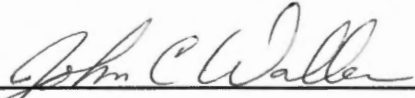


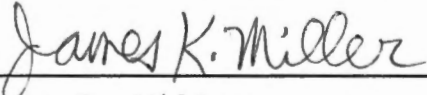
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RUMEN-ESCAPE PROTEIN AND ENERGY SUPPLEMENTS
FOR STARTING CALVES ON FEED

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Royce Eller Towns

August, 1990

AG-VET-MED.

THESIS
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This work is dedicated
to the memory of my grandfather,
Truman A. Eller

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ABSTRACT

In Experiment 1, calves were fed supplement containing rumen-escape protein (REP) and rumen-escape energy (REE) to determine its effects in starting animals on feed. Sixty steer calves were randomly allotted to 12 feedlot pens (five steers/pen) for a 42-d receiving period. Steers were assigned to three dietary treatments: (1) corn silage, (2) corn silage + Bull Developer (BD), and (3) corn silage + high level of REP and REE (HIGH). Calves were weighed on d 0, 14, 28, and 42. Steers fed the HIGH supplement had significantly higher average daily gain (ADG) than had those receiving corn silage alone but were similar to those consuming BD.

In Experiment 2, calves were fed supplements containing three levels of REP and REE. Trial 1 involved 168 newly-weaned steers and heifers (258 kg) allotted to 28 pens (six animals/pen) on the basis of body weight. Supplements consisted of: (1) BD, (2) Low level of REP and REE (LOW), (3) Intermediate level of REP and REE (MED), and (4) High. Supplements were fed along with BD and corn silage for a period of 28 d. Feed intakes were recorded daily and calves were weighed on d 0, 14, and 28. Significant differences in ADG were found only between BD and HIGH in the group of steers. In Trial 2, 72 newly-weaned steers (257 kg) were

allotted to 12 pens (six steers/pen) for 28 d. Three treatments (LOW, MED, and HIGH) were randomly assigned to the 12 pens (four pens/treatment). Average daily gain was lower ($P < .05$) on the MED treatment. In Trial 3, two groups of steers were allotted to 18 feedlot pens. In group 1, 54 steer calves (237 kg) were allotted to nine pens (six steers/pen). In group 2, 81 steer calves (212 kg) were allotted to nine pens (nine steers/pen). Treatments were the same as in Trial 2. Treatment had no significant effect on animal performance.

In Experiment 3, four ruminally-cannulated steers (545 kg) were used to evaluate the four supplements used in Experiment 2. Treatments were assigned in a 4x4 Latin square design. Steers were fed on the basis of d 14 levels of intake from Experiment 2, adjusted for differences in body weight. Steers were fed each treatment for a period of 10 d, with rumen fluid and blood being collected on d 8 and 10. Rumen pH, rumen ammonia (RA), blood urea nitrogen (BUN), and rumen volatile fatty acids (VFA) levels were measured at 2, 4, 6, and 8 h post-feeding. Rumen pH, RA, and BUN were affected by sampling time and period. No differences were detected between treatments.

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CHAPTER I

INTRODUCTION

Beef calves in Tennessee receive nutrients needed for growth and development from milk and forage pre-weaning. Digestion of forages occurs in the rumen through the action of cellulolytic bacteria; however, digestion of milk occurs post-ruminally due to closure of the esophageal groove while the calf is nursing. At weaning, a beef calf may have as much as one-half of its nutrient requirements supplied by milk. Milk contains protein of high biological value and energy, neither of which is exposed to degradation in the rumen. Therefore, the portion of the diet supplied by milk makes a greater net nutrient contribution to the calf than that supplied by feedstuffs consumed and exposed to rumen fermentation. At weaning, milk is no longer available and calves are forced to rely on rumen digestion of forages or other feedstuffs to obtain required nutrients.

In addition to these changes in diet, calves are exposed to a number of stresses at weaning. Many calves are removed from the farms, transported to auction barns, and shipped out of Tennessee to cattle-growing and finishing operations in other states. Much research has been conducted on shipping stress and its effect on starting

calves on feed (Lofgreen et al., 1980; Galyean et al., 1981; Hutcheson and Cole, 1986). Traditional starter diets have been based on feedstuffs to which the calves have been exposed. Therefore, these contain forages such as hay or combinations of hay and other feed ingredients (Lofgreen et al., 1980; Lofgreen et al., 1981; Hutcheson and Cole, 1986). Other approaches emphasize feeding ingredients that reflect the nutrient profiles expected in the next production phase. For example, a diet containing a blend of corn silage and concentrate that will be fed during the next production phase has been used (Waller et al., 1988).

In recent years, research has focused on rumen escape of protein and energy sources for maximum production of milk in dairy cows and maximum growth in young beef cattle. For newly-weaned calves, a logical approach to replacing the nutrients provided by the dam would be feeding a diet that contains quantities of rumen-escape protein (REP) and energy (REE) equivalent to those in milk. For previously-weaned feeder cattle, the use of REP and REE could improve the efficiency of nutrient utilization. Additional research is needed on the response of previously-weaned feeder cattle to starting diets formulated to supply REP and REE.

CHAPTER II

REVIEW OF LITERATURE

Starter Diets

Previous work in the area of starter diets has focused on meeting the nutritional demands of a stressed calf. A calf that has been subjected to weaning, marketing, and transport requires an advanced nutritional management scheme. These animals may eat only limited amounts of a diet or go completely off feed, leading to possibly serious health problems. The objective of a starter diet is to provide the required nutrients at an adequate level in a form that encourages intake.

The most common nutritional problem of newly received calves is poor feed intake. Feed consumption the first few days is usually quite low. From d 1 through 7, calves will consume only 0.5 to 1.5% of body weight (BW) as dry matter (DM) intake (Hutcheson and Cole, 1986). Formulating diets to meet the increased nutritional demands of these calves can be difficult when intakes are less than 1.5% of BW. Consideration must be given also to the fact that not all animals will eat during the first 2 wk after arrival. Hutcheson and Cole (1986) reported that of all healthy

calves, only 38.9% were eating the first day after arrival, only 62.2% after 2 d, and 88.1% after 7 d. The percentage of sick calves eating each day was considerably smaller, ranging from 27 to 70% over the 7-d period.

