Champion Feed Services Ltd.

Nutrition and Immunity of Feedlot Cattle

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Take Home Message

- ✓ The immune system accounts for a relatively minor portion of total nutritional requirements in the normal healthy animal but activation of the immune system in response to an immune challenge has a major impact on nutritional status and requirements for most nutrients.
- ✓ Nutrient deficiencies increase susceptibility to most infectious diseases, including bacterial, viral and parasitic diseases. Once disease has developed, nutritional deficiencies increase the severity of the disease and increase the probability of secondary infections. Deficiencies of vitamins or trace minerals significantly depress immune function and resistance to stress even when animals are otherwise well fed with sufficient energy and protein.
- ✓ Stress increases requirements of many nutrients essential for immune function and leads to multiple short term nutrient deficiencies in shipping-stressed cattle. Consequently, nutrition has the largest impact on morbidity and mortality during the first month after arrival at the feedlot.
- ✓ The immune system is suppressed in stressed cattle, contributing to the high incidence of respiratory disease in the first 45 days on feed. Some nutrients such as vitamin E can be fed at levels above normal requirements to stimulate immunity of immunosuppressed animals.

The Problem

Cattle are most vulnerable to infectious disease during the first 45 days on feed due to the combined influence of increased disease exposure, stress-induced immunosuppression and nutritional deficiencies exacerbated by stress and poor intake. The economically important clinical signs, lesions, and death loss in shipping fever usually can be attributed to bacterial pneumonia due to *Pasteurella haemolytica*, *Pasteurella multocida*, or *Haemophilus somnus* (**19**). These bacteria are common in the nasopharyngeal area of healthy cattle. Lungs of normal healthy cattle can resist challenge from surprisingly large numbers of bacteria. But when the animal is stressed, has a respiratory viral infection, coccidiosis, or is otherwise immunosuppressed, relatively small numbers of bacteria can result in pneumonia (**19**).

All animals require energy, amino acids, fatty acids, fat soluble vitamins (A, D, E, K), water soluble vitamins (B-vitamins), trace elements and macrominerals for both health and growth. When availability of any of these nutrients is limited, deficiency symptoms occur most quickly in tissues with the highest rates of protein synthesis or metabolic activity. The immune system is particularly sensitive to a nutrient deficiency because any immune response requires rapid synthesis of proteins for immune cells and immune products. Most nutrient deficiencies including vitamins and trace minerals directly or indirectly affect synthesis of these proteins. Other nutrients regulate the immune response (vitamins A and D), or act as antioxidants to protect immune cells and other cells from the toxic effects of a wide variety of enzymes and chemicals used by the immune cells to destroy bacteria and infected cells. Compared to other systems in the body, the immune system has especially high requirements for antioxidant nutrients but these nutrients are quickly depleted when animals are stressed.

Nutrition has the greatest impact on immunity during the first two to four weeks after arrival in the feedlot, even more so in the first few days after arrival. It can be difficult to get enough nutrients into cattle, particularly those that need it the most. Nonetheless, proper nutrition during the days immediately after shipping to the feedlot (and ideally, immediately before shipping) influences immune function directly, and also indirectly by improving resistance to stress. Providing key nutrients can reduce stress-induced weight loss and immunosuppression, improve weight gain and reduce morbidity and mortality from bovine respiratory disease.

Background: What is Immunity to Infection?

Animals resist infection using non-specific mechanisms ('innate' immunity) and specific mechanisms (acquired immunity). Almost all immune mechanisms are less effective in stressed animals.

Innate immunity

Innate immunity includes:

- epithelial tissue which covers body surfaces (example skin or hide, hoof, cornea) and lines body cavities (respiratory, urogenital, gastrointestinal) is a physical barrier to keep infectious agents from entering the body. Breaks in this covering layer caused by physical damage or by nutrient deficiencies such as vitamin A and zinc can result in infectious agents gaining access to the body;

- secretions that block (mucus) or wash out (saliva, tears) infectious agents, and numerous antimicrobial compounds in body fluids and secretions; frequently affected by stress;
- cells in blood and tissue that engulf, kill and digest infectious microorganisms. These are called phagocytes and include macrophages, monocytes, and neutrophils. They continually circulate through blood and migrate into tissues in search of invading pathogens. This important defence is seriously impaired by stress;
- normal microbial flora can compete with disease causing organisms, thereby holding them in check; less effective in stressed animals.

