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Beef Cattle Management Update

PROTEIN REQUIREMENTS OF HIGH PERFORMANCE FEEDLOT CATTLE

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INTRODUCTION

Recent changes in the industry may affect protein nutrition of feedlot cattle. The industry standard is changing from a heavy, backgrounded yearling British breed steer, to a calf, containing 50% exotic blood, placed directly in the feedlot after weaning. In some cases, genetic merit of the cattle, increased energy density of the diet, and androgenic/estrogenic implant combinations allow previously unattainable growth rates. Composition of growth has changed as well, each unit of liveweight gain includes more protein than previously, especially in rapidly growing steers. Steers gaining 3.5 lb/d or more in 1991 may be vastly different than the steers that NRC (1984) protein requirements were based on and designed for. These high growth, or high lean growth cattle are well outside the range of cattle used in the data sets that NRC (1984) requirements are based on. This does not mean that NRC (1984) is incorrect for industry average cattle. A majority of cattle on feed are within a range for which NRC (1984) is appropriate. However, the presence of higher performing cattle, along with a general attitude in the industry that NRC (1984) underestimates protein needs, imply that reevaluating protein nutrition may be appropriate for some cattle.

FACTORS AFFECTING PROTEIN REQUIREMENTS

NRC uses DMI, ADG and NE_g (energy deposition) based on sex condition (bull, steer or heifer), age (calves or yearlings), frame size (medium or large) and previous nutritional status (compensating or not) in calculation of protein requirements. NRC (1984) requirements assume use of an estrogenic implant. For purposes of this discussion, it will be assumed that differences between protein requirements of rapidly growing cattle and typical cattle of the same weight, are assumed to be almost entirely due to differing tissue protein deposition. The premise here is that composition of gain affects protein requirements and that variables in addition to age, frame size

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and compensatory status are required to accurately predict composition of gain in some cases. Frame score, muscle score, and more specific description of anabolic implant status will be suggested.

RATE AND COMPOSITION OF GAIN OF FEEDLOT CATTLE

Tissue protein deposition is the largest contributor to protein needs of growing cattle. Because of changes in genetics, hormonal growth implants, and diets and management, composition of carcass gain has changed greatly in the past decade. These changes may not have been anticipated by NRC (1984), since necessary data were unavailable. Byers (1979) stated that as rate of gain of steers exceeded 2.2 lb/d, subsequent increases in the rate of tissue deposition were entirely due to increased fat deposition. Theoretically, if this is true, weight gain in excess of 2.2 lb/d should require little or no dietary protein to support. While the 2.2 lb/d value may represent a portion of the current cattle population, a substantial number of cattle have potential for tissue protein deposition in excess of that observed by Byers (1979).

Within and among breed changes. The industry typical steer has shifted to include exotic breeding. For example, there are 488% as many registered Limousin bulls in commercial herds in 1991 as there were in 1981. Increased use of muscular breeds has resulted in cattle that are leaner and have greater ability to deposit carcass protein, although liveweight gain of these cattle is not always superior.

Distinct changes have also occurred within the British breeds. Research has compared "modern" or "current" Hereford and Angus sires to "traditional" sires of one or two decades ago. Sires representing the current population of these breeds sire faster growing, leaner offspring than historical sires. Thus, at any given weight, steers representing the present population will be leaner than historic cattle of similar size and any unit of liveweight gain will include a greater portion of lean.

Implants and other carcass modifiers. As described in Figure 1, implants increase performance by enhancing lean tissue deposition. While NRC (1984) assumes use of estrogenic implants, no differences between estrogenic implants are considered, nor are additional effects of Trenbolone Acetate (TBA), since TBA was approved in 1987. Use of TBA in combination with estrogen (TBA+E) allows realization of rates of weight gain, and particularly protein deposition, that were previously unattainable (for example, see Table 1). In some types of cattle use of TBA+E increases growth approximately 10% above estrogen alone, with increased carcass protein (and noncarcass protein to some extent) accounting for the difference.

Since increased weight gain would be accompanied by increased feed intake as well as a greater published requirement to support the resultant rate of growth, presence of TBA does not, per se, invalidate published requirements. However, implants increase the proportion of lean in gain, even when rate of gain is held constant. While addition of TBA to implant programs results in minor increases in feed intake, compared to estrogen implanted cattle, carcass protein deposition is enhanced to a greater extent.

