Review of Bovine Respiratory Disease: Nutrition and Disease Interactions[a]

N. Andy Cole, PhD, Supervisory Research Animal Nutritionist
Conservation and Production Research Laboratory
Agricultural Research Division
U.S. Department of Agriculture
Bushland, Texas

Feeder calves encounter numerous physiologic and psychologic stressors (e.g., feed and water deprivation, weaning, inclement weather, antagonistic encounters, infectious agents, and transport) during movement from one production point to another. These stressors induce hormonal changes, anorexia, exhaustion, nutrient losses, altered nutrient metabolism, dehydration, behavioral changes, and immunosuppression. The adverse effects of many of these stressors seem to be additive. Affected calves present special nutritional, management, and health challenges to cattle producers and consultants.

Inadequate nutrition can accentuate the adverse effects of stress. Although proper nutrition generally cannot prevent stress or infection, it may have both direct and indirect beneficial effects on the animal. Proper nutrition can assist in preparing the animal for a period of stress, can decrease the adverse effects of stress, and can enhance recovery from stressful periods. Thus proper nutrition can help prevent the immunosuppression caused by stress.

Interrelationships among Stress, Nutrition, and Immunity

Basic Concepts

The immune system of mammals consists of three components:

- Mucosal barrier immunity
- Humoral immunity (antibodies)
- Cell-mediated immunity

Although often discussed separately, each component is intricately linked to the other two. Nutrition can affect many aspects of the immune system, among them (1) anatomic development of lymphoid tissues, (2) mucus production, (3) synthesis of immunologically active substances, (4) cellular proliferation, (5) cellular activation and movement, (6) intracellular killing, and (7) modulation and regulation of immune processes.[1]

In general, severe nutrient deficiencies impair at least one of the three components of the immune system (Table 1), but even subclinical deficiencies can impair immune response.[2] Much of the research concerning the interrelationship between nutrition and immunity is complicated by the fact that nutritional modification may have positive effects on one immune component while having negative effects on others. This suggests that modifications in nutrition that can be beneficial in protecting the animal from a specific virus at the same time may have adverse effects on the animal's ability to avoid a bacterial infection.

The "real world" value of much of the data concerning the effects of specific nutritional deficiencies and excesses on components of the immune system is often unclear. For example, are data collected on normal subjects applicable to those subjects when numerous stressors have had deleterious effects on their immune system? At what point is a depression in a specific immune

[a]The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

TABLE 1
Summary of the Effects of Nutritional Supplementation of Deficient Diets on Immune Response and Feeder Calf Health

	Immune Component		
Nutrient	*CMI*	*Humoral*	*% BRD*
Protein			
Chronic	D	NE, I	?
Acute	I, D	I, D	D
Protein-calorie	I	I	D
Vitamins			
A	—	I	NE
D	—	NE	NE
E	I	I	I, NE, D
C	I	I	—
B_1	NE	I	NE, D
B_{12}	I	I	NE, D
Minerals			
Iron	I	—	—
Zinc	I	—	NE, D
Selenium	I	I	NE, D
Copper	I	I	—
Iodine (thyroxine)	I	NE, I	NE
Chromium	?	?	D?
Amino acids	I	I	—

CMI = cell-mediated immunity; % BRD = percentage of calves treated for bovine respiratory disease; I = increased; D = decreased; NE = no effect; ? = variable data; — = insufficient data. From Chandra RK: *Ann NY Acad Sci* 587:9–16, 1990 and References 6, 8, 21–22, 50, 52–55, 73–86, and 92–96.

component large enough to actually decrease the animals' ability to fend off a natural infection? Do short-term nutritional deficiencies have adverse effects on immunity?

Stress Effects on Nutrient Metabolism, Endocrine Response, Feed Intake Regulation, and Nutrient Requirements

Numerous metabolic changes occur in calves during marketing/transport (Table 2). Some stressors (e.g., infection) induce a hypermetabolic state in which nutrient balance is decreased, even if there is no decrease in nutrient intake.[3] Although many of these metabolic changes can be corrected in 1 or 2 days, others require as long as 14 days for complete correction. The nutritionist therefore has two principal objectives in feeding the stressed feeder calf: (1) decrease or prevent metabolic changes and (2) speed recovery without causing other deleterious effects.

