in meat and improves the colour, fat stability and shelf life.
- ✓ Extremely high dietary vitamin D concentration for 5 to 10 days before slaughter improves tenderness but causes unacceptable tissue residues and is not legally permitted.
- ✓ B-vitamin requirements of feedlot cattle are not known. Stress and/or illness can increase requirements, resulting in short-term deficiencies. B-vitamin supplementation, particularly in the first 10 days after arrival in the feedlot, may improve performance and/or reduce morbidity. Depending on the B-vitamin, supplementation may alleviate nutrient deficiencies of rumen microbes, or of the animal itself, or both microbes and the animal. In other cases, supplementation may have no benefit whatsoever if microbes degrade the added B-vitamins for energy.
- ✓ Thiamin deficiency (polioencephalomalacia) is the only B-vitamin deficiency disease occurring in feedlot cattle in Alberta.

Introduction

Problem

Vitamin A is the most important vitamin for feedlot cattle. Alberta feedlot diets based on barley, wheat, or oats will not contain enough vitamin A precursors (carotenoids) to meet requirements unless supplemented. A large proportion of dietary vitamin A is destroyed in the rumen and abomasum of cattle fed high-concentrate diets, but if adequate amounts are fed, enough dietary vitamin A will remain to meet requirements.

Deficiencies of vitamin A or E may depress immune function whereas supplementation with higher levels than required for normal growth and development may enhance immunity. Deterioration of beef during storage results when both muscle pigments and fats react with oxygen (oxidation), resulting in less desirable colour, flavour, and odour. Vitamin E is an important antioxidant in muscle that can prevent oxidation of muscle pigments and fats. However, the amount of dietary vitamin E sufficient for growth and health under normal conditions does not provide enough tissue vitamin E to enhance meat quality. Feeding high dietary concentrations of vitamin E for a prolonged period of time increases the concentration of vitamin E in meat and improves meat quality and shelf life.

Background: Functions of Vitamins and Deficiency Symptoms

Vitamin A

Vitamin A is required for normal growth and health of feedlot cattle. It is essential for maintenance of epithelial tissue (skin, eye; lining of the gastrointestinal, respiratory, urinary and reproductive tracts), bone development, and normal vision. A deficiency of vitamin A may result in nonspecific symptoms including reduced feed intake and less rapid growth, rough hair coat, diarrhea, increased susceptibility to infections, excessive tearing, and blindness. Night blindness is the only symptom unique to vitamin A deficiency. Depressed vitamin A concentrations in blood or liver, increased spinal fluid pressure, or changes to the eye (direct examination, conjunctival smears), are used to confirm deficiency. Probably marginal deficiencies are most likely to be a concern to producers, although an occasional animal may spontaneously develop deficiency symptoms on a normal diet. Vitamin A has a high margin of safety and toxicity is unlikely.

Cattle on lush green pasture may accumulate substantial reserves of vitamin A in the liver, which can meet requirements for up to 2 to 4 months in the feedlot. Conversely, if cattle were grazing dormant range or poor quality forage, their reserves will be low. Vitamin A stored in the liver may be unavailable to animals that are deficient in zinc. Due to the wide animal to animal variation in liver storage, the low cost of vitamin A, and the variation in source of feedlot cattle, dietary supplementation of vitamin A is advised in all cases.

Vitamin D

Deficiency is unlikely in cattle housed outdoors. Vitamin D is needed for absorption of calcium and phosphorus, normal mineralization of bone, calcium metabolism, and immune function. Deficiency symptoms include depressed appetite, irritability, tetany, swollen and stiff joints, rickets, and convulsions.

Vitamin E

Vitamin E occurs in feeds as alpha-tocopherol, and other forms with lesser vitamin E activity. Heat, oxygen, moisture, fat, trace minerals, and nitrates reduce vitamin E stability in feeds. The concentration of vitamin E in feeds declines during storage, particularly in high moisture feeds. Consequently, synthetic vitamin E is used to ensure vitamin E requirements are met.