Specific or acquired immunity

Exposure to a foreign substance (antigen) results in the development of immune cells and antibodies specific against that particular antigen only. Specific immunity takes time to develop, and therefore is effective in preventing infection only if the animal was previously exposed to that antigen. It is also important for recovery from many infections. The foreign substance (antigen) may be a live virus or bacteria but does not have to be infective or alive to induce immunity. Weakened or dead viruses or bacteria, and even specific fragments of pathogens or pieces of their DNA can be used in vaccines to induce immunity with reduced risk of disease. Exposure to the antigen triggers growth and development of two types of blood cells specific for eliminating the antigen. These are the T-cells (responsible for cell-mediated immunity) and the B-cells responsible for antibody production (humoral immunity).

T-cells secrete numerous hormones (such as interleukins and interferon) which upregulate or downregulate the entire immune system as needed, and increase effectiveness of other immune cells including phagocytes and B-cells. In addition, some T-cells directly destroy target cells. Antibodies are fairly large proteins that are secreted by B-cells and found in blood plasma, nasal secretions and other fluids. Because of their size, they cannot enter into bovine cells so are not effective against intracellular pathogens. All antibodies act by binding to the foreign substance. In many cases, this prevents the virus or bacteria from replicating or being infective, but also makes it much easier for other immune products or cells to destroy the pathogen. Vaccines may be designed to stimulate primarily an antibody response or an increase in cell-mediated immunity, depending on which type of immune response is most effective against a specific pathogen.

A nutrient deficiency does not affect all immune mechanisms equally, nor does it always affect the same mechanism equally for different antigens. A group of deficient animals may have adequate antibody responses to some antigens (or vaccines), and depressed antibody responses to other antigens. Similarly, under practical conditions, deficient animals may be more susceptible to some but not all disease causing organisms.

Nutritional Requirements of Stressed Animals

Acute or prolonged stress makes animals more susceptible to disease by increasing levels of hormones which suppress the immune system and by depleting nutrients critical to an effective immune response. Stressful stimuli in cattle include handling, transport, physical trauma, fatigue, fasting, and unfamiliar environment. These induce hormonal responses which control and alter animal metabolism. Cortisol, epinephrine, norepinephrine, aldosterone, beta-endorphin, and enkephalins are released in large amounts in response to stress. A short-term stress may have relatively minor effects on metabolism and nutritional status. A long-term, chronic stress may cause substantial metabolic changes. Metabolic changes during stress are designed to control and reserve energy and other nutrients for use in the most vital processes needed to combat the stress. Metabolic pathways shift from anabolic processes (growth) to primarily catabolic (tissue breakdown of proteins and fat).

Table 1. NRC, 1996 (**16**) nutrient recommendations for stressed calves (dry matter basis).

Nutrient	Suggested range
Dry matter, %	80.0 – 85.0
Crude protein, %	12.5 – 14.5
Net energy of maintenance, Mcal/kg	1.3 – 1.6
Net energy of gain, Mcal/kg	0.8 – 0.9
Calcium, %	0.6 – 0.8
Phosphorus, %	0.4 – 0.5
Potassium, %	1.2 – 1.4
Magnesium, %	0.2 – 0.3
Sodium, %	0.2 – 0.3
Copper, ppm	10.0 – 15.0
Manganese, ppm	40.0 – 70.0
Zinc, ppm	75.0 – 100.0
Cobalt, ppm	0.1 – 0.2
Selenium, ppm	0.1 – 0.2
Iodine, ppm	0.3 – 0.6
Vitamin A, IU/kg	4,000 – 6,000
Vitamin E, IU per day	400 - 500

Note: NRC recommendations for trace minerals (esp. selenium, copper and zinc) are conservative compared to Alberta recommendations. In most of western Canada, 0.3 ppm added dietary selenium is recommended.

Table 2. The percentage of shipping-stressed calves eating during the first 10 days after arrival at feedlot.