Accomplishment of these objectives is complicated by low feed intakes during marketing and the first 1 to 2 weeks after arrival at the feedyard. These low feed intakes are caused by a combination of decreased ruminal function and metabolic adaptations that occur during stress.[4–7] Nonetheless, partial compensation for the stress-induced hypermetabolic state can be made by an increase in nutrient density of the diet.[8]

One of the most obvious metabolic changes that occurs during marketing/transport is weight loss (shrink). Even in short-haul (less than 6 hours) cattle, approximately 50% of weight loss involves gut contents and approximately 50% involves tissue loss.[9,10] In general, a 24 hour transport peri-

TABLE 2
Influence of Stress on Selected Metabolic Characteristics

Variable	*Fasting*	*Transport*	*Infection*
Nitrogen and phosphorus balance	D	D	D
Feed intake	D	D	D
Ruminal fermentation	D	D	D?
Serum insulin	D	?	I[a]
Serum growth hormone	NE[b]	?	?
Serum T_3 and T_4	D	D?	D
Plasma urea nitrogen	I	I?	D
Plasma glucose	I, D	I, D	I, D
Serum phosphorus	I?	D	D
Serum copper	NE	?	I
Serum zinc	I, D	?	D
Serum iron	D	D	D
RBC hemolysis	I?	I	?
Immune variables			
WBC count	D	I	I, D
Blastogenesis	?	D	?
Parasite shedding	?	I	?

I = increase; D = decrease; NE = no effect; ? = insufficient data or highly conflicting data; T_3 = triiodothyronine; T_4 = thyroxine.
[a]Accompanied by decreased glucose tolerance.
[b]Baseline concentrations are not affected, but response to feeding or glucose infusion is markedly altered.

od has the same metabolic effects as a 48 to 72 hour feed and water deprivation period.[10-12] The major stressors associated with transport seem to be loading and noise.[10-13] If ruminants are well fed before a fasting/transport period, there seem to be sufficient quantities of Ca, Mg, Na, Cu, Zn, and Fe in the gastrointestinal tract to prevent excessive losses of these nutrients from the tissues. However, tissues must be used as a source of some other nutrients (P, K, N, and water).[14]

Practical Nutrition of Stocker/Feeder Calves

Feeding prior to the Stress of Marketing/Transport

Ruminants have a potentially large reserve of nutrients and water within the digestive tract. Increased performance and decreased morbidity and mortality can be realized if maximum use is made of this reserve.[15] Hence, the diet fed to calves before a stress period can be critical in determining their post-stress health and performance.

The diet of feeder calves at the farm of origin usually consists of grass and milk. Between the ages of 140 to 210 days, calves receive about 81% of their digestible energy intake from grass and about 19% from milk.[16] As a result, the diet calves receive at the farm/ranch can be highly variable, depending on the quality and quantity of grass available. Other factors such as plant toxins like the fescue endophyte *(Acremonium coenophialum)* may adversely affect nutrient[17] and immune[18,19] status of calves when they leave the farm of origin.

One method to ensure that calves are properly nourished upon leaving the farm is to wean them 4 weeks before sale and feed

TABLE 3
A 17 Trial Summary of the Effects of Preweaning and/or Preconditioning for 30 Days on Feeder Calves[a]

Parameter	*Trials*	*Control*	*Preconditioned*
On farm (last 30 days)			
Weight gain (lb)	17	43	48
Feed intake (lb)	12	0	363
Feed/added gain (lb/lb)	12	—	79.2
Transport shrink (%)	10	8.75	9.00
Feedyard performance			
Daily gain (lb)	13	2.34	2.32
Feed/gain (lb/lb)	7	7.17	7.48
Morbidity (%)	15	38.6	30.5
Mortality (%)	15	2.0	1.2

[a]See References 23 and 24 for data sources.

a balanced ration (preweaning). Practically, however, this procedure requires considerable extra time, labor, investment, risk, and skills by the cow-calf producer. Except when grass conditions are very poor, preweaning does not substantially benefit the cow herd.[20] Controlled research studies tend to indicate that, on average, calves preweaned and fed ad libitum for 30 days do not have sufficient improvements in either health or performance at the feedyard for the cattle feeder to pay a premium for the preweaning and feeding[21-26] (Table 3). On average, these calves gained 30 to 60 lb and consumed 200 to 500 lb of a 50% concentrate diet, whereas calves left with the cow and provided no supplemental feed gained 10 to 50 lb during the same period. At the feedyard, preweaned calves have about 20% less morbidity and death loss but 0 to 7% poorer feed conversions than calves that were not preweaned. Thus, on average, economic benefits realized from improved health were negated by poorer feed conversions. More recent empirical evidence suggests that preweaning calves 45 to 60 days before sale and feeding them so that they gain about 2 lb per day is more economical than a 30 day ad libitum preweaning program.[27] It is also likely that preweaning large-framed calves is more economical than preweaning small-framed ones.