At least part of this depression of intake can be attributed to reduced rumen function. Lack of water and feed during the marketing process reduces the rumen fermentation capacity by as much as 75% (Cole and Hutcheson, 1981). This same study suggested that it may take 7 d for rumen VFA, pH, and ammonia values to return to pre-fast levels.

These low levels of intake make it difficult for the manager to provide the calves with adequate nutrition. For example, a diet containing 60% concentrate and 14% crude protein (CP) will provide a protein-deficient diet until consumption reaches approximately $3.5 \text{ kg} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$ for 181-kg steers (Thompson and O'Mary, 1983). Using intake data of Hutcheson and Cole (1986), this diet would result in a protein deficiency for up to 10 days in as many as 75% of the calves.

Pre-Stress Nutrition

In previous years, providing adequate pre-stress nutrition was seen as a way to alleviate stress-related problems. In a study conducted by Pate and Crockett (1974), a group of just-weaned calves was transported from a Florida ranch to a Texas feedyard. Calves that had been creep-fed for 24 d had less shrink, higher average daily gain (ADG), and less morbidity than had non-creep-fed calves. These calves did not pass through any marketing channels prior to transport; thus, a portion of stress was reduced or possibly eliminated. In contrast, Stuedemann *et al.* (1966) noted adverse effects on feedlot performance when calves were creep-fed for long periods of time.

Limited availability of feed during the marketing and transport process can result in calves being fasted for 24 h or more. Cole and Hutcheson (1988) fed steers 8-, 12-, and 16%-CP diets 14 d prior to fasting and diets containing 10 and 15% CP post-fast. They observed that those fed the 16%-CP diets had lower feed intakes upon realimentation. Their results indicated that CP content of a receiving diet can affect feed intake, but the magnitude of this effect was dependent upon the CP content of the pre-fast diet. Similarly, increasing the CP content of the diet prior to

fasting can delay some of the adverse effects of fasting in sheep (Koenig and Boling, 1981).

However, since most Tennessee beef calves are raised in a forage-based production system, pre-stress dietary roughage content also could be important as a means of reducing stress. Cole and Hutcheson (1985) noted that increasing levels of pre-stress roughage intake provided steers with a greater reserve of energy, water, and electrolytes. This reduced time needed to adapt calves to new diets. Later work (Cole and Hutcheson, 1987a) indicated that roughage level in pre-fast diets had no effect on post-fast weight gains or feed intakes when pre-fast intake was held constant. Total roughage intake appeared to have a greater effect on post-fast performance than did level of roughage in the diet.

Feeding a 55%-concentrate diet 3 d prior to transport reduced morbidity and mortality of calves as compared to feeding grass hay alone (Hutcheson et al., 1984). However, calves fed hay pre-shipment shrunk less than did those fed 55%-concentrate diets.

Post-Stress Nutrition

The diet a calf receives upon arrival at the feedlot can have a major impact on subsequent health and performance. Much of the work reported in this area can be divided into three major categories: (1) protein source and level, (2) energy source and level, and (3) vitamins, minerals, and feed additives.

Protein source is seen as an important aspect of a receiving diet. A normal ruminant depends largely upon microbial protein synthesis in the rumen for its protein supply. Stress reduces microbial protein output from the rumen, making the type of protein in these diets very important. In a 28-d study by Eck et al. (1988), urea, cottonseed meal, and a 50:50 mixture (CP basis) of blood meal (BM):corn gluten meal (CGM) were used as protein sources for incoming feedlot cattle. Protein sources were fed individually and in various combinations with urea. Superior rate of gain and efficiency of gain of calves consuming the BM-CGM diet was reported. Feed intake also tended to increase as level of BM-CGM increased. Complementary effects between BM and CGM have been observed in previous research (Aines et al., 1985; Roth et al., 1986). However, Phillips (1984) did not observe a response to various combinations of CGM and urea over a 56-d post-

stress period. Phillips et al. (1986) observed also that CGM supplementation produced weight gains similar to those of calves fed soybean meal (SBM).

Studies have suggested (Cole and Hutcheson, 1982) that the protein requirement of a stressed calf is about 20% higher than that of a non-stressed calf. This, along with information about reduced intake levels, led to the development of higher-protein rations for receiving cattle. Cole et al. (1984) reported that by d 14, steers fed a 16%-CP receiving diet had faster gains and lower feed/gain ratios than had those fed lower CP diets. By d 56, steers initially fed the higher-CP diet for 14 d still gained faster than did those receiving lower CP diets, indicating a carryover effect from the 16%-CP receiving diet. Cole and Hutcheson (1988) reported that steers fed a 15%-CP diet consumed more DM than did those fed a 10%-CP diet. Similarly, Eck et al. (1988) reported greater gain and feed intake by animals fed 12.5%-CP diets than by those fed a 10.5%-CP diet over a 28-d period.

Previous researchers have sought energy sources for receiving diets that would promote rapid recovery from stress (Prigge et al., 1977; Addis et al., 1978; Lofgreen et al., 1975). Barley, corn, rolled milo, and wheat have been the main energy components in a variety of trials (Lofgreen,

1977; Prigge et al., 1977; Lofgreen et al., 1981; Hutcheson and Cole, 1986). In a comparison of wheat and barley, Prigge et al. (1977) reported that cattle fed barley or a barley-wheat combination consumed more feed and had fewer health problems than did calves consuming diets which contained wheat. In agreement with these data, Addis et al. (1978) noted higher dry matter intake (DMI) by calves receiving barley as compared to those consuming wheat. Average daily gains also tended to be higher when barley was included in the diet (Addis et al., 1978).

A study involving fat in receiving rations was conducted by Cole and Hutcheson (1987b). As compared to similar rations containing no added fat, 4% (DM basis) fat in the diet improved ADG and tended to increase feed intake over the first 14 d. By d 28, no significant effect was observed. Fat tended also to reduce the feed intake and increase death loss in morbid calves.