The primary function of vitamin E is as an antioxidant. Normal metabolism in the body generates toxic, reactive oxygen by-products, which must be deactivated. Because it is fat-soluble, vitamin E is particularly important in protecting cell membranes from damage. Vitamin E maintains the structure and function of all muscles (skeletal, heart, smooth muscle), and is essential for the immune system. A selenium-containing enzyme, glutathione peroxidase, is an important antioxidant in muscle, but does not eliminate the vitamin E requirement. White muscle disease is not common in feedlot cattle. It is caused by a deficiency of either selenium or vitamin E, and is treated by injection of vitamin E and selenium and by correcting dietary deficiencies.

Vitamin K

Vitamin K is required for normal clotting of blood. A deficiency can result in excessive bleeding or death from haemorrhage. Vitamin K deficiency is rare in cattle, but may be caused by consumption of mouldy sweet clover. Vitamin K is provided by K_1 in green forage or from K_2 synthesized abundantly by rumen bacteria. Feedlot diets are not supplemented with vitamin K.

B-vitamins

Thiamin, riboflavin, niacin, pantothenic acid, folic acid, vitamin B_6, vitamin B_{12}, biotin and choline are essential B-vitamins for all animals, including cattle. B-vitamin concentration of the diet usually has very little influence on the B-vitamin status of cattle. Bacteria in the rumen synthesize most B-vitamins in excess of the probable requirements. Microbial synthesis of most B-vitamins increases with increasing energy intake, so is generally higher for grain compared to forage diets. If B-vitamins are added to the diet, rumen bacteria either reduce B-vitamin synthesis, resulting in no net change to supply, or destroy the added B-vitamins. Depending on the B-vitamin, virtually none to a high proportion of the dietary B-vitamin may escape ruminal degradation (**15**). Choline is completely destroyed in the rumen. Whereas cattle can accumulate nutritional reserves of vitamins A, D, and E, storage of B-vitamins is limited, except for vitamin B_{12}.

Cattle with reduced intakes due to stress or disease may suffer from short-term B-vitamin deficiencies, due to reduced synthesis, increased requirements, and limited reserves of B-vitamins within the body. Preliminary evidence suggests that activating the immune system to fight off infection or develop immunity rapidly depletes B-vitamins important to the immune response (**3**).

Thiamin

Thiamin deficiency (polioencephalomalacia) occurs sporadically in cattle, and is most common in cattle fed high grain diets. It results from destruction of thiamin in the rumen by a thiamin-degrading enzyme or production of compounds structurally similar to thiamin (analogs) that block the action of thiamin (**5**). The coccidiostat, amprolium, is a weak thiamin analog that can interfere with the utilization of thiamin. Thiamin is required to activate enzymes involved in carbohydrate metabolism and is particularly important for normal brain function. Symptoms of deficiency include reduced appetite, apathy, incoordination, progressive blindness, convulsions and death. The head may be bent towards the back. The disease is reversible if treated before the brain is severely damaged. The treatment is intravenous or intramuscular injection of thiamin (thiamin hydrochloride or other forms). Typical dose rates are 200-500 mg for calves and 1000-2000 mg for adult cattle, equivalent to 2-15 mg/kg body weight. Most injected thiamin is excreted within 24 hours. Consequently, multiple injections of thiamin (2-4 times a day for 1-2 days) are occasionally recommended (**11**). Of all the B-vitamins, thiamin is usually the most limiting on grain diets.

However, dietary supplementation of one gram thiamin/animal/day during the receiving period and/or when feeding high-wheat diets did not improve performance in some Kansas studies in which animal thiamin status was not measured.

Vitamin B_{12}

Vitamin B_{12} is manufactured by rumen bacteria. It contains a trace mineral, cobalt, which must be provided in the diet. Cobalt concentrations in feeds are not well known and therefore ruminant diets are supplemented with cobalt at approximately 0.1 ppm to ensure adequate production of vitamin B_{12}, which is too costly to add directly to feedlot diets. Vitamin B_{12} is the only B-vitamin stored in substantial amounts in the liver. When animals are transported or stressed, the break down of body tissue, including liver, increases blood concentrations of vitamin B_{12}. Ruminal production of vitamin B_{12} is lowest, and production of B_{12} analogs is highest, on grain diets compared to forage diets. Vitamin B_{12} deficiency is unlikely unless diets are deficient in cobalt for a prolonged period. The symptoms can include poor appetite, retarded growth, and poor condition.