A second method of providing proper nutrition for calves at the farm that requires less investment and time than preweaning and feeding is creep feeding. Best returns seem to occur when calves are creep fed for about the last 60 days at the farm. Poorer economic returns occur when the creep feeding period is shorter or longer than 60 days.[28] Creep feeding of "large-framed" calves seems to be more economically profitable than creep feeding of "small-framed" calves.[29]

Several studies indicate that the best economic returns occur when calves are limit fed during the creep period[30-35] (Table 4). Providing each calf daily with 1 to 3 lb of a creep ration formulated to balance for grass conditions can yield a 0.2 to 0.5 lb per day increase in calf weight gain. Once calves learn to eat the creep ration, intakes can be limited via the use of salt.[31] Limited creep rations have ranged from a simple 90% cottonseed meal/10% salt mixture to very complex formulations.

Limited creep feeding of calves can be difficult to manage, and some producers object to the high salt concentrations often required in the creep ration to limit intakes. However, studies in Florida indicate that

TABLE 4
Influence of Limited Creep Feeding on Feeder Calves

Study and Parameter	*Control*	*Creep*	*Preconditioned*
Pate and Crockett[30]			
Sale weight (lb)	508	513	497
Daily gain (lb)	1.91	2.20	2.05
Morbidity (%)	26	2	10
Mortality (%)	2	0	0
Lusby[31]			
Preweaning ADG (lb)	1.16	1.42	
Creep feed/added gain (lb/lb)	—	5.5	
Transport shrink (lb)	11.7	19.8	
Feedlot ADG (lb)	2.09	2.29	
Treatments/calf	3.2	2.6	

ADG = average daily gain.

TABLE 5
Response of Florida Calves to Limited Creep Feeding of Cottonseed Meal or Molasses for 60 Days

Parameter	*Control*	*Cottonseed Creep*	*Molasses Creep*
Creep intake (lb/day)	—	0.44	0.77
Daily gain (lb)	1.46	1.68	1.87
Added gain (lb/day)	—	0.22	0.41
Feed/added gain (lb/lb)	—	2.00	1.88
Cost/added gain ($/lb)	—	0.26	0.09

Data from T. Weaver, U.S. Sugar Corp.

molasses-based, liquid creep feeds can be used very successfully[b] (Table 5). Compared to grain-based creep feeds, liquid creep feeds can be easier to manage, require less labor, do not require high salt concentrations to limit intake, and may be more easily adjusted to control intake.

Results of one study indicate that limited creep fed calves have about 20% to 25% less morbidity and death loss and 0 to 3% better feed conversions at the feedyard.[30] Thus, from a practical standpoint, limited creep feeding offers many advantages over a preweaning program under most circumstances.

[b]Weaver T: Personal communication.

Feeding during Marketing/Transport

Because of costs and logistics, most auction and order-buyer facilities provide calves with a diet of only low quality hay; properly formulated diets and supplements are usually not available. Compared to calves fed a low quality hay, calves fed a nutritionally balanced, 50% concentrate pretransport diet lose about 30% less weight, 25% less water, and 30% less protein during a 24 hour transport period.[10,11] In addition, calves fed a nutritionally balanced diet while in the auction or order-buyer facility have lower morbidity and better feedyard performance than calves fed low

TABLE 6
Effects of Order-Buyer Barn Diet[a] on Feedlot Performance[b]

Parameter	*Hay*	*50% Concentrate Diet*	*Improvement*
Daily gain (lb)	2.51	2.68	6.8%
Morbidity (%)	44.5	39.3	13.2%
Mortality (%)	6.15	2.99	51.4%
Feed/gain (lb/lb)	5.57	5.41	2.9%

[a]Diets were fed for 3 days before transport from Tennessee to Texas.
[b]Means of three studies (References 21 and 70 and Koers WC et al: *J Anim Sci* 41:408, 1975).

TABLE 7
Typical Dry Matter Intake (DMI) of Newly Arrived Feeder Calves

Days after Arrival	*DMI (% of body weight)*
1–7	0.5–1.5
8–14	1.5–2.5
15–28	2.5–3.5

Data from Hutcheson DP, Cole NA: *J Anim Sci* 62:555–560, 1986.

TABLE 8
Cumulative Percentages of Calves Eating during the First 7 Days after Arrival at the Feedyard

	Calves Eating (%)	
Day	*Healthy*	*Morbid*
1	38.9	27.0
2	66.2	47.3
3	84.5	66.6
4	88.9	75.8
5	90.2	80.1
6	94.6	81.7
7	94.6	83.4

Data from Hutcheson DP, Cole NA: *J Anim Sci* 62:555–560, 1986.

quality hay (Table 6). However, some calves will not eat a 50% concentrate diet at the auction or order-buyer facility. Therefore, to assure that all calves receive nutrients at the auction or order-buyer barn, calves should be offered both a 50% concentrate diet and good quality hay at these facilities.