Day	Calves eating, %	Range, %
1	21.7	0-50
2	36.7	10-60
3	56.7	30-90
4	61.7	30-90
5	66.7	40-90
6	68.3	40-90
7	70.0	60-90
8	71.7	60-80
9	73.3	60-90
10	85.0	60-100

Source: Hutcheson, Texas Beef Conference, 1980.

Stressed animals have higher nutritional requirements, but do not consume as much feed as unstressed animals (**Table 1**). Feed intake is the foremost nutritional problem for highly stressed loads of cattle (Table 2). The first objective is to get enough feed into the animal so that it can stop breaking down its own tissues for fuel and begin to eliminate nutrient deficits. Cattle produce blood glucose essential for the central nervous system and red blood cells by breaking down body proteins in liver, kidney, intestine, and skeletal tissue to provide glucose precursors. Body fat is broken down to provide fatty acids, the primary energy source for most other tissues. These free fatty acids can be converted to ketone bodies, primarily ß-hydroxybutyric acid and acetoacetic acid, which can lead to a metabolic acidosis.

Table 3. Dry matter feed intake of newly arrived calves (% of body weight).

Day	Healthy	Diseased
0-7	1.55 ± 0.51	0.90 ± 0.75
0-14	1.90 ± 0.50	1.43 ± 0.70
0-28	2.71 ± 0.50	1.84 ± 0.66
0-56	3.03 ± 0.43	2.68 ± 0.68

Source: (**6**)

The nutrient concentration of the diet has to be increased to compensate for the low intake (Table 3). Stressed cattle are often deficient in energy, amino acids, vitamin A, B-vitamins, calcium, phosphorus, potassium, magnesium, zinc, and copper (**14**). Antioxidant requirements are markedly increased by both stress and disease, because both result in accelerated productive of highly reactive oxygen by-products, peroxides, and free radicals. Antioxidants such as vitamin E and vitamin C are quickly depleted in stressed animals, particularly in the white blood cells where they are critically important for immune function.

Stressed, previously fasted cattle differ from normal cattle in ability to utilize certain feeds and nutrients because of changes in rumen function. Stressed calves have a lower tolerance for nonprotein nitrogen (e.g. urea) than normal calves, which should be limited to 30 grams or less per day during the first 2 weeks of feeding. Stressed calves also have a low tolerance for dietary fat, and for silage compared to nonfermented feeds. Feed intake, gain, and immune function are improved when stress calves are fed sufficient undegradable intake protein (UIP). There is some indication that stressed calves may differ from normal cattle in having some bypass of soluble nutrients that are normally completely degraded in the rumen by bacteria. If so, it may be possible to take advantage of reduced ruminal function in the first 1-2 days on feed to supplement nutrients such as glucose, choline, ascorbic acid, and various B-vitamins when these requirements are known.

Effects of Disease on Nutritional Status

Infection results in a complex array of metabolic responses which affect the nutritional status of the animal. Feed intake decreases more than 50% in cattle with respiratory disease and fever, and takes 10 to 14 days to return to normal. During this time, requirements of virtually all nutrients increase, even though nutrients are deflected from growth to immunity. Proteins must be synthesized for the immune response, development and resolution of fever, and repair of cell and tissue damage. Body proteins are broken down to provide energy and amino acids for the immune system. Losses of important minerals such as magnesium, potassium, phosphate, and zinc are also increased.

Immune activation increases requirements for antioxidant nutrients, trace minerals, and vitamins similar to the effect of stress. Consequently, when cattle are stressed before an immune challenge, nutrients critical to the immune response are likely to be in short supply. Trace minerals and B-vitamins are required as co-factors for the chemical reactions involved in breaking down body tissues and synthesizing new proteins.

The major extracellular electrolytes, sodium and chloride, are influenced by hormonal changes. Urinary excretion of salt may increase during the onset of infection, and may lead to dehydration. The kidneys may then begin to retain body salt and water. Diarrhea can result in substantial direct fecal losses of sodium, chloride, bicarbonate and potassium.

Effect of Nutritional Status on Resistance to infection

Good nutrition improves disease resistance of stressed cattle, by helping to counteract the suppression of the immune system caused by stress hormones and by providing nutrients essential for maintaining and activating the immune system as required.