Dietary/management changes. Substantial nutritional and management differences characterize cattle feeding in 1991 compared to previous decades including increased dietary energy density, leaner carcass endpoints, and increased feeding of calves instead of yearlings. Each of these could affect feedlot protein nutrition.

Diets containing .66 or .68 Mcal NE_g/lb have become common in the industry with some feedlots experimenting with diets as high as .70. For the most part, these increases in dietary energy have been independent of changes in concentration of other nutrients. Either protein or energy consumption can limit protein deposition, through separate and independent mechanisms. Figure 2 describes that as energy intake increases, the dietary N level that will produce maximum N retention increases. The inverse is certainly true as well, increased dietary energy density may result in N content of the diet limiting protein deposition. Increased energy density of feedlot diets often has been accompanied by little or no change in protein content. Dietary energy may have increased to a point that protein has become the limiting nutrient in some cases.

Responding to demands for leaner meat products and improved efficiency, industry average carcasses have become somewhat leaner. This has been accomplished without decreasing carcass weight, suggesting that the ability of the cattle to deposit muscle has increased and that muscle comprises a greater portion of weight gain. Feeding calves instead of yearlings results in much the same compositional change as the leaner carcass endpoints. In addition, calves consume less feed than yearlings of comparable weight. While NRC (1984) recognizes differences between calves and yearlings, feedlots may not have adequately incorporated these differences.

The net effect of these changes in diet, management, genetics and implants has been to increase the diversity of the cattle population and potential for performance. As a result, cattle often perform at rates not predicted by NRC (1984). Additionally, differences in composition of gain suggest that rate of gain alone is insufficient to describe differences among cattle.

CALCULATED EFFECTS OF ALTERED COMPOSITION OF GAIN ON PROTEIN UTILIZATION

For this discussion, protein nutrition of three example steers will be considered. The steers will be designated "typical," "high growth" and "high lean growth." Performance and composition values (Table 2) were arbitrarily chosen based on industry average figures and published composition data. Feed consumption and dietary protein content values are from NRC (1984).

The high lean growth steer would deposit .38 lb of carcass protein per day, .14 lb (61%) more than the typical steer. While the high lean growth steer would consume 2.9 lb (15%) more feed, dietary protein content would be similar (10.15 vs 10.30). Thus, according to NRC (1984), increased feed consumption is sufficient to account for any difference in dietary protein needs and an 18% increase in protein consumption can allow a 61% increase in protein deposition.

The high lean growth steer deposits 17.1% of his dietary protein intake as carcass protein, compared to 12.5% for the typical steer, a 36.8% improvement in protein efficiency. In contrast, a high performance (110 lb milk/d) dairy cow is 15.2% more efficient than a typical (70 lb/d) cow (37.1% protein efficiency vs 32.2%; (NRC, 1989), because the high producing cow would consume 45% more protein (9.21 lb/d vs 6.4). The marginal efficiency of the high producing dairy cow is 48.2%, not particularly different from the marginal efficiency of the high performance steer, 43.0%.

Not all high growth cattle are particularly lean. Table 2 also describes a high growth steer with typical carcass composition. Although this steer would gain weight faster than the typical steer, due to greater intake, total, marginal or partial protein, efficiency would differ little from that of the typical steer. Because of similar size, weight and age, the high growth and high lean growth steer would have similar requirements according to NRC (1984), despite 29% greater protein deposition in the high lean growth steer.

Differences in protein efficiency are reduced slightly if empty body protein deposition (143% of carcass protein deposition) is used in calculations. Nonetheless, conclusions are similar in this case.

While cattle do not need to be undergoing compensatory growth to attain ADG rates of 3.5 lb/d, NRC protein requirements of compensating steers may be more appropriate to describe protein needs of high performance cattle. If the high lean growth steer in the example is considered to be compensating, his requirement would increase to 2.27 lb of dietary protein, 10.9% of the expected 20.8 lb intake and 21.5% greater than the typical example steer, a relatively modest increase.

IS ESCAPE PROTEIN REQUIRED?

Microbial protein is adequate to maintain moderate growth of typical feedlot cattle but microbial protein synthesis falls short of the recommended levels in most cases. While any typical feedlot diet includes some protein that will not be degraded in the rumen, high growth or high lean growth cattle may require a fraction of their protein supply in highly undegradable form.