Various studies suggested that the optimum level of energy in a receiving diet is between 50 and 75% concentrate (Lofgreen et al., 1975; Lofgreen et al., 1980; Lofgreen et al., 1981). In a comparison of 20-, 55-, 72-, and 90%-concentrate diets, Lofgreen et al. (1975) reported improved performance as energy level increased up to the 72% level. Calves receiving the 90%-concentrate diet were slower

starting on feed than were those fed 72% concentrate. In agreement with these findings, Lofgreen et al. (1980) observed that flaked milo diets containing 50 and 75% concentrate produced more rapid and more efficient gains than did a diet of 25% concentrate. Other work by Lofgreen et al. (1981) demonstrated that newly-received calves gain more weight and gain more efficiently when fed a 75%-concentrate diet (alone or with free choice hay) than when fed hay alone. It should be noted that in each of these experiments, lightweight calves ranging in weight from 160 to 170 kg were used.

In studies involving yearling calves (232-254 kg), Lofgreen (1977) noted that calves performed better when fed diets containing 55% concentrates than did those receiving either 20- or 72%-concentrate levels. However, after 26 d, there was little difference between the 55- and 72%-concentrate diets. In a second trial, Lofgreen and Prokop (1978) reported that stressed calves receiving 55%-concentrate diets again outperformed those fed other rations. Maximum feed consumption and reduced health problems indicate that a 55%-concentrate diet should be considered a standard diet for receiving stressed yearling cattle. Lofgreen and Prokop (1978) stated that these data and those from previous studies suggest that the advantage

gained from a 55%-concentrate diet is directly proportional to the degree of stress incurred by the animals.

Because of the reduced microbial synthesis of B-vitamins, addition of these to receiving rations could be beneficial to stressed cattle. Work by Cole et al. (1979) indicated that the effects of B-vitamin supplementation were variable, depending upon previous nutrition of the calves. Other work by Cole et al. (1982) showed that calves fed an intermediate B-vitamin level had poorer feed conversions after 2 mo than did calves given high levels or none at all. B-vitamin supplementation may be of benefit to stressed calves at times but Cole et al. (1982) suggested that further research is needed to determine optimum levels.

Little is known about the mineral requirements of stressed calves. Hutcheson et al. (1984) suggested that cellular deficiencies of potassium (K) are likely when animals are stressed. Their data suggested that stressed calves require about 20% more K during the first 2 wk after arrival at the feedlot than do non-stressed calves. Based on these data, the suggested level of K supplementation would be 1.3 to 1.4% of the DM in the receiving diet. Additions of K at these levels resulted in increased daily gains and improved animal performance of transported calves (Hutcheson et al., 1984; Hutcheson et al., 1978).

Natural feed additives such as yeast have positively affected animal performance when included in diets of non-stressed ruminants (Ruf et al., 1953). However, results have not been conclusive. Phillips and VonTungeln (1985) added yeast to receiving diets at levels of 1 and 2% of the diet DM. Addition of yeast tended to increase DMI, while ADG also increased but not consistently. The response to yeast culture addition is not understood nor is its mode of action known (Phillips and VonTungeln, 1985).

Decoquate (DEC), a coccidiostat, has been added to receiving diets in an attempt to improve animal performance (Hutcheson and Cummins, 1982). When fed at 59.8 mg DEC per kg receiving diet, calves exhibited greater intake of feed, better feed conversion, and started on feed sooner than did control calves (Hutcheson and Cummins, 1982). However, DEC did not produce any differences in ADG.

The addition of intestinal microbes may be of some benefit in re-establishing the microbial population of the rumen and intestines. Lactobacillus acidophilus (LAC) establishes itself in the intestinal tract of monogastrics and may have some merit in the feeding of ruminants (Hutcheson et al., 1980). In a study by Hutcheson et al. (1980), LAC improved the performance of calves for 3 wk after arrival at the feedlot. However, after calves began

to consume more than 15 g of LAC per day, gains fell below those of controls. Commercial probiotics contain LAC as a major component. A study by Waller et al. (1988) at the University of Tennessee showed that performance was unaffected by the addition of probiotics to diets fed to short-hauled cattle.

Rumen Escape Protein

Total protein reaching the small intestines of ruminants is made up of microbial protein and protein that escapes rumen degradation. The protein that escapes rumen degradation is made up of two fractions: (1) protein that resists microbial breakdown in the rumen and (2) protein that passes directly to the omasum by action of the esophageal groove. The first type may be referred to as "escape protein" while the latter is considered "bypass protein" (NRC, 1985). Although bypassing of high-quality proteins in adult ruminants is possible (Miller et al., 1969), it may not be feasible in production situations. However, rumen escape of protein may be useful in meeting the protein needs of high-producing ruminants or stressed ruminants having an altered rumen function.

The amount of protein escaping the rumen is highly variable, depending upon the physical nature of the protein, rate of degradation, level of intake, and rate of passage (Van Soest, 1982). Proteins that are water-soluble, as in fresh forages, will pass from the rumen more rapidly than will proteins not soluble in water (Van Soest, 1982). Hair and feather proteins have extensive cross-linking and are therefore more resistant to proteolytic enzymes (Nugent and Mangan, 1978).

The physical nature of proteins can be altered by the addition of chemicals such as formaldehyde and tannin or by heat treatment. Formaldehyde treatment increases crosslinking and increases escape of proteins (Ferguson et al., 1967). Driedger and Hatfield (1972) used tannin to protect SBM from rumen degradation. Methods of processing also affect rumen escape. Pelleting, extrusion, rolling, and flaking may produce enough heat to alter the structure of a protein, making it more resistant to rumen degradation. Heat of fermentation within a silo also can increase the escape protein of ensiled forages (Merchen and Satter, 1983).

Protein degradation is affected also by rate of passage. The longer a protein stays in the rumen, the more it will be degraded. Particle size of the feed (Balch and

Campling, 1965) and level of intake (Balch and Campling, 1965; Zinn et al., 1981; Lindberg, 1982) affect rate of rumen passage. Tamminga et al. (1979) noted that lactating cows consuming 12.9 kg DM had higher escape values (45%) than did those with 8.2 kg DMI (29%). Level of intake has a great effect on rate of passage when DMI is less than 2% BW. This effect diminishes as DMI increases above 2% BW (NRC, 1985).