Energy. Stressed calves seem to have an altered eating pattern—unlike normal calves, they won’t eat more of a lower energy diet, and given a choice, they select a diet with about 72% grain during the first week after arrival at the feedlot. Consequently, performance of lightweight stressed calves is increased with high-concentrate receiving diets (>60% grain), although morbidity rate may increase as well (**7**). Generally, the percentage of calves treated for BRD (morbidity), and/or the severity of illness (days of medical treatment per calf) increase as the proportion of grain in the starter diet increases. Glen Lofgreen, a pioneer in receiving calf nutrition, found in his work that any additional pounds of gain put on in the first

28 days was maintained or enlarged over a 253 day feeding period. On the other hand, feeding good quality hay plus a protein supplement may work well in some cases, but calves may not fully compensate for lower gains in the receiving period. The optimum concentration of grain in the receiving diet depends on the age and weight of animal, previous management, stress level, and other factors; cattle with lower intakes (calves) can safely consume diets with a higher proportion of grain than can cattle with higher intakes (yearlings).

Protein. A large number of studies have been conducted comparing protein levels and sources for receiving diets. In general, diets that contain relatively low or high levels of dietary proteins adversely affect immunity to infection compared to diets with moderate protein levels (**7**). Averaged for 15 studies, the trial-indexed morbidity rate was lowest for diets containing 12 to 14% protein, and increased as protein increased to 22% of DM. However, the best performance is usually achieved at higher levels of dietary protein (16 to 20%). Similarly, performance was usually best for diets using soymeal, which has a low rumen bypass value, whereas morbidity was better when less soluble, higher bypass proteins were fed (distillers dried grains, blood meal). Nissen et al. (**13**) reported that gain and feed efficiency improved as metabolizable protein concentration increased, serum cortisol increased linearly, and the proportion of calves responding to the IBR vaccine decreased linearly.

Vitamins A and D, within the ranges that are normally fed, are important in regulating immunity. Vitamin A deficiency reduces resistance to all types of disease, including parasites. Vitamin A supplementation is essential for cattle fed grain-based diets. Incoming cattle can be marginally deficient in vitamin A depending on the previous diet, and may not be able to utilize vitamin A efficiently if deficient in trace minerals. Under practical conditions, vitamin D deficiency is unlikely to be a concern even when cattle are not supplemented, unless they also do not have access to sunlight.

Antioxidant nutrients are crucial to the immune response, becoming rapidly depleted during infection. The amount of antioxidant nutrients in the diet determines the antioxidant status of the animal. These key nutrients include dietary antioxidants such as carotenes, vitamin E, and vitamin A, and trace minerals such as selenium, zinc, copper, and manganese used to synthesize antioxidant enzymes. Antioxidants protect immune cells and surrounding tissue from damage caused by the immune response, which otherwise would damage the animal as much or more than the disease organisms. Antioxidants are particularly important for the effectiveness of phagocytes, which are the front line of defence against invading pathogens. If phagocytes are deficient in antioxidants, microbial killing is ineffective.

Vitamin E is currently the most important antioxidant in feedlot diets. There is some recent information that other feed ingredients such as Tasco™ (kelp meal) and Agrado™ (synthetic antioxidant) may have significant antioxidant activity within the animal.

Supplementation with vitamin E has improved growth, feed efficiency, morbidity, and antibody titres of feedlot cattle, but not consistently (**15**, **20**). Results of five trials summarized by Secrist et al. (**20**) are shown in Table 4. In studies with dairy calves, vitamin E supplementation decreased ($P < 0.05$) serum cortisol concentrations, an indicator of stress (**17**, **18**). Dietary vitamin E in excess of requirements for growth increases resistance to stress and disease. Whether or not an economic benefit is achieved by supplementation is difficult to predict. The vitamin E status of the cattle, exposure to stress and disease, and other factors may influence the response.

Table 4. Effect of supplemental dietary vitamin E on morbidity and performance of transport-stressed calves (weighted means from 5 trials) Secrist et al. (**20**).