Niacin

Niacin is an essential component of two enzyme co-factors (NADH, NADPH) that are involved in more than 200 reactions in the metabolism of carbohydrates, fatty acids, and amino acids. Niacin supplementation of cattle on corn grain or corn silage diets has improved gain and feed efficiency by up to 5 and 10% respectively, and appears to be useful in adapting cattle to urea. Research is needed to determine if cattle fed barley-based diets would benefit from niacin supplementation.

Vitamin C

Vitamin C is a water-soluble antioxidant vitamin that is completely destroyed in the rumen. No economical rumen-protected forms of vitamin C are currently available. Cattle synthesize their own vitamin C, but can become depleted in vitamin C when stressed by transport or disease. Although vitamin C supplementation of milk replacer has improved health of young calves, benefits of supplementation have not been proven for older cattle. There are some unconfirmed anecdotal reports that vitamin C may reduce respiratory disease when supplemented during the receiving period. Our work with shipping-stressed cattle suggests that stressed cattle can benefit from dietary supplementation of certain nutrients which would normally be destroyed in the rumen.

Dietary Recommendations for Feedlot Cattle

Vitamin A and E must be supplied in the diet. Synthetic vitamin D or a natural vitamin D precursor in plants can meet the vitamin D requirement, or vitamin D can be produced in the bodies of cattle exposed to sunlight. Although it may not be needed, Vitamin D is relatively inexpensive and often it is included in feedlot diets at about 1 IU per 10 IU Vitamin A. Many nutritionists now feel that feeding vitamin D to outdoor feedlot cattle is not necessary.

Vitamins A, D, and E are artificially synthesized. During the manufacturing process, vitamins A and E are stabilized by linking them with an acetate molecule; additionally, vitamins A and D are protected by incorporation with an antioxidant inside a gel beadlet. Almost all vitamin A used in animal diets is vitamin A acetate (retinyl acetate). A number of compounds have varying amounts of vitamin E activity. The compound with the greatest potency is R,R,R-alpha-tocopherol. The commercial synthesis of vitamin E produces a mixture of eight related chemicals collectively called all-*rac*-alpha-tocopheryl acetate. This product is adsorbed onto a carrier such as wheat midds and sold as vitamin E adsorbate.

Table 1. Vitamin intake recommendations for feedlot cattle.

	-------------------- Recommendations --------------------			
Vitamin	Alberta[1,2]	NRC 1996	Roche[3]	Standard Practice
Vitamin A	2500-5000 IU/kg	2200 IU/kg	40,000 -60,000 IU/d	40,000 - 80,000 IU/d
Vitamin D		275 IU/kg	4,000 - 6,000 IU/d	0 - 8,000 IU/d
Vitamin E				
• stressed	100 IU/kg	400 - 500 IU/d	400 - 500 IU/d	
• normal	15 IU/kg	50 - 100 IU/d	200 - 300 IU/d	50 - 100 IU/d
• meat quality			500 IU/d for 100 days	

[1]Alberta Agriculture COWBYTES Beef Ration Balancer 1999, Version 3.0
[2]Vitamin A requirement based on NRC requirements plus 5%; Vitamin E requirement for stressed animals is based on a target intake of 500 IU/d so dietary concentration varies depending on intake
[3]Hoffmann-La Roche Inc. (Switzerland) is a major vitamin suppliers; others are BASF (Germany) and Rhone-Poulenc (France).

The stability of the fat soluble vitamins in feed is diminished by exposure to ultraviolet light (sunlight), oxygen, heat, fats and oils, moisture, and trace minerals. Vitamins are most stable when kept cold, dark, and dry in the original concentrated form or diluted with grain or dry feed. They are least stable and activity will be lost over time when combined in a concentrated premix of vitamins and trace minerals, or in a livestock mineral. However, vitamins may be safely provided in any dry (pelleted or not pelleted) or liquid supplement used to balance feedlot rations. Stability should not be a major concern unless a supplement is stored for a prolonged period of time. Dry mash or pelleted diets retain 95% of supplemental vitamin A activity after 3 months storage.

