IMMUNE RESPONSES TO PROPER NUTRITIONAL MANAGEMENT[1,2]

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INTRODUCTION

Cattle encounter numerous physiological and psychological stressors during their life, especially during movement from one production point to another. These stressors induce hormonal changes, anorexia, exhaustion, altered nutrient metabolism, dehydration, and suppressed immune response. Further, the adverse effects of many of these stressors appear to be additive.

Proper nutrition can have direct beneficial effects on the immune system. In addition, proper nutrition can have indirect effects on the immune system by preparing the animal for a period of stress, reducing the adverse effects of stress and enhancing recovery from stressful periods, thus, helping to prevent immune suppression caused by stress.

THE IMMUNE SYSTEM

The immune system of mammals is composed of three components: Mucosal-Barrier Immunity, Humoral Immunity (antibody), and Cell-Mediated Immunity (CMI). Mucosal-Barrier Immunity is non-specific while Humoral and CMI are specific for a particular pathogen. Although often discussed separately, each component is intricately linked to the other components.

Nutrition can affect the immune system in many ways, among them: 1) anatomical development of lymphoid tissues, 2) mucus production, 3) synthesis of immunologically active substances, 4) cellular proliferation, 5) cellular activation and movement, 6) intracellular killing of pathogen, and 7) modulation and regulation of immune processes (Sherman, 1990).

In general, severe nutrient deficiencies impair at least one component of the immune system (Table 1). More recent research indicates that even subclinical deficiencies can impair immune response (Rivlin, 1990). Many nutrition-immunity studies are complicated by the fact that nutritional modification may have positive effects on one immune component while having negative effects on other components. This suggests that modifications in nutrition that could be beneficial in protecting the animal from a specific virus may, at the same time, have adverse effects on the animals ability to avoid a bacterial infection (The "feed a cold, starve a fever" scenario).

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[2]Mention of a specific product or piece of equipment does not constitute an endorsement by the USDA and does not imply their approval to the exclusion of other products that may be suitable.

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 not clear. 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 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?

The wealth of information concerning the effects of nutrition on immune function is too great and complex to cover in this short space. This review will attempt to cover the applied research concerning nutritional effects on the health and performance of feeder calves stressed by marketing and transport.

TABLE 1. SUMMARY OF THE EFFECTS OF NUTRITIONAL DEFICIENCIES ON IMMUNE RESPONSE AND FEEDER CALF HEALTH[a]

Nutrient	Immune component		
	CMI	Humoral	% BRD
Protein, chronic	I	NE, D	?
acute	I,D	I,D	I
Protein-calorie	D	D	I
Vitamins			
A	-	D	NE
D	-	NE	NE
E	D	D	I,NE,D
C	D	D	--
B_1	NE	D	NE,I
B_{12}	D	D	NE,I
Minerals			
Iron	D	-	--
Zinc	D	-	NE,I
Selenium	D	D	NE,I
Copper	D	D	--
Iodine (thyroxine)	D	NE, D	--
Amino Acids	D	D	--

[a] CMI = cell-mediated immunity. % BRD = percentage of calves treated for bovine respiratory disease. I = increased, D = decreased, NE = no effect. From Chandra, 1990 & other papers.

PRESTRESS NUTRITION

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

ON FARM NUTRITION. The diet of feeder calves at the farm-of-origin usually consists of grass and milk; although calves receive less than 15% of their nutrition from milk during the last 60 days before weaning. As a result, the diet calves receive before leaving the farm/ranch can be highly variable, depending upon the quality and quantity of grass available. Other factors such as plant toxins like the fescue endophyte may adversely affect immune status of calves when they leave the farm-of-origin (Dew et al., 1988; Purdy et al., 1989).

TABLE 2. EFFECTS OF PREWEANING/PRECONDITIONING ON FEEDER CALVES[a]

Item	Trials	Control	Preconditioned
On farm (last 30 d):			
Weight gain, lb	17	43	48
Feed intake, lb	12	0	363
Added gain/lb feed, lb	12	--	0.013
Transport shrink, %	10	8.75	9.00
Feedyard performance:			
Daily gain, lb	13	2.34	2.32
Gain/feed, lb	7	0.139	0.133
Morbidity, %	15	38.6	30.5
Mortality, %	15	2.0	1.2

[a] Cole, 1985.