Item	Control	Vitamin E[1]
Daily gain, kg.	0.80	0.92
Dry matter intake, kg	7.48	7.49
Feed/gain ratio	12.42	9.00
Morbidity	55.1	47.9

[1]Vitamin E levels used were 400 to 1000 IU/head/day.

Magnesium and phosphorus are the most important macrominerals associated with the immune response; their supplementation levels have influenced mortality in other animal species but have not been studied in this regard in cattle.

Trace mineral supplementation of backgrounding and feedlot diets in Alberta is important for maintaining resistance to infectious disease. Trace minerals have numerous functions as components of vital proteins. Young growing animals are depositing protein at high rates and are therefore more vulnerable to trace element deficiencies than older animals. Copper, zinc, manganese, and selenium are required for the production of antioxidant enzymes. Deficiencies of copper and selenium impair the ability of bovine phagocytes to kill invading microorganisms. A zinc deficiency increases nonspecific infections, and inhibits normal healing of wounds. Supplementation with zinc or with high levels of trace minerals has improved recovery from respiratory disease in several studies. Although chromium is depleted in stressed animals, and chromium supplementation has improved immune function in some studies, more information is needed to determine when supplementation would be cost-effective.

Organic iodine or EDDI has a history of use for foot rot control at levels exceeding those required for growth. Young, growing cattle may be most susceptible to footrot. As of 1990, EDDI is no longer cleared for use as a drug for control of bovine foot rot because of environmental and health concerns. However, use of EDDI within the range permitted by the Feeds Act (0.1-10 ppm in DM) can provide sufficient iodine for foot rot control (**1**, **12**). Feeding supplemental vitamin A and trace minerals to counteract marginal deficiencies in receiving calves appears to be at least as effective as EDDI for reducing footrot without the associated risks.

B-vitamins and vitamin C affect immunity and resistance to stress. Cattle are unusual in that most B-vitamins are supplied by microbial synthesis in the rumen, rather than the diet, in fact dietary B-vitamins are usually degraded in the rumen. Production of B-vitamins by rumen microbes is directly related to energy availability in the rumen; synthesis of vitamin C in the animal is directly related to energy availability in animal tissue (**5**). The combination of stress and low intake can result in low availability of B-vitamins which may affect rumen microbes and/or the animal itself.

In spite of the fact that B-vitamin requirements of cattle are not known, and that dietary B-vitamins are partially or extensively degraded in the rumen, B-vitamin supplementation of receiving diets has improved performance and reduced shipping fever in several studies (Tables 5 - 8). Brethour at Kansas State had previously improved performance of steers fed an 'acidgenic, high-wheat ration' by feeding a combination of 1 gram of thiamin and 100 grams sodium bicarbonate. He speculated that acidosis following a 30-60 hour post-weaning fast may contribute to shipping stress, and that thiamin supplementation would improve energy balance and reduce lactic acid accumulation. Brethour and Duitsman (**2**) improved gain and reduced shipping fever substantially by adding vitamin C, or thiamin, or thiamin and bicarbonate, to the diet for the first 30 days after weaning (**Table 5**). This was a small, non-replicated study in which calves were fed good quality alfalfa hay with sorghum silage and rolled milo grain. B-vitamin supplementation reduced morbidity of shipping-stressed calves but tended to increase morbidity of shipping-stressed

Table 5. Effect of ascorbic acid, sodium bicarbonate, and thiamin in backgrounding diet on health and performance during first 30 days after weaning (**2**).

Treatment	aureomycin 75 mg	Aureo S-700	Vitamin C 1 gram/ head/day[1]	Thiamin 1 gram/ head/day[2]	Thiamin + 100 g/d sodium bicarbonate[2]
No. of animals	32	31	31	31	31
Daily gain, lb.	0.12	0.25	0.58	0.81	1.09
Feed intake, lb. as-fed	11.6	11.9	12.0	12.4	12.6
No. calves treated	15	11	2	1	1

[1]Vitamin C increased gain slightly but significantly ($P<0.05$) compared to medicated controls; although only 2 calves were treated, some others suffered subacute sickness.
[2]Thiamin treatments significantly increased feed intake and weight gains compared to controls and greatly reduced shipping fever.

preweaned calves (Table 6). In a Kansas study, B-vitamin supplementation in combination with vitamin E tended to improve gain and significantly improved feed efficiency, without significantly affecting morbidity (**Table 7**).