When offered both concentrate and hay, calves normally consume 0.5% to 1% of their body weight of the concentrate portion and 1% to 1.5% of their weight of the hay. As hay quality improves, hay intake increases relative to concentrate intake. If calves are accustomed to eating a concentrate diet (either because of previous creep feeding or preweaning), intakes of the concentrate portion will be greater. Most newly weaned calves eat only enough hay and/or concentrate to meet their maintenance energy requirements during the short stay in the auction or order-buyer barn.[21,22] Therefore the diet should be formulated so that requirements for other nutrients (protein, vitamins, and minerals) are met if intake is limited (about 1% of body weight).

When given a nutritionally balanced diet before an extended transport period, calves have an increased capacity to tolerate the stresses of transit, start on feed faster, and have fewer health problems at the feedyard. Economic analysis indicates that feeding a nutritionally balanced diet

TABLE 9
Dietary Nutrient Requirements for a 440 lb Medium-Framed Steer Calf Eating 1%, 2%, or 3% of Body Weight[a]

Parameter	*Intake (% of Body Weight)*		
	1%	*2%*	*3%*
Average intake (lb)	4.4	8.8	13.2
Expected daily gain (lb)[a]	–0.29	1.10	2.35
Required concentration			
Crude protein (%)	15.8	13.0	11.8
Calcium (%)	0.55	0.50	0.55
Phosphorus (%)	0.45	0.28	0.27
Magnesium (%)	0.25	0.12	0.10[b]
Potassium (%)	1.60	0.80	0.60[b]
Sodium (%)	0.20	0.10	0.08[b]
Copper (ppm)	20	10	8[b]
Manganese (ppm)	100	50	40[b]
Iron (ppm)	125	62	50[b]
Zinc (ppm)	75	38	30[b]

[a]For calculations, it is assumed that ration has an NEm value of 1.7 Mcal/kg (77 mcal/cwt) and an NEg value of 0.95 Mcal/kg (43 mcal/cwt).
[b]Recommended values for all beef cattle diets from National Research Council: *Nutrient Requirements of Beef Cattle*, ed 6, rev. Washington, DC, National Academy Press, 1984.

rather than low quality hay at the order-buyer barn can result in about a $20 return for each dollar invested.

Feeding after the Stress of Marketing/Transport

The diet fed during the first 2 to 4 weeks after arrival at the feedyard or stocker operation can significantly affect morbidity, mortality, performance, and cost of gain. There is probably no single best receiving program for the stressed calf. The optimum program for each group of calves depends on their background, the amount of stress encountered during marketing/transport, feed costs, and cattle costs.

One major problem in feeding the market/transport-stressed calf is low feed intakes (Tables 7 and 8). Feed intake of stressed calves is highly variable, and many calves do not obtain adequate intakes until the second or third week after arrival; this makes proper formulation of the diets difficult (Table 9).

Energy

Under most circumstances, energy is the first limiting nutrient in the diet of market/transport-stressed calves, primarily as a result of their low feed intakes. In general, as the energy concentration of the receiving diet increases, net energy intake increases, morbidity and mortality increase, performance improves, and the cost of gain decreases[36,37] (Table 10). The adverse health effects of feeding higher energy diets to stressed calves can be partially overcome by providing free choice, good quality hay along with the concentrate diet for the first 3 to 7 days after arrival[36,37] (Table 11). The number of days that hay is fed should be based on the health of the cattle. If alfalfa is used in the receiving program, it should be of average to good (not excellent) quality. If native hay or oat hay is fed, it should be of good to excellent quality.[36,37]

In operations with limited capacity to mix complete diets, calves can be fed good quality native hay, with each calf also

TABLE 10
Effect of Concentrate Level in Receiving Diet on Calf Health and Performance

Parameter	*% Concentrate in Diet*		
	25%	*50%*	*75%*
Morbidity (%)	47	49	57
Mortality (%)	4.57	2.35	4.65
Treatment days/calf	2.5	2.7	3.3
Daily gain (lb)	1.25	1.40	1.47
Feed/gain (lb/lb)	7.58	7.07	6.12
Relative cost/lb gain ($)	1.00	1.02	0.98

Data from References 36 and 37.