Cattle can be provided with vitamin A, D and (or) E by intramuscular injection. Injection is not recommended because of the possibility of injection site lesions, regardless of the age of the animal, and variable effects on performance. Injections of vitamins A and D at any age may cause lesions at the injection site which persist until slaughter. There have been studies in which vitamins A and D or vitamin E injected into receiving cattle either failed to affect performance or tended to increase morbidity and reduce performance, for unknown reasons.

Specific Uses of Vitamins

Vitamin E to enhance meat quality

During storage, muscle pigments and fats react with oxygen, resulting in less desirable colour, flavour, and odour (1). Colour stability is relatively more important in beef than in lighter meats such as turkey, chicken, and pork because beef is more susceptible to visible discolouration. Fresh beef has a desirable bright cherry red colour associated with oxymyoglobin, the oxygenated form of myoglobin. During storage in the retail package, the iron is gradually oxidized, converting the oxymyoglobin to metmyoglobin, which is brown. This process also converts the iron into a more reactive form capable of catalyzing degradation of other constituents of meat. Oxidation of unsaturated fatty acids in meat (in membranes, intramuscular fat or marbling, and in intermuscular or seam fat) causes a rancid flavour. Furthermore, oxidized fats such as cholesterol oxides may be a health risk.

Vitamin E (alpha-tocopherol) is an important meat antioxidant that prevents oxidation of fats, and indirectly reduces oxidation of oxymyoglobin. Dietary vitamin E is absorbed and stored in all tissues in the cellular membranes. Muscles vary in vitamin E concentration. Supplementation with high levels of vitamin E (500 IU/day for 100 days) increases the concentration of vitamin E in meat. Depending on the muscle and the supplementation regime, the vitamin E concentration may increase by 25% to 400%. The standard supplementation protocol (500 IU/d, 100 d) may double the vitamin E concentration in the round tip and ground chuck, and increases vitamin E by about 25% in the T-bone steak (**9**). Because the vitamin E in meat is distributed throughout the fat, dietary supplementation of vitamin E results in much better control of oxidation than adding vitamin E directly to meat cuts or ground meat.

The amount of vitamin E incorporation into muscle increases as the dietary concentration and(or) duration of supplementation increases. Supplementation must be done continuously until slaughter. However, the short period of feed withdrawal before slaughter does not significantly affect vitamin E in muscle.

Feeding cattle high levels of vitamin E increases retail shelf-life by 2-3 days. In a U.S. study of Safeway stores, one to two of every ten retail cuts placed in the display case was eventually discounted due to discoloration. Vitamin E supplementation reduced the number of marked down round tip steaks, T-bone steaks, and ground chuck by 64% to 88% (9). At the same time, TBA values (indicating fat oxidation) were 200-300% higher in the control cuts compared to vitamin E cuts after 7 days retail display. The cost of vitamin E supplementation for improved meat quality is currently $2.00-$3.00 per animal, but can vary because of fluctuations in worldwide prices for vitamin E. Although conventional markets do not pay premiums for vitamin E-fed beef, more cattle will be fed vitamin E in future as value-based alliances proliferate. Supplemental vitamin E is currently fed to cattle in most U.S. beef alliances for domestic markets, whereas even higher levels (1000 IU/animal for 100 days) are fed to cattle for production of beef for distant export markets. Time will tell if vitamin E will continue to be the most effective dietary antioxidant for meat quality. One U.S. alliance has begun to use a cheaper synthetic antioxidant in place of vitamin E in feedlot diets, whereas Texas Tech University is investigating the use of a kelp product as a dietary antioxidant for improved meat quality.