Lowered rumen pH associated with increased levels of intake also may reduce the activity of rumen microbes (Van Soest, 1982). Tamminga et al. (1979) reported the optimum pH for proteolysis and deamination to be between 6 and 7.

The extent of protein degradation in the rumen is important to researchers and livestock producers. Soybean meal protein, one of the most commonly used protein sources for ruminants, has been shown to have a relatively high level of rumen degradability (Waller, 1978). By-product feeds such as BM, CGM, fish meal, brewers grains, and distillers grains are more resistant to ruminal degradation than are most feed grains and oil meals. NRC (1985) listed tentative estimates of protein escaping the rumen for these feedstuffs as: SBM, 28%; BM, 82%; CGM, 55%; fish meal, 80%; brewers grains, 53%; and distillers grains, 62%.

Although extent of degradation is important, information is needed also concerning the quality and availability of these proteins escaping the rumen. Klopfenstein et al. (1980) used the slope-ratio technique to evaluate various protein sources for growing ruminants. They compared eight different protein sources to SBM which was given a relative efficiency value of 100%. The calculated protein efficiency values were based on growth produced in beef cattle. The relative efficiency values were: BM (ring-dried), 250%; BM (conventional), 200%; CGM, 200%; brewers grains, 190%; dehydrated alfalfa, 190%; meat meal, 185%; distillers grains, 173%; and distillers grains (with solubles), 137%. According to these data, the protein supplements tested were more resistant to ruminal degradation than was SBM.

For supplementation of stressed cattle, one or a combination of these protein sources appears to be the best choice. Ring-dried BM has the highest efficiency value, an escape value of 82%, and is high in lysine, but low in sulphur amino acids. Corn gluten meal has the next highest efficiency value, an escape value of 55%, is high in sulphur amino acids, but is low in lysine. When fed together, the two should complement one another and provide the small intestines with an improved amino acid profile. Eck et al.

(1986) reported that a 50:50 mixture of BM:CGM produced performance similar to that on SBM and superior to that on other combinations of these two feeds. Other researchers (Aines et al., 1985; Roth et al., 1986) noted complementary effects between BM and CGM. When evaluating the effects of protein source and level on gains by feedlot cattle, Eck et al. (1988) found BM:CGM to be superior to cottonseed meal or urea. In the same study, ADG and efficiency of gain increased linearly with increasing addition of BM:CGM, and it was suggested that the addition of BM:CGM to receiving diets may increase feed intake also. Research (Irlbeck et al., 1990) on grazing cattle has indicated that there may be no difference between CGM and BM:CGM efficiencies.

Rumen Escape Energy

Stressed cattle need extra energy in addition to supplemental protein. Because of the low intakes by stressed calves, the energy density of the diet must be increased. With 2.25 times the energy content of corn, fat is the logical source of such energy. Feeding high levels of fat has adverse effects on the rumen, among which are lowering DMI and reducing digestibility of feeds (Marchello et al., 1971; Johnson and McClure, 1972). By using fats that escape rumen degradation, problems normally associated

with feeding fats and oils could be alleviated. In recent years many researchers have sought rumen escape fat sources for lactating dairy cows. Two methods that have been shown to be effective for protecting fat are the formation of calcium salts of long-chain fatty acids (CSFA) and encapsulation with denatured protein. Palmquist (1984), of The Ohio State University, developed the concept of using calcium salts of palm oil to protect the energy source from rumen microorganisms. Calcium salts of fatty acids may require maintenance of rumen pH above 6.0 (Palmquist, 1984). In young calves, Fallon et al. (1986) noted a depression of DMI and liveweight gain associated with feeding CSFA. This may preclude their use in diets for stressed calves.

Encapsulation of fats involves coating lipids with a layer of denatured protein, making them unavailable to rumen microbes. An example of this technology is Booster Fat, a product of the Balanced Energy Co. The fat is coated with a mixture of dehulled SBM and alginic acid. Soybean meal treated in this manner is insoluble at rumen pH yet disintegrates at the lower pH of the abomasum (Balanced Energy Co., 1989). Encapsulated fats have had no undesirable effects on DMI or digestibility when fed to dairy cows (Wrenn et al., 1978; Smith et al., 1978).

Summary

There are many types of stress associated with young beef calves. Changes in environment, deprivation of feed and water, and adaptation to new diets impose demands on these calves that may alter their nutrient requirements (Cole and Hutcheson, 1982; Hutcheson and Cole, 1986; Hutcheson, 1988). Compounding the problem, typical responses to such stressors are decreased intake and depression of rumen function (Cole and Hutcheson, 1985; Hutcheson and Cole, 1986). To alleviate these problems, ingredients that are readily consumed by calves have been used in conventional starter diets (Lofgreen et al., 1975; Lofgreen et al., 1980; Lofgreen et al., 1981). Protein and energy levels were increased to compensate for poor intakes (Lofgreen et al., 1981; Hutcheson and Cole, 1986; Cole and Hutcheson, 1988). However, diets such as these have relied upon rumen digestion and function for the required nutrients.

A seemingly more useful approach would be supplying protein and energy without relying on rumen function. Technology has provided high quality protein sources and fats that escape rumen degradation (Aines et al., 1985; Palmquist, 1984). These REE and REP sources have already

been used for maximizing milk production in dairy cows (Palmquist, 1984) and enhancing growth in young beef cattle (Eck et al., 1986).

Prior to weaning, a calf is dependent upon a diet of REE and REP in the form of milk from the dam. As the calf nurses, milk bypasses the rumen by way of the esophageal groove. In beef cattle, this has resulted in 6.5 to 8.5 kg of milk per day (Holloway et al., 1979; Chenette and Frahm, 1981; Daley et al., 1987) being shunted past the rumen. Average composition of this milk was 2.92 to 3.44% CP (Chenette and Frahm, 1981; Daley et al., 1987) and 3.4 to 6.2% butterfat (Holloway et al., 1979; Chenette and Frahm, 1981; Daley et al., 1987). Estimates of total nutrient escape are .19 to .29 kg CP/d and .22 to .53 kg energy/d. By proper selection of REE and REP sources, nutrition lost by a calf due to weaning can, in effect, be replaced. Supplements of this nature may alleviate the problems associated with starting newly-weaned or previously-weaned cattle on feed.