TABLE 11
Influence of Feeding No Hay, Free Choice Alfalfa Hay, or Free Choice Native Hay with a 75% Concentrate Receiving Diet on Feeder Calf Health and Performance

Parameter	*No Hay*	*Alfalfa Hay*	*Native Hay*
Morbidity (%)	41	37	30
Mortality (%)	0.9	0.0	0.9
Daily gain (lb)	1.02	1.12	0.90
Feed/gain (lb/lb)	7.99	8.04	9.64
Relative cost/lb gain ($)	1.00	0.84	0.89

Data from References 36 and 37.

receiving 2 lb of a pelleted, 40% protein supplement daily.[38] The major limitation of this system is poor early performance.[37]

Highly stressed calves seem to have a low tolerance to supplemental fat in the receiving diet. Adding 4% fat (tallow/vegetable oil blend) to the receiving diet of stressed calves improved animal performance[39] (Table 12); however, when morbid calves received 4% fat in the diet, mortality increased. This finding suggests that although fat can be used in the receiving diet, it should not be added to hospital pen diets.

Stressed calves prefer a dry diet over a diet high in corn silage but seem to adapt to a corn silage-based diet within 7 to 14 days.[40–43] The type of grain (corn versus wheat versus sorghum) in the receiving diet seems to have little effect on calf health or performance.[46–48]

Protein

The crude protein requirements of stressed calves do not appear to be appreciably greater than those of nonstressed calves.[49,50] Because of low feed intakes, however, the concentration of protein in the diet must be increased to meet the calves' requirements. In general, best results have been obtained in research studies when the receiving diet contained 13.5% to 14.5% crude protein.[49–55]

Stressed calves have a low tolerance for urea and other non–protein-nitrogen sources. Urea intakes should be limited to

TABLE 12
Effect of Added Fat in the Receiving Diet on Calf Health and Performance

	Added Fat (%)	
Parameter	*0%*	*4%*
Morbidity (%)	60.2	57.8
Mortality (%)	8.4	12.0
Daily gain on day 56 (lb)	2.20	2.42
Feed/gain on day 56 (lb/lb)	6.09	5.61

Data from Reference 39.

less than 30 g per head daily during the first 2 weeks after arrival.[56-58]

In general, feeding high "ruminal escape" (bypass) proteins to stressed calves has produced favorable results; however, improvements in health or performance are rarely sufficient to justify their high cost.[41,54,57,59-69] Calculations by Preston and Bartle[67] suggest that best results were obtained when about 60% of supplemental protein (i.e., 45% of total protein or 5.4% of diet dry matter) was composed of ruminal escape protein. The data of Brake and associates[54] suggest there may be an interaction between protein source and concentration in the receiving diet (Figure 1).

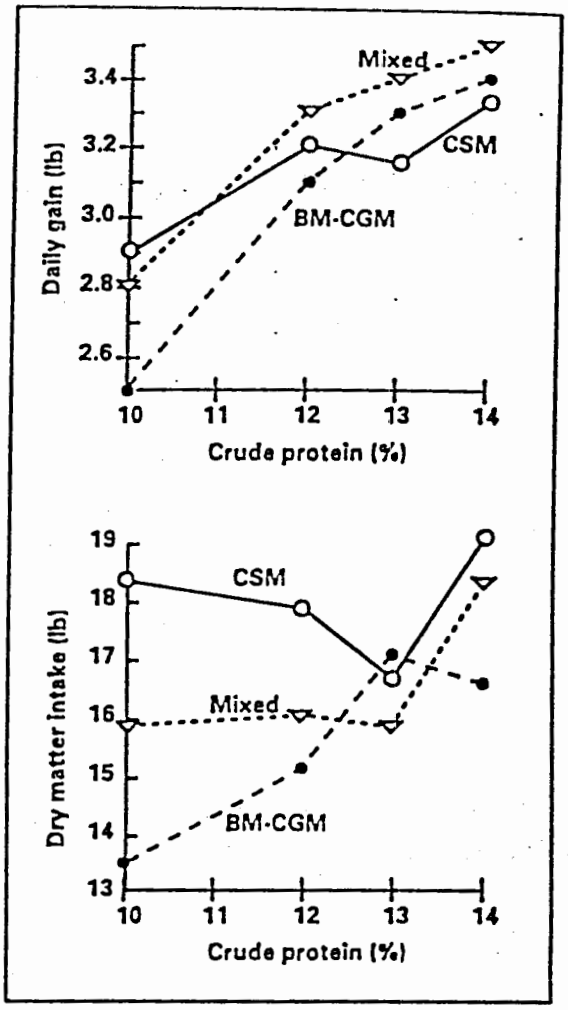

Figure 1. Effects of protein concentration and source on daily gain and dry matter intake of stressed feeder calves. *CSM* = cottonseed meal; *BM-CGM* = 50/50 blood meal/corn gluten meal; *Mixed* = mixture of 15% BM, 8% CGM, 33% hydrolyzed feather meal, 22% meat and bone meal, and 22% CSM.[84]

Minerals

As with protein, the mineral requirements of stressed calves do not seem to be appreciably increased compared to those of nonstressed calves. (One exception is potassium. The potassium requirement of stressed calves seems to be approximately 20% greater than nonstressed calves.[70]) However, the concentrations in the receiving diet must be increased to compensate for low feed intakes.