One method to assure that calves are properly nourished upon leaving the farm is to wean them 4 weeks before sale and feed 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 (Basarab et al., 1986). On average, preweaned calves do not have sufficient improvements in either health or performance at the feedyard for the cattle feeder to pay a premium for preweaned calves. (Table 2).

A second method of providing proper nutrition that requires less investment and time, is to limit-creep-feed calves during the last 60 to 90 days on the farm (Table 3). Providing calves with 1 to 3 lb/calf daily of a creep ration formulated to balance for grass conditions can yield a .2 to .5 lb/day increase in calf weight gain. Once calves learn to eat the creep ration, intakes can be limited via the use of salt (Lusby, 1989).

AUCTION/ORDERBUYER BARN. Because of costs and logistics, most auction and orderbuyer facilities provide calves with a diet of only low quality hay; properly formulated diets and supplements are usually not provided. Calves fed a balanced, 50% concentrate pre-transport diet will have lower morbidity and better feedyard performance than calves fed low quality hay (Table 4). However, because some calves will not eat a 50% concentrate diet at the auction/order-buyer facility, calves should be fed a 50% concentrate diet plus good quality hay at these facilities. During the short stay in the auction or order-buyer barn, freshly weaned calves will eat only enough hay and/or concentrate to meet their maintenance energy requirements (Cole et al., 1979; 1982). The diet, therefore, should be formulated so that requirements for other nutrients are met when dry matter intake is about 1% of body weight.

TABLE 3. INFLUENCE OF LIMITED CREEP FEEDING ON FEEDER CALVES

Item	Control	Creep	Preconditioned
Pate & Crockett, 1974			
Sale weight, lb	508	513	497
Daily gain, lb	1.91	2.20	2.05
Morbidity, %	26	2	10
Mortality, %	2	0	0
Lusby, 1989			
Preweaning ADG, lb	1.16	1.42	
Added gain/lb creep, lb	--	0.185	
Transport shrink, %	2.62	3.33	
Feedlot ADG, lb	2.09	2.31	
Treatments/calf	3.2	2.6	

TABLE 4. EFFECTS OF ORDERBUYER BARN DIET ON FEEDLOT PERFORMANCE[a]

Item	Hay	50% Conc.	Improvement
Daily gain, lb	2.51	2.68	6.8%
Morbidity, %	44.5	39.3	13.2%
Mortality, %	6.15	2.99	51.4%
Gain/feed, lb	0.179	0.185	3.2%

[a] Koers et al., 1975b; Cole et al., 1979; Hutcheson et al., 1984. 50% Conc. = 50% concentrate diet.

POSTSTRESS NUTRITION

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

A major problem in feeding the market/transport stressed calf is low feed intake (Table 5). Feed intake of stressed calves is highly variable and many calves do not obtain adequate intakes until the second or third week after arrival, which makes proper formulation of diets difficult.

TABLE 5. TYPICAL DRY MATTER INTAKE (DMI) OF NEWLY ARRIVED FEEDER CALVES. (Hutcheson & Cole, 1986)

Days after arrival	DMI, % of body weight
1 - 7	.5 to 1.5
8 - 14	1.5 to 2.5
15 - 28	2.5 to 3.5

ENERGY. In general, as the energy concentration of the receiving diet increases, morbidity and mortality increase, performance improves and costs of gain decline (Lofgreen, 1983, 1988). Adverse health effects caused by feeding higher energy diets to stressed calves can be overcome by providing free-choice good quality hay along with the concentrate diet for the first 3 to 7 days after arrival (Tables 6 & 7).