The objective of this research was to determine the effectiveness of using a BM:CGM blend and REE in supplement for starting cattle on feed.

CHAPTER III

MATERIALS AND METHODS

Experimental Diets

Diets in the following experiments were used to determine if there was any beneficial effect from the addition of REP and REE sources to starting diets when compared to typical diets. A BM:CGM blend and encapsulated fat were mixed in a supplement to be fed at $0.45 \text{ kg} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$. A blend of 43.05% BM and 56.95% CGM was found to provide an amino acid profile similar to that of milk. Three supplements were formulated to represent three levels of milk intake pre-weaning: average (MED), 20% above average (HIGH), and 20% below average (LOW). Average milk intake from Tennessee beef cows was found to be $3.4 \text{ kg} \cdot \text{d}^{-1}$. Rumen escape protein and REE sources were added to obtain calculated amounts of protein and energy escaping the rumen. Bull Developer was used as a control supplement as it is a typical high-energy supplement that has been used previously for starting calves in the University of Tennessee system. Tables 1 and 2 provide information concerning formulation and content of the diets.

TABLE 1. Composition of Diets.

Item, % of DM	Diet			
	BD	Low	Med	High
Cracked corn	58.63			
Animal fat	2.24			
Cottonseed hulls	20.33	30.13	23.84	17.70
Cottonseed meal	10.28			
Dehydrated alfalfa	3.12			
Soy mill feed		30.83	24.39	18.11
BM:CGM blend		16.38	24.41	31.89
Encapsulated fat		10.70	15.00	19.51
Cane Molasses	4.29	9.96	9.97	10.01
Dical.		1.34	1.22	1.14
Limestone	0.55	0.17	0.33	0.42
Trace mineral salt	0.56	0.50	0.50	0.52
Potassium chloride			0.34	0.70

TABLE 2. Chemical Composition of Diets.

Item ^a	Diet			
	BD	Low	Med	High
Dry matter, %	88.54	87.36	88.01	88.68
Crude protein, %	12.42	17.47	22.40	26.96
Calcium, %	0.35	0.70	0.71	0.69
Phosphorus, %	0.33	0.42	0.41	0.41
ADF, %	18.93	37.22	30.05	23.01
NDF, %	27.66	48.91	40.02	31.27
NE _{maint} , Mcal/kg ^b	1.89	1.32	1.41	1.47
NE _{gain} , Mcal/kg ^b	1.14	0.79	1.01	1.23
REP, % ^c	51.21	55.07	60.83	64.39
REE, % ^c	0.00	10.70	15.00	19.51

^a - DM basis, except DM.

^b - Estimated from values in NRC, 1984.

^c - Estimated from calculations of rumen escape of protein and energy sources; expressed as a percent of total protein and total energy.

Experiment 1

This experiment was conducted at the Blount farm of the University of Tennessee Knoxville Experiment Station (KES). To obtain a more uniform group of animals, 60 steer calves were selected from a group of 75 purchased animals. Steers were blocked on the basis of body weight and randomly allotted to pens on side A of barn B (five steers/pen). Three dietary treatments were randomly assigned to the 12 pens in a randomized complete block design. Calves were fed hay *ad libitum* upon arrival. Hay offered was gradually decreased to zero by d 8 of the 42-d feeding period. Silage was fed on d 2 at $1.4 \text{ kg} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$ and increased as hay offered decreased to replace all hay by d 8. The three treatments consisted of: (1) Control (no supplement), (2) BD, and (3) HIGH. Animals on treatments BD and HIGH received 0.9 kg of assigned supplement $\cdot \text{head}^{-1} \cdot \text{d}^{-1}$. Cattle were fed once daily at 0830 with feeding level adjusted to promote full feed intake. Feed samples were taken at weekly intervals and analyzed for DM and CP. Animals were weighed at 0900 after feeding on d 0, 14, 28, and 42.

Data from this experiment were analyzed using the General Linear Model (GLM) procedure (SAS Institute, 1985). The independent variables (block and treatment) were evaluated to determine their effects on the dependent

variables, ADG, DMI, and feed:gain ratio (F/G). The Statistical model was as follows: $ADG, DMI, \text{ and } F/G = \text{treatment} + \text{block} + \text{treatment} \times \text{block}$. Individual animal was used as the experimental unit for analysis of ADG, while pen was used as the experimental unit for DMI and F/G. Student-Newman-Keuls mean separation procedure was used to assess the significance of mean differences when the analysis indicated differences to be significant.

Experiment 2

Trial 1. One hundred sixty-eight newly-weaned calves from the KES herds were used to evaluate diets containing REP and REE in a 28-d adaptation study. Seventy-two Angus steers averaging 256 kg were allotted to 12 pens in KES Blount farm feedlot barn B in a randomized complete block design with three pens per treatment. Ninety-six Angus heifers averaging 259 kg were assigned to barn A in a randomized complete block design with four pens per treatment. Calves were weighed at time of weaning and allotted to blocks based on body weight. Each pen was randomly allotted to one of four dietary treatments. Mixed-grass hay was fed *ad libitum* on day 0, gradually decreasing to none on d 14. All calves received $0.45 \text{ kg} \cdot \text{head}^{-1}$ of BD on d 1, increasing by $0.45 \text{ kg} \cdot \text{d}^{-1}$ to $6.4 \text{ kg} \cdot \text{head}^{-1}$ on d 14

then decreasing to zero by d 27. Silage feeding began on d 15 at $1.4 \text{ kg} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$, increasing daily and completely replacing BD by d 27. Experimental supplements were fed at $0.91 \text{ kg} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$ for the entire 28-d period. The four treatments consisted of: (1) control (BD), (2) LOW, (3) MED, and (4) HIGH. Animals were fed once daily at 0830 with levels of feed adjusted to promote *ad libitum* intake. Feed samples were taken at weekly intervals and frozen for later analysis. Animals were weighed prior to feeding on d 0, 14, and 28.