It is well documented that infection and stress affect trace mineral metabolism, especially Zn and Cu.[6,12,14,71-76] Nevertheless, studies on several trace mineral (Cu, Fe, Zn, Se) requirements of stressed calves have been inconclusive. In addition, studies using organic/chelated forms of these minerals compared to inorganic forms have yielded variable or inconclusive results.[73-78] These highly variable results may be a result of interactions between trace mineral concentrations and sources.[77]

Numerous studies have been conducted to evaluate the effects of selenium supplementation on animal health, performance, and immune response.[79-83] As with

TABLE 13
Influence of Vitamin Supplementation on Feeder Calf Health and Performance

Vitamin(s) Given	*Method of Administration*	*% Change with Supplementation*		
		BRD	*ADG*	*Gain/Feed*
A and D	Injected	–3.0	+4.1	–1.1
A, D, and B_{12}	Injected	+3.0	+1.6	+2.4
A (11,000 IU/kg)	Fed	+28.0	–20.0	–9.0
Thiamine (1 g/head/day)	Fed	–17.0	+2.0	—
Niacin (250 ppm)	Fed	–4.0	+29.0	+45.0
B complex	Fed	–3.0	+4.2	+5.1
E (50 IU/head/day)	Fed	—	+5.3	—
E (100 IU/head/day)	Fed	—	+7.2	—
E (300 IU/head/day)	Fed	—	+14.0	—
E (400 IU/head/day)	Fed	–2.6	+5.2	+5.0
E (400 IU/head/day) + B complex	Fed	–0.5	+10.9	+10.9
E (800 IU/head/day)	Fed	–27.2	+38.4	+36.3
E (1600 IU/head/day)	Fed	–11.7	+22.2	+28.5
E (196 IU/kg)	Fed	—	+7.1	+0.3
E (340 IU/head)	Injected	–15.7	–10.8	–15.0
E (340 IU/head)	Injected	+14.3	+6.8	+10.0
E (1500 IU/head)	Injected	—	+14.3	—
E (1500 IU/head)	Injected	—	0.0	0.0
E (2000 IU/head)	Injected	+33.8	–1.2	–7.6
E (2500 IU/head)	Injected	+4.0	–1.9	—
E (3000 IU/head)	Injected	+12.6	–4.7	—

— = no data provided.
Data from References 21, 22, 54, 79, 81, 90–93, 96, and Hays VS et al: Oklahoma State University Animal Science Research Report MP-119, 1978, pp 198–201.

other trace minerals, experimental results have not been conclusive. Because Se use is regulated by federal agencies and there are concerns over its effect on the environment, Se supplementation should be monitored carefully and should be based on Se concentrations in basal ration ingredients.

Several recent studies have suggested that supplemental Cr may have beneficial effects on stressed calves.[84–86] As with Se, Cr is a potential environmental hazard; therefore supplementation should be monitored carefully.

Canadian workers demonstrated that providing electrolytes in the drinking water of slaughter bulls could increase hot carcass weight.[87,88] This suggests that provision of an electrolyte solution to market/transport-stressed calves might decrease tissue shrink. However, when lambs were subjected to stressors similar to those encountered by calves during marketing and transport, provision of an electrolyte solution did not affect the animal's response to stress.[89] Results at our location suggest that to obtain benefit from the provision of electrolyte solutions the concentration of electrolytes may need to be varied, depending on the level of stress encountered by the calf.[c]

[c]Cole NA: Unpublished data.

Vitamins

Studies testing the effects of injecting or feeding vitamins to stressed calves also have yielded variable results (Table 13). Some studies have shown dramatic improvements in health and performance,[90,91] whereas others have shown no effect[21,22,92] or even negative effects.

Feeding of B vitamins, especially niacin (100 to 200 ppm), has tended to decrease sickness and improve performance of stressed calves.[90,93] High intakes of vitamin E seem to stimulate the immune response if the vitamin is given before bacterial challenge but appear to have no effect when the vitamin is given after the challenge.[94,95] Most studies have noted improved performance and/or health of stressed calves fed supplemental vitamin E in the receiving diet. However, the performance and health responses of calves to injections of vitamin E have been more variable.[80,81,83,96] These variable results are probably due to the greater variability in the quality, composition, and recommended injection site (intramuscular versus subcutaneous) of the injectable vitamin E products that are available. Therefore producers and consultants should be wary and select injectable vitamin E products based on good research.