NRC (1985) has made recommendations for level of degradable protein in the diet (Table 3). NRC (1985) suggests that for various levels of intake and energy density the efficacy of urea changes. For example a typical feedlot steer consuming .66 Mcal NE_g/lb DM at 2.25% of its body weight will see no benefits from urea above 9.5% assuming a 30% escape protein in the diet, according to NRC (1985).

In European research, cattle implanted with estradiol responded to differing levels of undegradable protein. There was a positive, linear response of liveweight gain (LWG) to UDP concentration. UDP inclusion had no effect on LWG of control animals. The authors suggested that currently recommended levels (ARC, 1980) of UDP should be increased for implanted steers. However, in U.S. research no response to protein sources differing in degradability in rapidly growing steers treated with somatotropin was obtained, although somatotropin increased growth and muscling and reduced fatness of these steers.

We have studied the response of growing steers to supplemental fishmeal and hormonal growth promotants (Anderson and Johnston, unpublished results; Table 4). In a 2x2 design, steers were implanted with estrogen or TBA+E and fed a control diet containing 11.5% crude protein or the same diet with .3 lb/d of supplemental protein from fishmeal. Both fishmeal (5.6%) and TBA+E (9.8%) increased ADG, the combination of fishmeal and TBA+E increased ADG by 12.7%.

Our data, along with those of others, suggest that growth promotants improve protein efficiency. For example, in our work, steers implanted with TBA+E and fed the control diet grew slightly faster than steers implanted with E, which consumed .35 lb/d more protein than the TBA+E steers. The explanation that this observation is trivial because protein needs of both groups were met is invalidated by the response of the TBA+E steers that were fed fishmeal.

PRACTICAL CONSIDERATIONS

Protein/energy source interactions. When analyzing protein needs one must consider the grain source. A 1000 lb steer consuming 24 lb of a 85% corn-based concentrate diet will meet approximately 2/3 of its protein requirement (assuming a recommended level of 12.5%) from the corn grain. One-half of the 8% crude protein supplied by the corn is escape (NRC, 1989). Approximately 1/3 of the recommended level will be escape protein from the corn. In comparison (Table 5) only 25% of the recommended level of crude protein is escape from the grain if barley is used instead of corn. This change in escape protein supported by the diet will change the efficacy of urea utilization in each of the different diets.

Another consideration is the value of the roughage as a source of protein. Recent speculation is that the fiber from the roughage has no energy value due to the extremely low pH in the rumen of cattle on high concentrate diet and high rate of passage. If this is true, utilization of protein in roughage, especially poorly soluble forage sources, may be minimal. Considering protein and including protein from forage may result in underfeeding protein.

Tailoring protein to cattle type. If the premise is accepted that using weight, age, frame size, rate of gain and compensatory status to describe protein needs is inadequate, the obvious question is whether protein nutrition, either quantity or type, can be tailored to cattle type and performance. If so, what input variables are required to adequately describe cattle for calculation of protein requirements?

Improved physical description of cattle would likely improve prediction of requirements. Frame score would be more specific than only large and medium classifications. A physical description of muscling would also likely improve prediction.

If NE_g accurately predicted the ADG of the high growth steer depicted in Table 2, growth of the high lean growth steer would have been underestimated, due to reduced energy content of gain. Perhaps failure of NE_g to accurately predict gain would be an appropriate signal that composition differed from NRC (1984) assumed values, suggesting that protein needs may differ as well.

As an example, in a recent study (Anderson et al., 1991; Table 1), large framed, muscular yearling steers were implanted (TBA+E) or not implanted. Nonimplanted steers consumed 21.8 lb DM/d and gained 2.88 lb/d. TBA+E steers consumed 23.1 lb DM/d of the same diet and gained 4.42 lb/d but had leaner, more muscular carcasses than nonimplanted steers at similar slaughter weights. In this study, observed ADG/predicted = 102.1% for control steers but 147.8% for TBA+E steers. Thus, protein deposition of the TBA+E steers was vastly underpredicted by NRC (1984) NE_g values. This error is magnified if TBA+E steers had greater maintenance requirements than nonimplanted steers (observed/predicted = 160.8% if NE_m requirement is increased 25%).

These steers were fed a diet containing 11.5% protein. Both control and TBA+E steers consumed more protein than required according to NRC (1984), by approximately the same proportion (Table 1). However, carcass protein deposition efficiency (carcass protein deposition/protein available for gain), was 68% greater for the TBA+E steers (23.8% vs 14.2). Thus, it is reasonable to question whether protein or energy was limiting in the TBA+E group.