TABLE 6. EFFECT OF CONCENTRATE LEVEL IN RECEIVING DIET ON CALF HEALTH AND PERFORMANCE. (Lofgreen, 1983)

Item	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
Gain/feed, lb	0.132	0.141	0.163
Relative cost/lb gain	1.00	1.02	.98

TABLE 7. INFLUENCE OF ALFALFA OR NATIVE HAY FED WITH A 75% CONCENTRATE RECEIVING DIET ON FEEDER CALVES. (Lofgreen, 1983)

Item	75% Conc.	+ Alfalfa	+ Native
Morbidity, %	41	37	30
Mortality, %	0.9	0.0	0.9
Daily gain, lb	1.02	1.12	0.90
Gain/feed, lb	0.125	0.124	0.104
Relative cost/lb. gain	1.00	.84	.89

In operations with limited capacity to mix complete rations, calves can be fed good quality prairie hay along with 2 lb/head daily of a pelleted, 40% protein supplement (Smith et al., 1988). In typical feedyard operations, however, it is best to feed a 50 to 70% concentrate complete diet plus hay because calves fed the supplement/hay program during the first 4 weeks in the feedyard do not compensate for their early poor performance later in the feeding period (Lofgreen, 1983, 1988).

Adding 4% fat to the receiving diet of stressed calves improved animal performance (Table 8). However, when morbid calves received 4% fat in the diet, mortality increased. This suggests that although fat can be used in the receiving diet, it should not be added to hospital pen diets.

TABLE 8. EFFECT OF ADDED FAT IN THE RECEIVING DIET ON CALF HEALTH AND PERFORMANCE. (Cole and Hutcheson, 1987)

Item	0% fat	4% fat
Morbidity, %	60.2	57.8
Mortality, %	8.4	12.0
Daily gain, lb		
Day 14	2.30	3.31
Day 56	2.20	2.42
Gain/feed, lb		
Day 14	0.175	0.266
Day 56	0.164	0.178

Stressed calves prefer a dry diet over a diet high in corn silage but appear to adapt to a corn silage based ration within 7 to 14 days (Preston & Smith, 1973, 1974; Preston & Kunkle, 1974; Koers et al., 1975a; Davis & Caley, 1977).

Type of grain (corn vs sorghum) in the receiving diet appears to have little effect on calf health or performance. Best results appear to be obtained when a mixture of grains is fed (Brethour & Duitsman, 1972b; Addis et al., 1975, 1978b).

PROTEIN. The crude protein requirements of stressed calves (g/day) do not appear to be appreciably greater than those of non-stressed calves. However, because of low feed intakes, the concentration of protein in the diet must be increased to meet the calves' requirements. We currently recommend a crude protein concentration of 13.5 to 14% (dry matter basis) in receiving rations (Bartle et al., 1988; Cole & Hutcheson, 1988; 1990; Eck et al., 1988; Brake et al., 1992; Figure 1).

Stressed calves have a low tolerance for urea and other non-protein-nitrogen sources. Urea intakes should be limited to less than 30 g/head daily during the first 2 weeks after arrival (Preston et al., 1975; Cole et al., 1984).

In general, feeding high "ruminal escape" (bypass) proteins to stressed calves has produced favorable results (Preston & Smith, 1974; Preston et al., 1975; Malcolm et al., 1991; Brake et al., 1992; Figure 1). Preston and Bartle (1990) suggested 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. Initial data suggest there may be an interaction between protein source and concentration in the receiving diet (Figure 1).