Beneficial Effects of Nutrients in Excess of Growth Requirements

Several nutrients such as vitamin E and selenium enhance immunity above normal levels when fed in excess of requirements for growth. These same nutrients stimulate immunity when immune function is below normal, as in animals that are stressed. Some nutrients such as vitamin E and chromium influence production of stress hormones such as cortisol. Antioxidant nutrients in general, including vitamin E and selenium, also reduce the susceptibility of cells throughout the body to the cortisol that is produced in

Table 6. Effect of pretransit management and B-vitamin supplementation on morbidity and mortality at the feedlot (**4**).

Item	Control	Control + B-vitamins	Prewean	Prewean + B-vitamins
No. of animals	46	46	46	46
No. calves treated	30b	19a	19a	28ab
No. repulls	6ab	2ab	1a	11c
Avg. days treated/calf	9.9	6.2	6.3	8.4
Deaths respiratory disease	2	1	1	1
Total deaths	2	1	2	1

Calves were from 17 farms in Tennessee. Control calves were weaned the day of sale, preweaned calves were weaned 30 days before leaving the farm, and fed a 50% concentrate diet at the farm; both groups shipped to auction barn, held for 3 days, then shipped 1600 km to Bushland, Texas.

Table 7. Effect of B-vitamin supplementation of receiving diets on performance and health during first 56 days in feedlot (**21**).

Item	Level of added B-vitamin supplementation Control (0)	1 x estimated requirement	10 x estimated requirement	SEM[1]
No. of calves	48	48	48	—-
Initial weight, kg	117	116	116	1.6
Weight gain, kg/day	1.24	1.20	1.15	0.036
Dry matter/gain	3.83	3.80	3.86	0.016
Clinically sick, %	50.2[a]	33.1[b]	34.5[ab]	5.1
Sick days, avg. all calves	3.8	5.0	4.8	0.75
Mortality, %	4.0	1.9	4.4	1.1

[1]standard error of mean, n=4 pens/treatment
[abc]Means in a row significantly different (P<0.10).

response to stress. Vitamin E is depleted in stressed cattle whereas vitamin E supplementation appears to counteract stress-induced immunosuppression (see vitamin article). A small excess of selenium may also be beneficial (**9**).

Implications

Optimal Immunity

The immune system appears to have priority for nutrients over growth. Immune activation is costly. Resources devoted to immune activation cannot be used for growth. As a result, any immune response will depress growth rate and feed efficiency (**8**). The optimum immune response is the one that is the shortest in duration and the lowest in intensity while successfully eliminating the pathogen. An extreme immune response not only wastes resources but may cause local cell damage and depress productivity. Reducing challenges to the immune system by providing a clean environment and reducing stress can improve growth rate, even in the absence of disease.

In normal healthy cattle, there is a trade-off between growth and immunity – both cannot be maximized at the same time. This is not usually a practical concern because the immune system functions very well at nutrient levels ideal for growth. Compared to the adapted feedlot steer, the stressed feeder calf is in a unique situation because of the conflicting nutrient demands for immune activation (vaccination and/or disease exposure), responding to stress, recovering from short-term nutrient deficiencies, and growth. This animal has potential to respond to some key immune-enhancing nutrients with significantly increased gain and improved immunity. Some very promising research has been done in this area but much more is needed to evaluate products and economics of use.

However, cattle feeders dealing with less than ideal facilities or management, limited labour, or lightweight, high risk cattle may prefer to sacrifice some growth but reduce disease risk by adapting cattle to full feed more slowly than usual. This can reduce the incidence of respiratory disease, death loss, and medical costs during the receiving period.

Balancing Diets for Immunity

Generally, nutrition has most impact on health during the first month on feed and particularly for highly-stressed or lighter-weight cattle. Many of the cattle entering Alberta feedlots are marginally deficient in several trace minerals, especially if they previously grazed dormant native range or pasture. Receiving rations should be adequately supplemented with trace minerals, vitamin A and vitamin E. Feeding higher levels than normal of these nutrients in the receiving period can compensate for reduced intake and marginal deficiencies on arrival.