Inclusion of TBA use or nonuse seems to be required for accurate prediction of ADG. Foutz et al. (1990) reported that implantation with TBA resulted in observed NE_g content of the diet as much as 13% greater than predicted in steers gaining approximately 3.2 lb/d. In another study (Johnston and Anderson, unpublished data), NE_g was an excellent predictor of ADG of steers growing in excess of published values (large frame steers, ADG = 4.0 lb/d). In this case, steers received less efficacious anabolic implants and were depositing carcass fat rapidly, as predicted by NRC (1984).

Description of muscling may or may not improve prediction. In the work of Stanton et al. (1988), NE_g predicted ADG of muscular steers more accurately than ADG of average steers (Table 6). These steers consumed diets containing .61 Mcal NE_g/lb and grew at relatively rapid rates (grand mean 3.3 lb/d). Perhaps genotype, endocrine manipulation, and dietary energy density and the interactions between these variables must be considered for accurate prediction of protein requirements.

Requirements vs recommendations. A calculated nutrient requirement based on factorial data should not be considered a feeding recommendation. Thonney (1987) summarized several individual feeding experiments which indicated that the standard error of a feed consumption mean is typically 10%. Thus, with all other items equal, dietary protein concentration should exceed the mean requirement by 20% in order to meet the needs of 97.5% of the cattle within a group, based on differences in intake alone. Exceeding the recommended dietary concentration by 10% would meet the needs of 84% of the cattle in this example.

When individual differences in weight, rate and composition of gain and appetite are included, it would seem that meeting the nutrient needs of all individual cattle within a group requires feeding at a level well above published requirements. On the other hand, if differences among individuals within a group are related, i.e. those with the highest requirement also consume the most feed, perhaps formulating diets to meet average needs and allowing differences in consumption to provide for differences in requirements is sound.

The practical significance of this is that the common industry practice of feeding diets containing 1-2 percentage units more protein than NRC (1984) suggests, is likely a sound practice. Feeding to meet the needs of those with the greatest requirement results in overfeeding of a portion. This implies that recommended nutrient content of diets for uniform groups of cattle could be lower than for nonuniform groups, not because the individual requirements are lower but simply because variation in requirements within a pen is reduced.

Percentage vs quantity. Protein requirements calculated with the factorial method are expressed in g/d. However, diets are typically formulated to contain a specified percentage of protein. This percentage is based on assumed levels of intake, but is typically not altered if observed intake differs from projected. Therefore if the quantity of protein is the true requirement, cattle may be over or underfed due to deviations from expected intake. Theoretically, if a diet is properly formulated, and if weight gain above expected is entirely comprised of fat, any feed provided in excess of anticipated intake need only contain 3.3% protein, since F would be the only protein need.

SUMMARY

The current population includes some cattle that grow at rates far in excess of the maximum predicted by NRC (1984); in particular, carcass protein deposition may exceed anticipated values. Protein requirements of these cattle are not known, nor are the effects of altered composition of gain. Crude protein requirements of high lean growth cattle can be estimated though extrapolation of NRC (1984) equations. For actual requirements of high lean growth cattle to equal estimated requirements, protein deposition efficiency must be improved dramatically. Use of metabolic modifiers improves protein deposition efficiency, superior genetics may produce the same result. If not, protein concentration of the diet may need to be increased in some cases. Research is limited but current practice of feeding 1-2 percentage units more protein than recommended by NRC (1984) seems warranted, although diet formulation based on quantity, rather than percentage of protein would be most efficient. Inclusion of slowly degraded protein sources has increased performance of cattle with high genetic merit, treated with metabolic modifiers. Failure of Net Energy to accurately predict gain may be used as a signal that protein deposition, and potentially protein needs, are atypical. Inclusion of frame score, a description of muscling, and specific description of anabolic implant use may improve estimation of protein requirements.