Other Nutritional Factors

A number of feed additives and supplements are currently available for use in stressed feeder calves. Both positive and negative data have been reported for most of these products. The use of feed additives in receiving diets must be based on need, efficacy, cost, and legality of combinations. Need and efficacy are usually determined by factors such as the source of the cattle, the amount of stress placed on the cattle, health of the cattle, weight and age of the cattle, season of the year, and the like.

The use of antibiotics in receiving diets has generally been associated with good results when morbidity and mortality were low.[97,98] When morbidity and mortality were high, use of antibiotics in the feed has been less promising, probably because calves did not consume enough of the ration containing the antibiotic. Variable response to prophylactic antibiotic treatment may be a result of the apparent increase in strains of *Pasteurella* resistant to many of the available antibiotics.[99,100]

Many stressed feeder calves excrete coccidia oocysts, and studies have indicated that the feeding of a coccidiostat upon arrival can be beneficial.[100–105] Best results with dietary coccidiostats have generally

TABLE 14
Recommended Nutrient Content of a Feedyard Receiving Diet for Market/Transport-Stressed Feeder Calves

Nutrient	*Range*
Dry matter (%)	82–90
NEm (mcal/cwt)	60–85[a]
NEg (mcal/cwt)	36–51[a]
Concentrate (%)	50–70[a]
Crude protein (%)	13.0–15.0
Urea (g/head/day)	<30
Calcium (%)	0.5–0.7
Phosphorus (%)	0.4–0.5
Potassium (%)	1.0–1.3
Sodium (%)	0.2–0.3
Magnesium (%)	0.2–0.3
Sulfur (%)	0.15–0.25
Manganese (ppm)	50–100
Copper (ppm)	10–20
Iron (ppm)	75–125
Zinc (ppm)	75–100
Selenium (ppm)	0.1–0.2
Cobalt (ppm)	0.1–0.2
Vitamin A (IU/lb)	1100–2000[b]
Vitamin E (IU/lb)	20–50[b]
Fat (%)	<6

[a]For calves weighing 400 lb or less use the greater value, for 500 lb calves use an intermediate value, and for 600 lb calves and yearlings use the lower value. Ration should be fed with free choice hay for the first 3 to 7 days.
[b]If pelleted, double the value to compensate for pelleting loss.

TABLE 15
Interaction between Vitamin E Injections and Vaccination with a *Pasteurella haemolytica* Toxoid

Item	*Nonvaccinated Calves*		*Vaccinated Calves*[a]	
	Not Given Vitamin E	*Given Vitamin E*[b]	*Not Given Vitamin E*	*Given Vitamin E*[b]
Initial weight (lb)	382	382	378	378
Daily gain (lb)	1.66	1.65	1.75	1.74
Morbidity (%)	50	45	13	40
Treatment days/calf	2.0	2.5	2.5	1.9
Mortality (%)	6.7	3.4	0.0	3.3

Data from Reference 96.
[a]Calves vaccinated for *Pasteurella haemolytica* (IM) upon arrival at the feedyard.
[b]Calves injected IM with 2000 IU of vitamin E upon arrival.

been noted when morbidity and mortality were high.

The use of ionophores (monensin, lasalocid) upon arrival is complicated by the use of other additives such as antibiotics and coccidiostats. Addis and coworkers[106] recommended that monensin be limited to about 10 g per ton of receiving ration during the first 2 weeks. However, Prichard and Thompson[107] suggested that best results occurred when monensin was fed at 30 g per ton. Several studies have indicated that lasalocid in the receiving diet can have beneficial effects on performance.[101,108,109]

Most calves that enter feedyards carry a parasite burden, even if they are given an anthelmintic 30 days before shipment.[110] Because internal and external parasites can have marked effects on calf energy requirements,[111,112] calves should be treated for economically important helminth and arthropod parasites, even if the animals were "preconditioned."[113,114]

Some studies have shown beneficial effects of feeding (or dosing) *Lactobacillus*, yeast, and other microbial cultures upon arrival.[71,115-120] In general, the results have been variable and dose dependent. The use of these products in sick calves seems to be more promising than mass use in all incoming calves. The proportion of microorganisms that are destroyed by antibiotic treatment is not known.