Trial 2. Seventy-two newly-weaned steer calves averaging 257 kg were assigned to 12 feedlot pens at the Middle Tennessee Experiment Station (MTES) at Spring Hill, Tennessee. Three of the four treatments used in Trial 1 (treatments LOW, MED, and HIGH) were assigned to the pens in a randomized complete block design with four pens per treatment. Animals were fed using the schedule described in Trial 1. Steers were weighed at 0730 on d 0, 14, and 28.

Trial 3. In group 1, 54 steer calves averaging 237 kg were randomly allotted to nine feedlot pens (six steers/pen) at the Highland Rim Experiment Station (HRES) at Springfield, Tennessee. Steers were blocked according to

pre-weaning level of milk intake. In group 2, 81 steers averaging 212 kg from HRES research herds and feeder calf sales were allotted to nine feedlot pens (nine steers/pen) at HRES. Steers were blocked on the basis of body weight. The three supplement treatments from Trial 1 (treatments LOW, MED, and HIGH) were assigned to the pens in a randomized complete block design with three pens per treatment per group. Animals were fed in the same manner as were those in Trial 1. Steers were weighed in the early morning on d 0, 14, and 28.

Data from this experiment were analyzed using the same method as for analysis of data from Experiment 1.

Experiment 3

Four ruminally-cannulated Angus steers (545 kg) were used in a 4x4 Latin square design to evaluate the four supplements used in Experiment 2. Steers were randomly allotted to the first four pens on side A of barn B at KES Blount farm. Feed offered to each steer was based on d 14 intake levels from Trial 1 of Experiment 2 and adjusted for differences in weight between rumen-cannulated steers and steers in Trial 1. Steers received $8.8 \text{ kg BD} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$ and $1.3 \text{ kg supplement} \cdot \text{head}^{-1} \cdot \text{d}^{-1}$. Animals were fed at 0730 each day. Each period was 10 d in length (7 d dietary

adjustment; collection of rumen fluid and blood on d 8 and 10). On collection days (8 and 10), blood and rumen fluid samples were taken at 2, 4, 6, and 8 h post-feeding. At each sampling time, steers were removed from their pens as a group and restrained individually with a cattle chute. Blood was collected (20 ml per steer) by jugular puncture and stored in ice until the end of the day. Rumen fluid samples were taken via rumen cannulae, and pH was measured immediately with a portable pH meter. Each sample was stored in two 50-ml storage tubes and immediately frozen with liquid nitrogen to stop microbial activity. At the end of each sampling day, blood was removed from the ice and allowed to warm to room temperature before centrifuging. Serum was harvested and frozen for later analysis.

In the laboratory, rumen fluid samples were thawed overnight in a walk-in cooler (4°C) and centrifuged at 10,000 RPM for 10 minutes. Rumen ammonia concentration in the supernatant was measured using a modification of the Sigma Kit 640 procedure. Five ml of supernatant was mixed with 1 ml phosphoric acid containing 2-ethyl butyric acid as an internal standard and centrifuged at 13,000 RPM for 15 minutes. The supernatant was then analyzed for volatile fatty acid (VFA) content by gas chromatography. Blood

plasma was thawed at room temperature, and BUN was determined by Sigma Kit 640.

Data from Experiment 2 were analyzed using the General Linear Mixed Model (GLMM) procedure (Blouin and Saxton, 1989). The independent variables (period, animal, treatment, day, time, and treatment x time) were evaluated to determine their effects on the dependent variables (RA, BUN, pH, and rumen VFA). The statistical model was as follows: $RA, BUN, pH, VFA = \text{period} + \text{animal} + \text{treatment} + \text{period} \times \text{animal} \times \text{treatment} + \text{day} + \text{period} \times \text{animal} \times \text{treatment} \times \text{day} + \text{time} + \text{treatment} \times \text{time}$. Generalized least squares means were calculated.

CHAPTER IV

RESULTS

Experiment 1

Animals fed HIGH treatment had higher ($P < .05$) ADG than did animals receiving no concentrate supplement, but there were no differences between BD and HIGH. Dry matter intake was not different ($P > .05$) among the 3 treatments, although animals fed treatment HIGH did tend to have higher DMI. Animals fed treatments BD and HIGH required less ($P < .005$) feed per kg of gain than did those consuming Control. This was expected due to the higher nutrient density of the BD and HIGH diets. Data from this experiment are reported in Table 3.

Experiment 2

Trial 1 (Steers). Increasing levels of REP and REE in starting rations resulted in no significant difference ($P > .05$) in DMI or F/G ratio. Average daily gain tended to increase as REP and REE levels increased, but significant differences ($P < .02$) were found only between treatments BD and HIGH. Animal performance data are listed in Table 4.

TABLE 3. Experiment 1 Animal Performance

Item	Treatment			SE ^a
	Control	BD	High	
Average daily gain, kg	.84 ^b	1.11 ^{bc}	1.36 ^c	.12
Dry matter intake, kg/day	6.27	6.54	7.31	.36
Feed/Gain	7.73 ^b	6.37 ^c	5.57 ^c	.27

^a - Standard error of the mean

^{b,c} - Means in the same row that do not have a common superscript differ ($P < .05$).

TABLE 4. Experiment 2 Trial 1 Animal Performance

Item	Treatment				SE ^a
	BD	LOW	MED	HIGH	
- - - - Average daily gain, kg - - -					
Steers	.76 ^b	.95 ^{bc}	.95 ^{bc}	1.14 ^c	.08
Heifers	.87	.89	.98	1.01	.08
- - - - Dry matter intake, kg/d - - -					
Steers	5.53	5.50	5.58	5.62	.04
Heifers	5.43	5.43	5.35	5.33	.06
- - - - - - - Feed/Gain - - - - - - -					
Steers	7.61	6.07	6.40	5.18	.75
Heifers	6.49	6.34	5.70	5.53	.31

^a - Standard of the mean

^{b,c} - Means in the same row that do not have a common superscript differ ($P < .05$).