Benefits of long-term vitamin E supplementation on feedlot performance

Benefits to feeding vitamin E for prolonged periods are not limited to meat quality. Although it is difficult to pick up significant effects of vitamin E on performance within a single experiment, when numerous trials are compared vitamin E appears to improve ADG and feed efficiency. Averaged across 21 studies with feedlot cattle fed levels from 20 to 2000 IU per head, supplemental vitamin E increased ($P<0.02$) ADG (1.42 vs 1.38 kg) and tended to improve ($P<0.08$) feed:gain ratio (6.41 vs 6.53). Although the response to vitamin E may be greatest earlier in the feeding period, supplemental vitamin E also increased gain toward the end of the feeding period of calves that were fed for a long period of time. In addition, means for fat thickness, quality grade, and yield grade increased for supplemental vitamin E, but these differences were not statistically significant. Variation in responses to vitamin E among feedlot trials was attributed to differences in initial vitamin E status of calves, vitamin E content of the basal diet, and stress level of the cattle. The reviewers considered that the mean feed efficiency improvement should economically justify vitamin E supplementation at 500 IU daily (**13**).

Injectable vitamin A, D, E at feedlot entry

Most vitamin injectables are sources of vitamins A and D. Typically vitamin E is included at very low levels, and is included as an antioxidant to protect vitamin A and not in sufficient amounts to affect vitamin E status of the animal. Injectable vitamin E formulations differ in both the carriers and the forms of vitamin E (tocopheryl acetate or tocopherol) used, which may affect availability. Some formulations of vitamin E acetate have resulted in a high frequency of knots on the hide. Possibly the source of vitamin E and amount of tissue damage may account for conflicting responses to vitamin E injections in cattle. Injections of vitamins A, D, or E may result in lesions (scarring or abscesses) at the injection site regardless of the age at injection.

Injectable vitamin A/D is occasionally given to cattle on arrival at feedlots. Does it improve animal health and performance or is dietary supplementation adequate? At least five studies were conducted in Kansas between 1974 and 1985. Results were not conclusive. For example, the same concentration of injected vitamin A/D reduced gain and increased feed/gain in one study, and increased gain in another study. Differences between treatments were consistently small and may not have been statistically significant. Injection of vitamin A is recommended only for animals showing signs of deficiency or when feeding of vitamin A is not possible.

Injecting cattle with vitamin E instead of supplying vitamin E by diet is not recommended due to negative responses to injected vitamin E acetate in various studies with receiving calves. For example, injecting vitamin E at 3000 IU per animal on arrival actually increased sick days by 32% and tended to reduce performance. We obtained similar results when calves coming off wheat pasture were injected with vitamin E alcohol at feedlot entry (data not published).

Dietary vitamin E supplementation of stressed calves

Vitamin E requirements of cattle are markedly increased by stress or disease. The vitamin E concentration in blood, especially in white blood cells critical to the immune response, rapidly becomes depleted during the receiving period, and during other times when cattle are stressed. Research at Colorado State University showed that vitamin E in blood neutrophils was undetectable for up to 4 weeks after arrival even though calves were fed 1000 IU vitamin E per day (**12**). Vitamin E deficient neutrophils cannot successfully kill pathogens. Vitamin E supplementation of high-risk cattle has two major functions: it not only can help replenish tissue vitamin E but in addition, also counteracts the suppression of the immune system caused by stress (**4**). Vitamin E stimulates immune function when fed at levels above those required for normal growth, and also has been shown to increase the effectiveness of vaccines when used as an adjuvant.

Many studies have shown that performance and health of stressed calves may benefit from high concentrations of dietary vitamin E (400-800 IU/day) during the first month in the feedlot. Most of these studies were done in the U.S. using calves obtained through auction barns and shipped long distances but, even then, improvements due to vitamin E were detected mainly in batches of calves with the highest incidence of disease. Feeding high concentrations of vitamin E in calf feedlot starter diets in Alberta may improve health when the disease risk is high, but when morbidity is low it may not be consistently cost-effective.

Results from five receiving trials testing vitamin E at 450 to 1600 IU per head daily were analyzed by Secrist et al. (**13**). Daily gain tended ($P<0.14$) to be increased (0.92 vs 0.80 kg), with no effect on DM intake, thus feed to gain ratio tended to improved ($P<0.10$) by vitamin E (9.0 vs 12.4). Morbidity tended to be reduced by vitamin E (48 vs 55%).