A few studies have shown beneficial effects (on average, a 9% decrease in incidence of bovine respiratory disease and a 9% increase in daily gain) from daily feeding of 40 to 100 g of sodium bicarbonate per head upon arrival.[121-124]

Over the years, a number of commercial products have been reported to improve ruminal function and thereby improve feed intake, health, and performance. In general, the stress of administering these products is greater than the benefits achieved.[97,125] Our studies indicate that replacing the ruminal fluid of a stressed sheep with fluid from a nonstressed animal did not affect feed intake.[7] This is probably because metabolic, rather than ruminal, factors have the primary role in the control of feed intake in stressed calves.[4]

Suggested nutrient concentrations in a receiving diet for stressed feeder calves are presented in Table 14. As a general rule of thumb, receiving diets should be formulated so that the calf receives at least maintenance requirements for protein, vitamins, and minerals when feed consumption is 1% to 1.5% of body weight.

Nutritional and Management Interactions

Interactions between common processing procedures (vaccination) and nutritional

TABLE 16
Interaction between Preshipment Management and Postshipment Diet Energy Concentration

Item	*C-LE*	*PC-LE*	*C-HE*	*PC-HE*
DM intake (lb)	14.7	15.2	12.3	14.5
DE intake (mcal)	14.7	15.0	16.7	19.6
Morbidity (%)	10.0	10.0	40.0	13.3

Data from Cole NA, Hutcheson DP, Ross JE, Thorne J: Unpublished data.
C = control calves left with their dam at the farm; PC = preconditioned calves, weaned and fed a 50% concentrate diet for 30 days before leaving the farm; LE = calves fed a low energy feedlot receiving diet; HE = calves fed a high energy receiving diet; DE = digestible energy.

regimens seem to occur[96] (Table 15). This suggests that some procedures that have normally been considered "good insurance" may in fact be detrimental to animal health and/or performance.

Management and nutritional factors that occur before the stress of marketing/transport can markedly influence which management and nutritional practices would be optimum after the animals' arrival at the feedyard. If calves have been consuming a high protein diet (e.g., lush grass) before transport, higher protein concentrations are required in the receiving diet.[49] Calves that have been accustomed to concentrate diets at the farm of origin (via preweaning or creep feeding) will eat more of a concentrate-based receiving diet than calves unaccustomed to concentrates but will eat about the same amount of high-roughage diets[d] (Table 16).

Supportive Nutrition

Many stressed and morbid calves refuse to eat any diet offered to them. Under these circumstances, as well as in cases involving severe diarrhea, it may become appropriate or necessary to provide supportive nutrition along with pharmaceutical treatment to keep the calf alive. In the morbid calf, simply decreasing body temperature may be adequate to stimulate the calf to eat. The use of certain microbial culture products containing *Lactobacillus acidophilus*, fungi, or yeast cultures may stimulate feed consumption in some animals. When these methods do not succeed, more strenuous measures such as intravenous, oral, intraruminal, or intraperitoneal infusions may be warranted.

Many oral and parenteral electrolyte and nutrient solutions are currently available. The advantages, disadvantages, and proper use of these solutions have been extensively reviewed elsewhere.[126]

[d]Cole NA, Hutcheson DP, Ross JE, Thorne J: Unpublished data.

Conclusions

Although general recommendations can be made concerning the preshipment and postshipment nutrition and management of stressed feeder calves, research data and practical experience indicate that no one program can be devised that is best for every load of calves. Hence the practitioner, consultant, and cattle feeder must be prepared to adjust management to fit each load of calves.

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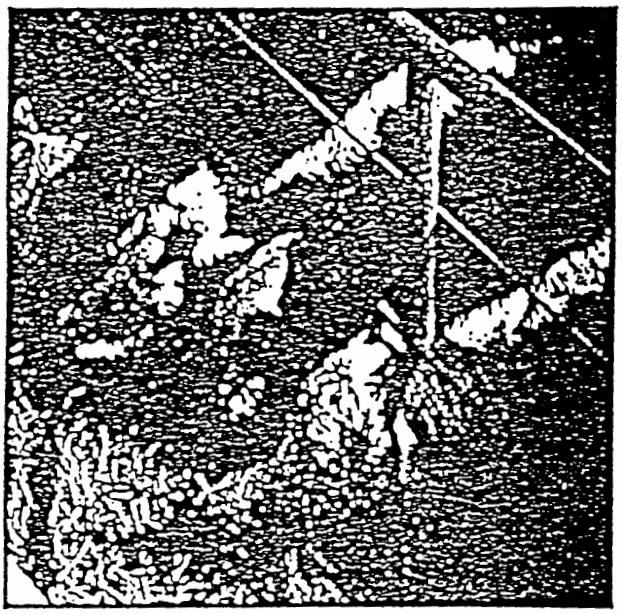
BOVINE RESPIRATORY DISEASE



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