TABLE 1. EFFECT OF TRENBOLONE ACETATE AND ESTRADIOL IMPLANTS ON PROTEIN UTILIZATION BY LARGE FRAME STEERS[a]

	Control	TBA+E
ADG, lb	2.88	4.42
ADFI, lb	21.8	23.1
F/G	7.6	5.2
ADG observed/predicted, %	102.1	147.8
ADG observed/predicted, %[b]	102.1	160.8
Protein requirement, lb/d[c]	2.20	2.29
Protein consumption, lb/d	2.51	2.66
Consumed/required, %	114.1	116.2
Maintenance protein, lb/d[c]	.88	.92
Protein available for gain, lb/d	1.63	1.74
Carcass protein deposition, lb/d[d]	.23	.41
Gross protein efficiency, %[e]	9.2	15.6
Protein deposition efficiency, %[f]	14.2	23.8

[a] Anderson et al. (1991), crossbred exotic steers (870 lb) fed 69 (TBA+E) or 103 (Control) days.
[b] Calculated with 25% increase in NE_m requirement for TBA+E steers.
[c] NRC (1984).
[d] Estimated.
[e] Carcass protein deposition/protein consumption.
[f] Carcass protein deposition/protein available for gain.

TABLE 2. COMPARISON OF COMPOSITION OF GAIN AND PROTEIN UTILIZATION OF TYPICAL, HIGH GROWTH AND HIGH LEAN GROWTH STEERS: ESTIMATED VALUES

	Typical	High growth	
		Lean	Typical
Weight on feed, lb	550	600	600
Slaughter weight, lb	1150	1250	1250
ADG, lb	2.80	3.50	3.50
Days on feed	214	186	186
ADFI, lb[a]	18.5	21.4	21.4
CP intake, lb/d[a]	1.87	2.20	2.20
CP content of diet, % of DM[a]	10.15	10.30	10.30
Dressing percentage	63	65	63
Carcass weight, lb	725	813	789
Carcass protein content, %	14.5	16.0	14.5
Carcass protein deposition, lb/d	.23	.38	.29
Protein deposition/intake, %	12.5	17.7	13.3
Marginal protein efficiency, %[c]	-----	54.6	17.9
CP req at 12.5% efficiency, lb	1.87	3.01	2.34
Percentage of DM	10.15	14.25	10.97
CP req at 17.1% efficiency, lb	1.37	2.20	1.71
Percentage of DM	7.38	10.30	8.01
Maintenance CP req, lb	.75	.85	.85
CP available for growth, lb	1.11	1.35	1.35
Partial protein efficiency, %[d]	20.9	28.0	21.8

[a] NRC, 1984.
[b] Crude protein.
[c] Example: [(.38 - .23) / (2.20 - 1.87)] x 100.
[d] Carcass protein deposition/CP available for growth.

TABLE 3. UREA USEFULNESS WITH VARIOUS RUMINAL DIGESTIONS OF DIETARY PROTEIN[a]

	% escape protein in diet							
	20	20	30	30	40	40	50	50
	Daily intake, % of BW							
NE_g, Mcal/lb	2.0	2.25	2.0	2.25	2.0	2.25	2.0	2.25
	% dietary protein above which urea is useless							
.59	9.4	9.8	10.5	11.0	12.0	12.5	13.8	14.4
.64	8.3	8.7	9.3	9.7	10.6	11.0	12.2	12.7
.70	6.5	6.6	7.2	7.3	8.2	8.3	9.4	9.6

[a] Adapted from NRC, 1985.

TABLE 4. EFFECTS OF IMPLANT STRATEGY AND SUPPLEMENTAL FISH MEAL ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF CROSSBRED STEERS[a]

Implant Protein	E CTL	E +FM	TBA+E CTL	TBA+E +FM	Pooled SE	Effects[b]
Performance d 0-56						
Start wt, lb	660.6	674.6	674.8	668.6	4.8	NS
End wt, lb	841.0	871.4	888.4	881.4	6.4	I, I*FM
ADG, lb	3.22	3.51	3.81	3.80	.06	I, i*fm
ADFI,lb	17.18	18.08	17.24	18.26	.07	FM
F/G	4.94	5.53	4.50	4.76	.18	i
Performance d 57-189						
ADG, lb	2.96	3.07	3.06	3.14	.05	NS
ADFI, lb	20.35	20.65	20.38	20.69	.02	FM
F/G	6.76	6.72	6.59	6.62	.23	NS
Performance d 0-189						
End wt, lb	1175	1219	1234	1236	9.8	I
ADG, lb	3.05	3.22	3.31	3.36	.04	I, fm
ADFI, lb	20.51	21.04	20.55	21.14	.04	FM
F/G	6.46	6.70	6.16	6.28	.21	NS
CP intake, g/d	1001	1164	1003	1167		NA[c]
Carcass data						
Dress, %	59.8	59.3	60.5	60.5	7.2	NS
Fat th., in	.40	.49	.48	.50	.02	I, FM
REA, in	12.2	12.3	12.7	12.5	.13	I
YG	2.66	2.98	2.87	2.98	.06	FM
Marbling	318	351	308	329	9.5	FM
Quality grade	5.67	5.97	5.55	5.81	.11	fm
Choice, %	64	73	52	68		NA

[a] Crossbred steers fed 169 days, reimplanted on d 84.
[b] I, FM = P<.01; i = P<.1; fm = P<.05; i*fm = P<.1; NS = no significant effects observed;
[c] NA = not analyzed.