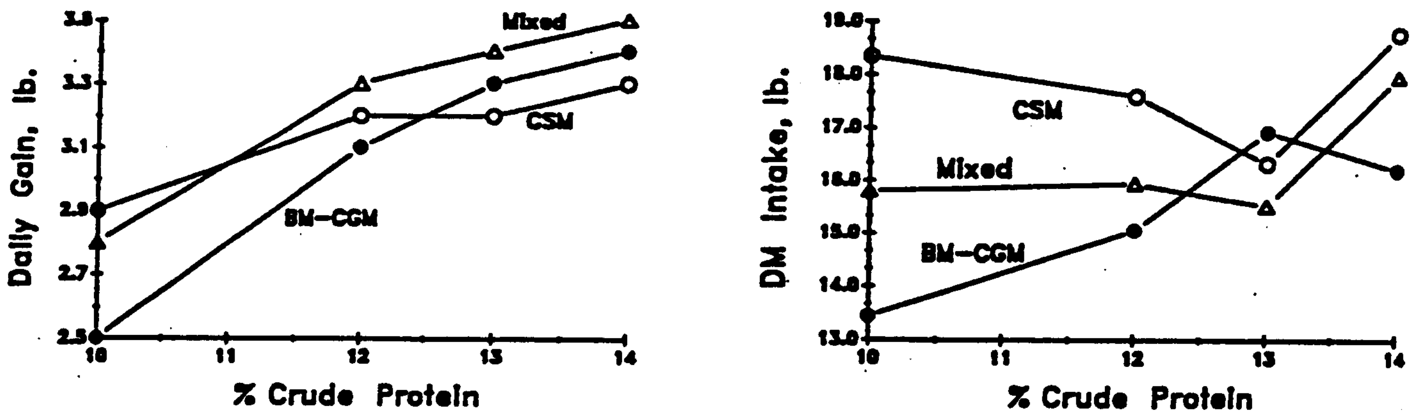

FIGURE 1. EFFECTS OF PROTEIN CONCENTRATION AND SOURCE ON DAILY GAIN AND DRY MATTER INTAKE OF STRESSED FEEDER CALVES. CSM = cottonseed meal, BM-CGM = 50/50 blood meal/corn gluten meal, Mixed = mixture of 15% BM, 8% CGM, 33% hydrolyzed feather meal, 22% meat and bone meal, and 22% CSM. Brake et al., 1992.

MINERALS. As with protein, the mineral requirements (g or mg/day) of stressed calves do not appear to be appreciably increased compared to non-stressed calves, however, the concentrations in the receiving diet must be increased to compensate for reduced feed intakes. One exception is potassium. The potassium requirement of stressed calves appears to be about 20% greater than non-stressed calves (Hutcheson et al., 1984).

Studies on the requirements of several trace minerals (Cu, Fe, Zn, Se) for stressed calves have been inconclusive. In addition, studies using chelated forms of these minerals compared to inorganic forms have yielded variable results.

VITAMINS. Studies testing the effects of injecting or feeding vitamins to stressed calves have also yielded variable results (Table 9). Some studies have shown dramatic improvements in health and performance while others have shown no effect. High intakes of vitamin E appear to stimulate the immune response if the vitamin is given before the bacterial challenge but to have no effect when given after the challenge (Ellis & Vorhies, 1976; Lewis et al., 1976).

In a number of studies injections of vitamin E had detrimental effects (or no improvement) on performance and animal health. Brake et al. (1992) noted higher serum creatine phosphokinase concentrations in steers injected sub-q with vitamin E suggesting that appreciable tissue damage occured at the injection site. Feeding of B-vitamins, especially niacin (100 - 200 ppm), has tended to reduce sickness and improve performance of stressed calves.

TABLE 9. INFLUENCE OF VITAMIN SUPPLEMENTATION ON FEEDER CALF HEALTH AND PERFORMANCE[a].

Vitamin(s) given	Method of Administ.	% change with supplementation BRD	ADG	Gain/Feed
A & D	Inject	-3.0	+4.1	-1.1
A, D & B_{12}	Inject	+3.0	+1.6	+2.4
Thiamine (1 g/hd)	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 (400 IU/hd/d)	Fed	-2.6	+5.2	+5.0
E + B complex	Fed	-0.5	+10.9	+10.9
E (1600 IU/hd/d)	Fed	-11.7	+22.2	+28.5
E (89 IU/lb DM)	Fed	--	+7.1	+0.3
E (1500 IU/hd)	Inject	--	+14.3	--
E (50 IU/hd/d)	Fed	--	+5.3	--
E (100 IU/hd/d)	Fed	--	+7.2	--
E (300 IU/hd/d)	Fed	--	+14.0	--

[a] Brethour & Duitsman, 1971, 1974, 1976; Overfield et al., 1976; Davis, 1978a; Cole et al., 1979, 1982; Byers, 1980; Hicks, 1980; Hutcheson & Cole, 1985; Brake et al., 1992; Lee, R.W., unpublished data.

OTHER NUTRITIONAL FACTORS. The use of feed additives in receiving diets must be based on several factors including need, efficacy, cost, and legality of combinations.