In order of priorities, providing a palatable diet on arrival and encouraging feed and water consumption is most important. There is little benefit from adding expensive nutrients to an unpalatable diet. Research has shown that it can take up to a week or more for all calves in a pen to consistently consume some feed within a single day. Average intake is only 1.5% of body weight in the first 2 weeks for lightweight feeder calves. Anything that can be done to enhance intake after arrival reduces the length of time in which the immune system is compromised by short-term nutrient deficiencies.

Whether the use of high levels of vitamin E or other feed additives to enhance immunity is economically justified will depend on individual feedlot circumstances. In situations where the cattle are most vulnerable to disease (high stress, younger animals, poor environmental conditions, etc.) and the disease risk is high, supplementing high levels of nutrients such as vitamin E during the receiving period may improve gain and reduce morbidity substantially. A large number of nutrients have shown promise for improving feeder calf health, including chromium, zinc methionine, B-vitamins, vitamin E, HMB, Agrad™, etc. It is very difficult to evaluate the impact of new products or individual nutrients on receiving calf health based on the limited number of small pen trials. It is quite possible that large scale studies would demonstrate costeffectiveness of many of these fed during the receiving period when considering the cumulative economic impact on morbidity (labour and drug costs), mortality, gain, and days to market. After cattle have recovered from stress-induced immunosuppression and are adapted to the finishing diet, balancing feedlot diets to meet requirements for growth usually provides adequate nutrients for immune function.

References

1. Berg, J.N., Maas, J.P., Paterson, J.A., Krause, G.F. and Davis, L.E. 1984. Efficacy of ethylenediamine dihydriodide as an agent to prevent experimentally induced bovine foot rot. Am. J. Vet. Res. 45(6):1073-1078.
2. Brethour, J.R. and Duitsman, W.W. 1972. Ascorbic acid, Aureo S-700, sodium bicarbonate, and thiamine in post-weaning, stress rations. Beef Cattle Investigations, Kansas State University, Bulletin 556, April 28, 1972.
3. Chang, G. X. et al. 1996. Effect of supplemental chromium on antibody responses of newly arrived feeder calves to vaccines and ovalbumin. Can. J. Vet. Res. 60:140-144.
4. Cole, N.A., McLaren, J.B. and Irwin, M.R. 1979. Influence of pretransit feeding regimen and posttransit B-vitamin supplementation on stressed feeder steers.
5. Cummins, K.A. 1992. Ascorbate in cattle: a review. Prof. Anim. Scientist 8:22-29.
6. Hutcheson, D.P. and Cole, N.A. 1986. J. Anim. Sci. 62:555-560.
7. Galyean, M.L., Perino, L.J., and Duff, G.C. 1999. Interaction of cattle health/ immunity and nutrition. J. Anim. Sci. 77:1120-1134. (thorough review of scientific literature re feedlot cattle health primarily U.S. work).
8. Klasing, K. C. 1993. Nutrition and metabolism of trace minerals during stress. California Animal Nutrition Conference, May 12 & 13, 1993, pp. 181-188.
9. Larsen, H.J.S. 1993. Relations between selenium and immunity. Norwegian J. Agric. Sci. Suppl. #11:105-119.
10. Lee, R.W., Stuart, R., Perryman, K. and Ridenour, K. 1985. Effect of vitamin supplementation of receiving diets on the performance of stressed beef calves. 1985 Cattle Feeders' Day, Garden City Branch, Agric. Exp. Stn, KSU, Manhattan.
11. Lofgreen, G.P., Dunbar, J.R., Addis, D.G. and Clark, J.G. 1975. Energy level in starting rations for calves subjected to marketing and shipping stress. J. Anim. Sci. 41:1256-1265.
12. Maas, J., Davis, L.E., Hempstead, C., Berg, J.N., and Hoffman, K.A. 1984. Efficacy of ethylenediamine dihydriodide in the prevention of naturally occurring foot rot in cattle. Am. J. Vet. Res. 45(11):2347-2350.
13. Nissen, S., Kuhlman, G., VanKoevering, M. and Link, G. 1989. Effect of protein intake on immune function and growth of stressed calves. J. Anim. Sci. 67(Suppl. 1):24 (Abstr).
14. Nockels, C. F. 1990. Mineral alterations associated with stress, trauma, and infection and the effects on immunity. The Compendium 12:1133-1139.
15. Nockels, C. F. 1991. Vitamin E requirement of stressed cattle. In: Vitamin E in Animal Nutrition and Management: A BASF Reference Manual, BASF Corporation, Parsippany, New Jersey, pp. 193-203.
16. NRC. 1996. Nutrient Requirements of Beef Cattle, 7th rev. ed. National Academy of Sciences, Washington, D.C.
17. Reddy, P. G. et al. 1987a. Vitamin E requirements of dairy calves. J. Dairy Sci. 70:123-129.