Experiment 2

Trial 1 (Heifers). Average daily gain tended to increase with increasing levels of REP and REE, but no significant differences were observed. The large variation between animals in this group probably prevented this trend from being significant. Dry matter intake and F/G were not affected ($P>.05$) by treatment. Animal performance data are listed in Table 4.

Trial 2. Dry matter intake and F/G were not affected ($P>.05$) by treatment. Average daily gain on MED treatment was significantly lower ($P<.05$) than on treatments LOW and HIGH. Again, high variability among animals in this group may have contributed to the erratic results. Animal performance data are listed in Table 5.

Trial 3 (Group 1). Treatment was found to have no significant effect ($P>.05$) on animal performance. Light and medium-weight animals had better ($P<.05$) F/G than heavier animals. These calves came from station herds and animal variation was high because of the limited number from which to choose. Animal performance data are listed in Table 6.

TABLE 5. Experiment 2 Trial 2 Animal Performance

Item	Treatment			SE ^a
	LOW	MED	HIGH	
Average Daily Gain, kg.	2.58	2.09	2.57	.07

^a - standard of the mean

TABLE 6. Experiment 2 Trial 3 Animal Performance

Item	Treatment			SE ^a
	Low	Med	High	
- - - Average Daily Gain, kg - - -				
Group 1	.89	.76	.87	.08
Group 2	1.05	.95	.91	.007
- - Dry Matter Intake, kg/d - - -				
Group 1	5.27	5.21	5.15	.08
Group 2	5.42	5.37	5.40	.10
- - - - - Feed/Gain - - - - -				
Group 1	6.53	7.45	6.26	.62
Group 2	5.40	5.97	6.22	.52

^a - Standard error of the mean

Trial 3 (Group 2). Animal performance was not affected ($P>.05$) by treatment. Consistent with all trials in Experiment 1, no differences were observed among the rumen-escape diets. Data for animal performance are listed in Table 6.

Experiment 3

Treatment had no significant effect ($P>.05$) on rumen pH, which was affected ($P<.05$) by sampling period and by sampling time ($P<.001$), increasing with time after feeding. Rumen ammonia concentrations also were different between periods ($P<.05$) and times ($P<.001$), decreasing from 2 h to 4 h, then gradually increasing until 8 h post-feeding. Treatment did not affect RA ($P>.05$). Blood urea nitrogen varied ($P<.001$) with sampling period and with sampling time ($P<.001$), with BUN generally decreasing with time after feeding. Increasing levels of REP and REE resulted in a nonsignificant ($P<.07$) linear increase in BUN. Treatment had no significant effects ($P>.05$) on rumen VFA concentrations. These results indicate that the rumen-escape diets probably had no negative effects on the rumen environment at the levels used. Data from this experiment are reported in Tables 7 and 8.

TABLE 7. Effects of REP and REE Supplements on Rumen and Blood Criteria.

Item	Hours Postfeeding	Treatment				SE ^a
		BD	LOW	MED	HIGH	
Rumen pH	2	5.47	5.48	5.58	5.56	.10
	4	5.47	5.52	5.56	5.53	.10
	6	5.49	5.75	5.75	5.69	.10
	8	5.59	5.80	5.90	5.86	.10
Rumen NH ₃ , mg/100 ml	2	8.07	6.97	7.37	7.04	1.43
	4	5.35	5.15	5.72	4.74	1.43
	6	5.79	5.53	6.00	4.99	1.43
	8	7.22	6.32	6.92	5.88	1.43
Blood Urea Nitrogen, mg/dL	2	7.75	8.40	9.46	10.14	.86
	4	7.81	7.39	8.01	9.08	.86
	6	6.67	7.04	8.29	8.33	.86
	8	6.15	7.37	7.92	7.72	.86

^a - Standard error of the mean

Table 8. Experiment 3 Ruminal fluid VFA

Hours Post-feeding	Treatment			
	BD	LOW	MED	HIGH
Acetate, mol/ml				
2	63.4	65.8	63.2	63.4
4	60.7	62.8	61.1	57.8
6	60.1	57.6	60.1	57.5
8	60.1	57.8	59.3	61.0
Propionate, mol/ml				
2	34.1	40.1	35.4	39.5
4	32.5	40.7	35.1	37.9
6	33.9	36.1	34.3	35.7
8	34.3	35.5	33.0	37.1
Butyrate, mol/ml				
2	10.9	10.6	10.3	10.3
4	9.4	9.3	9.7	9.1
6	9.4	8.5	9.8	9.3
8	10.9	9.1	10.3	10.1
Valerate, mol/ml				
2	1.3	1.8	1.4	1.7
4	1.2	1.6	1.7	1.4
6	1.3	1.5	1.2	1.3
8	1.6	1.4	1.2	1.4
Isovalerate, mol/ml				
2	2.0	2.0	2.0	2.2
4	2.0	1.9	1.8	1.9
6	1.9	1.9	1.8	2.0
8	2.2	4.8	2.1	2.4
Isobutyrate, mol/ml				
2	0.8	0.7	0.4	0.5
4	0.5	0.6	0.4	0.4
6	0.8	0.3	0.5	0.2
8	0.9	0.5	0.7	0.6

CHAPTER V

DISCUSSION

Receiving cattle and starting them on feed is a critical task for the post-weaning operations of the beef cattle industry. However, problems associated with this period are difficult to address using conventional experimental procedures. The major problem is the relatively short observation time associated with these studies. Typical starting periods in the stocker and feedlot industries are 3 to 4 wk in duration. A 28-day experimental period is relatively short when compared to the total time on feed, which is usually 100 to 150 d. Stress-related problems such as loss of appetite, unfamiliarity with surroundings, and timidity shown by some animals resulted in increased variability in animal performance. When variable animal performance is anticipated, the researcher has certain options available to reduce the impact on experimental results. One option is to lengthen the experimental period. The response period for Experiment 1 was extended from 28 to 42 d to evaluate the feed extension as a method of reducing variation in animal performance. The results of the 42-d feeding period were not different from those in the 28-d study; therefore, in

subsequent experiments a 28-d response period was used. However, not all sources of variation can be reduced within the limitations placed on the researcher following good management procedure. A response that is of economical and biological significance during the starting period is animal weight change. How fast a starting animal reaches its pre-stress weight has been used as an indication of a successful starting program (Richey and Gill, 1983; Waller et al., 1988). Accurate measurements of body weight are difficult to obtain in animals of this type due to variations in body fill, length of transport, etc. Cattle in these studies were weighed once on the initiation day of the trial. Handling the calves more than this would have added to the level of stress these cattle were experiencing and would not have been typical of procedures found in the stocker and feedlot industries.