Antibiotics (e.g. AS-700) in receiving diets have generally shown good results when morbidity and mortality were low (Brethour & Duitsman, 1971; Byers & Smith, 1976). When morbidity and mortality were high, use of antibiotics in the feed has been less promising, probably because calves simply did not consume adequate amounts of the diet.

Recommendations concerning the use of antibiotics in receiving programs are complicated by the apparent increase in strains of Pasteurella resistant to most of our available antibiotics (Post et al., 1991).

Many stressed feeder calves excrete coccidia oocysts and studies have indicated that the feeding of a coccidiostat upon arrival can be beneficial (Hutcheson & Cummins, 1982; Brazle, 1986).

The use of ionophores (monensin, lasalocid) upon arrival is complicated by the use of other additives such as antibiotics and coccidiostats. If monensin is fed in the receiving diet it should be limited to about 10 g/ton of feed during the first 2 weeks (Addis et al., 1978a).

Most calves that enter feedyards carry a parasite burden, even if given an anthelmintic 30 days before shipment (Cole & Hutcheson, unpublished data). Because internal and external parasites can have marked effects on calf energy requirements (Jordan et al., 1977; Cole & Guillot, 1987), calves should be treated for these parasites even if they were "preconditioned."

Some studies have shown beneficial effects of feeding (or dosing) Lactobacillus, yeast, and other microbial cultures upon arrival (Crawford et al., 1980; Hutcheson et al., 1980; Brethour, 1981; Cole et al., 1992). In general, the results have been variable and dose dependent. The use of these products in sick calves appears to be more promising than mass use in all incoming calves. The proportion of these living organisms that are destroyed by antibiotic treatment is not known.

A few studies have shown beneficial effects (average - 9% reduction in BRD and 9% increase in daily gain) from feeding 40 to 100 grams/head daily of sodium bicarbonate upon arrival (Brethour & Duitsman, 1972a, 1973, 1976; Orr et al., 1979).

A number of commercial products have been sold over the years which report to improve ruminal function and thus improve feed intake, health and performance. In general, however, the stress of administering these products is greater than the benefits received (Brethour & Duitsman, 1971; Koers et al., 1974).

Suggested nutrient concentrations in a receiving diet for stressed feeder calves are presented in Table 10. 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.

TABLE 10. RECOMMENDED NUTRIENT CONTENT OF A FEEDYARD RECEIVING DIET FOR MARKET-TRANSPORT STRESSED FEEDER CALVES (DRY MATTER BASIS).

Nutrient	Range	Nutrient	Range
Dry matter, %	82-90	NEm, mcal/cwt	60-85[a]
NEg, mcal/cwt	36-51[a]	Concentrate, %	50-70
Crude protein, %	13.0-14.5	Urea, g/hd/d	< 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	40-70	Copper, ppm	10-15
Iron, ppm	100-150	Zinc, ppm	75-100
Selenium, ppm	0.1-0.2	Cobalt,ppm	0.1-0.2
Vitamin A, IU/lb	1000-2000[b]	Vitamin E, IU/lb	20-50[b]

[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 3-7 days.

[b] If pelleted, double value to compensate for pelleting loss.

PRESTRESS/POSTSTRESS INTERACTIONS

Management and nutritional factors which occur before the stress of marketing/ transport can markedly influence the optimum management and nutritional practices that occur after arrival at the feedyard (Table 11). If calves have been consuming a high-protein diet (ie. lush grass) before transport, higher protein concentrations are required in the receiving diet (Cole & Hutcheson, 1988). Calves that have been accustomed to concentrate diets at the farm-of-origin 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. In addition, there appear to be interactions between common processing procedures (vaccination) and nutritional regimens (Galyean et al., 1991).

TABLE 11. INTERACTION BETWEEN PRESHIPMENT MANAGEMENT AND POSTSHIPMENT DIET ENERGY CONCENTRATION[a]

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

[a] Cole et al., unpublished data. C = control calves left with their dam at the farm; PC = preconditioned calves; LE = calves fed a low energy feedlot receiving diet, HE = calves fed a high energy receiving diet. DE = digestible energy.

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 best program can be devised for every load of calves. The practitioner, consultant and cattle feeder must be prepared to adjust management to fit each group of calves placed on feed.

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