18. Reddy, P. G. et al. 1987b. Vitamin E is immunostimulatory in calves. J. Dairy Sci. 70:993-999.

19. Roth, J. A. and Perino, L. J. 1998. Immunology and prevention of infection in feedlot cattle. Veterinary Clinics of North America: Food Animal Practice, Vol. 14(2):233-256.

20. Secrist, D.S., Owens, F.N., and Gill, D.R. 1997. Effects of vitamin E on performance of feedlot cattle: A review. Prof. Anim. Sci. 13:47-54.

21. Zinn, R.A., Owens, F.N., Stuart, R.L., Dunbar, J.R., and Norman, B.B. 1987. B-vitamin supplementation of diets for feedlot calves. J. Anim. Sci. 65:267-277.

Additional Information

22. Lofgreen, G.P. 1988. Nutrition and management of stressed beef calves—an update. Vet. Clin. North Am. Food Anim. Pract. 4:509-522.

23. Nagaraja, T. G., Galyean, M. L. and Cole, N. A. 1998. Nutrition and disease. (good feedlot review). Veterinary Clinics of North America: Food Animal Practice Vol. 14(2):257-277.

24. Reddy, P. G. and Frey, R. A. 1990. Nutritional modulation of immunity in domestic food animals. Adv. Vet. Sci. Comp. Med. 35:255-281.

Table 8. Performance summary for three vitamin E receiving calf studies* in Kansas (**10**).

Item	Control	Vitamin E	B Complex[1] + E
Daily gain, lb.	2.65[a]	2.79[b]	2.94[c]
Feed intake, lb. as-fed	16.74	16.50	15.56
Feed/gain, lb.	6.43[d]	6.11[de]	5.46[e]
Morbidity, %	46.3	42.5	43.4
Death loss, %	1.33	0.67	0

*total of 418 steer calves, 450 to 650 lbs., diet 54.4% dry rolled corn, 19% chopped alfalfa hay, 10% pelleted wheat midds, 6.7% molasses, 5.1% corn silage, 4.8% supplement, Deccox used first 28 days.
[1]B-vitamins included 600 mg niacin, 200 mg thiamin and 750 mg choline per head daily plus minor amounts of other B-vitamins.
[abc] P<0.08.
[de] P<0.02.

Table 9. Effect of ß-hydroxy-ß-methyl butyrate (HMB)* on performance and health of three loads of calves averaging 407 lb.

Item	Control	HMB (4 g/hd/day)	SEM	Probability
No. of animals	80	78		
No. of pens	3	3		
Overall ADG, lb.	1.11	1.31	0.09	0.11
ADG healthy calves, lb.	1.05	1.45	0.15	0.06
ADG sick calves, lb.	1.17	1.17	0.10	0.98
Feed intake, lb.	10.88	10.86	0.15	0.92
Feed/gain	11.08	10.39	0.37	0.31
Morbidity, %	73.0	63.4	5.03	0.18
Mortality, %	4.17	2.15	2.15	0.51
Treatment days	2.12	1.79	0.22	0.28
Repulls, %	4.62	2.23		
Treatment costs	$10.93	$7.66		

diet was 10 lb. prairie hay, 2 lb. soy/cottonseed meal-based supplement
*HMB is produced by the body during the metabolism of the essential amino acid leucine. HMB is believed to enhance immune function and performance. Not commercially available to our knowledge.