B-vitamin supplementation of stressed cattle

Most studies of B-vitamins in cattle have involved dietary supplementation. Because dietary B-vitamins are often destroyed in the rumen, many of these studies probably did not succeed in affecting B-vitamin status of the animal. Nonetheless, supplementation of receiving cattle with dietary B-vitamins has occasionally improved performance and health during the first 30 days on feed (**2**, **7**, **15**). Most of the benefit seems to occur from supplementation during the first 10 days after arrival. Animals most likely to benefit from B-vitamin supplementation are those with increased requirements related to stress or disease and reduced intake. Ruminal production of B-vitamins is highly correlated with energy consumption. Most B-vitamins are not stored in substantial amounts and therefore B-vitamin status could become depleted if feed intake is low and requirements high in the stressed or sick calves. For example, feeder calves hauled 1600 km had very low blood concentrations of vitamin B_6; even a mild respiratory infection (IBR) markedly reduced blood levels of B_6, pantothenic acid, B_{12} and vitamin C (**3**).

A general symptom of deficiency for most B-vitamins is depressed appetite. Consequently, B-vitamin injections are often given to sick cattle on a 'can't hurt, might help' basis. Efficacy of B-vitamin injections has not been proven. The effects of stress and disease on B-vitamin status in cattle are not known, but this information is crucial for development of effective B-vitamin injectables. Most B-vitamin injectables, like over the counter vitamin pills, tend to contain higher amounts of the cheapest B-vitamins (thiamin, niacin) and little or none of the more expensive B-vitamins (pantothenic acid, B_{12}, vitamin B_6). Use of B-vitamin injectables has diminished because of the concern over injection site lesions; however B-vitamins may be less likely to cause significant tissue damage than some of the preservatives such as phenol commonly added to them. B-vitamin injectables may be a useful therapeutic tool if they can be formulated based on science and without deleterious preservatives.

Vitamin D for improved tenderness

Feeding vitamin D at approximately 2000 times the daily requirement improves beef tenderness under research conditions, but is not approved for use in Canada (Health Canada, Bureau of Veterinary Drugs). Table IV of the Feeds Act limits the amount of vitamin D that can be fed to beef cattle to 33,000 IU per animal per day. The requirement is 275 IU per kg DM. Cattle and other species easily tolerate ten times the dietary requirement without difficulty. Higher levels of vitamin D are deleterious to the animal because of effects on calcium metabolism, including calcium deposition in kidney, cardiovascular system and respiratory tract, and to the consumer because of potential toxicity from extremely high vitamin D concentrations in organs such as liver.

The rationale for feeding high vitamin D to improve tenderness is that the skeletal muscles of all animals contain protein-degrading enzymes. These enzymes continue to function after death to break down muscle proteins. The discovery that some of these enzymes (m- and m-calpain) require calcium at specific concentrations for activation led to development of the calcium-activated (CAT) process to improve tenderness by infusing calcium solutions into carcasses shortly after slaughter. Positive results from CAT renewed interest in manipulating calcium status at time of slaughter. Calcium status is so tightly regulated in the living animal that the only method of increasing tissue levels is to feed extremely high levels of vitamin D, a hormone important in regulating calcium availability.

Most of the research on effects of vitamin D on tenderness involved cattle fed 5 to 7.5 million IU per animal per day for 5 to 10 days before slaughter. Blood calcium concentrations increase rapidly, and reach a plateau during this time period, but eventually return to normal as homeostatic mechanisms adjust. Feeding high vitamin D for too long is not effective for that reason.

Feeding high vitamin D increases muscle calcium by up to 50%, improves tenderness and reduces the percentage of tough steaks. There may also be a reduction in live weight, carcass weight, and yield grade. The cumulative intake of 25 to 50 million IU of vitamin D within a period of less than 2 weeks depresses dry matter intake, especially if top-dressed instead of incorporated into the total diet. The intake depression is dose dependent. Vitamin D accumulates in liver and some other organs above levels safe for human or pet consumption.

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