Cattle used in Experiment 1 were purchased from regional feeder calf sales by an order buyer and delivered to KES. However, in Experiment 2, cattle from both University herds and an order buyer were used. Analyses of experimental data indicated that cattle purchased by the order buyer were more uniform and exhibited less animal variation than those from University herds. The increased variability found in the University calves is due in part to

the purchased calves constituting a subsample selected from a large, diverse population, while the University calves are, in effect, an entire population. To minimize these experimental limitations, large numbers of animals must be used. This was attempted in Experiment 2, but due to limited facilities, trials were conducted at three separate research stations and animal variation continued to be a problem. Selection pressure was needed on cattle used within each station to more closely match a less variable group of purchased cattle.

Although very little sickness was incurred with these animals, morbidity and mortality of calves have been major problems associated with receiving experiments (Hutcheson *et al.*, 1980; Phillips *et al.*, 1986; Cole and Hutcheson, 1987b). Since these calves were purchased locally or assembled at the University research farms, they were not exposed to the same degree of stress as would have long-hauled calves.

Average daily gains, DMI and F/G for Experiment 1 were similar to those reported for other receiving experiments (Eck *et al.*, 1988; Lofgreen *et al.*, 1975). When compared to Control, steers consuming HIGH had higher ADG and DMI, along with improved F/G. Although performance tended to be higher for the HIGH treatment, it was statistically similar to BD.

HIGH diets may have offered an enhanced amino acid profile to the small intestine (Eck et al., 1986) and the energy density of the HIGH diet was greater than the BD diet (Table 2).

Isonitrogenous diets might have provided more insight into possible confounding of REP and CP in diets used in this experiment. However, to provide isonitrogenous diets a source of non-protein nitrogen (NPN), such as urea, would have been incorporated in the Control and BD diets. Urea and NPN compounds are not recommended for starting diets because of lower animal acceptance and increased danger of urea toxicity (Richey and Gill, 1983). If diets of equal CP were used, one would expect to see an effect from the REP treatments due to the higher-quality protein available for uptake in the gut rather than depending on microbial protein produced using NPN as a nitrogen source (Eck et al., 1988).

The objective of Experiment 2 was to determine an optimum level of REP and REE somewhat less than those contained in the HIGH treatment of Experiment 1. The three graded levels of REP and REE were calculated based on average milk intake by Tennessee beef calves. Since these calves were newly-weaned with various levels of milk intake pre-weaning, varying the level of REP and REE in the diet might more closely match previous milk intake levels. There

was also the risk of poor intake associated with BM by calves that had only been exposed to milk and forages. The low, medium and high levels would best fit these calves with limited exposure to feeds and hold risks associated with BM to an acceptable level.

Levels of BD fed were based on previous experience at KES (unpublished data) that indicated BD is highly palatable to newly-weaned calves. In addition, heifers used at two locations had been designated as replacement animals and therefore required minimum exposure to high risk diets. Lack of definitive differences in diets was probably a result of feeding BD at a higher level than needed for too long a period of time. Additionally, corn silage replacement of hay was perhaps too abrupt to provide adequate rumen digestion of the silage.

When rumen and blood criteria were evaluated in Experiment 3, rumen pH tended to increase with time after feeding (Table 7). However, magnitude of the increase was greater for the rumen-escape treatments than for the control treatment (Table 7). The control supplement contained more rumen-degradable energy which probably led to the sustained reduction in rumen pH (Thompson and O'Mary, 1983). Also, if pH had been measured at 0 h post-feeding, the BD treatment presumably would have experienced a greater drop in pH from

0 to 2 h, this due to the rapid release of the energy sources in the rumen (Van Soest, 1982).

The RA values indicate a marked increase at 2 h post-feeding, with the BD treatment tending to be higher than the others. Such results are reasonable since RA production is related to the rate of degradation of the supplemental protein. Again, if measurements had been made at 0 h, the BD treatment would most likely have exhibited a greater increase in RA concentration, since it peaked at a higher level (at 2 h) than did the other treatments. If the theoretical ruminal degradation values of BM and CGM were correct, then RA levels were as anticipated for LOW, MED and HIGH diets.

Blood urea nitrogen results were used as a secondary indicator of rumen ammonia production. Values for BUN tended to decline in a linear fashion as time after feeding increased (Table 7). No obvious differences in rates of decline were noted.

Rumen fluid VFA levels tended to be at a maximum at 2 h post-feeding and decline through the 6 h sample. At 8 h after feeding they again rise slightly, consistent with the data concerning RA.

Results from this research indicate that newly-received animals do respond to supplementation, regardless of the

rumen degradability of the supplement. Because of the high cost associated with rumen-escape products, the needs of a producer can be met, based on these studies, in a more economical manner by using rumen-degradable supplements in diets for receiving calves.

CHAPTER VI

SUMMARY

Problems associated with studies such as these are high variability among animals and the relatively short time period for evaluation of the diets. The data suggest that animals from university research herds are more variable than are those purchased from an order buyer. This is due to the purchased calves constituting subsamples selected from a population while the university calves are, in effect an entire population. Proper randomization and blocking of such animals is difficult without handling the cattle several times. The 28-d response period is short relative to the total feeding period and variation during this period is high. Large numbers of animals chosen for uniformity will reduce the effect of this type of error.

Data from this study indicate that REP and REE sources may be useful in starting calves on feed, but they were no better than BD. Animal performance tended to increase linearly with increasing REP and REE levels. Eck et al. (1988) found that ADG increased linearly with increased BM:CGM proportion in the diet. Based on these studies the

stocker or feedlot manager will see a more economical response to supplementation when using rumen-degradable products rather than rumen-escape diets.

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VITA

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