TABLE 5. THE EFFECTS OF VARIOUS GRAIN SOURCES ON QUANTITY OF PROTEIN ESCAPING RUMEN FERMENTATION: ESTIMATED VALUES[a]

	Corn	Sorghum	Barley	Corn/Wheat[b]
Diet DM intake, %	85	85	85	85
Grain intake, lb	20.6	20.6	20.6	20.6
Crude protein, %	10	11	12	10/13.5
Total protein intake, lb	2.06	2.27	2.47	2.42
Crude protein, % DMI	8.5	9.35	10.1	9.9
Escape potential, % of CP	50	50	30	50/20
Escape protein, % of CPI	34	37	24	26

[a] Assume a 1000 lb steer consuming 24 lb of a 12.5% CP diet.
[b] Corn = 42.5% of diet DM; Wheat = 42.5% of diet DM.

TABLE 6. RATIO OF OBSERVED TO PREDICTED ADG OF MUSCULAR OR AVERAGE STEERS[a]

	Muscle score[b]	
Days on feed	1	2
84	.98	.78
112	1.04	.87
140	1.12	.82

[a] Stanton, et al., 1988.
[b] 1 = muscular, 2 = average.

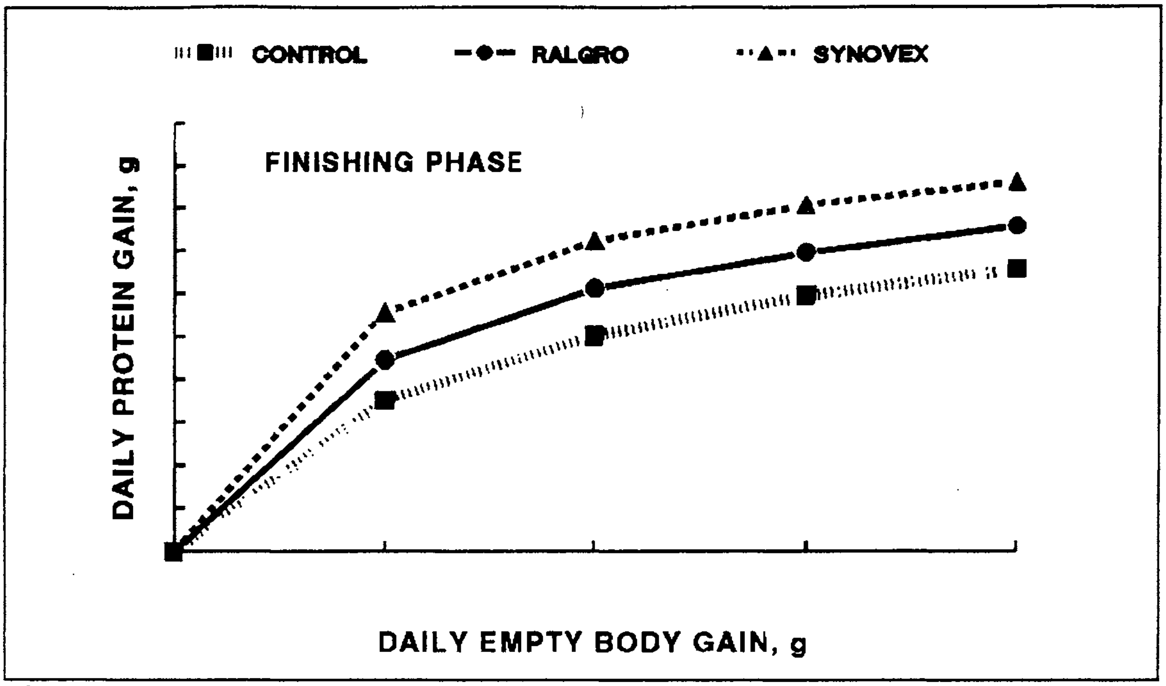

Figure 1. The effect of implants and rate of gain on empty body protein deposition. Lemieux et al. (1990).

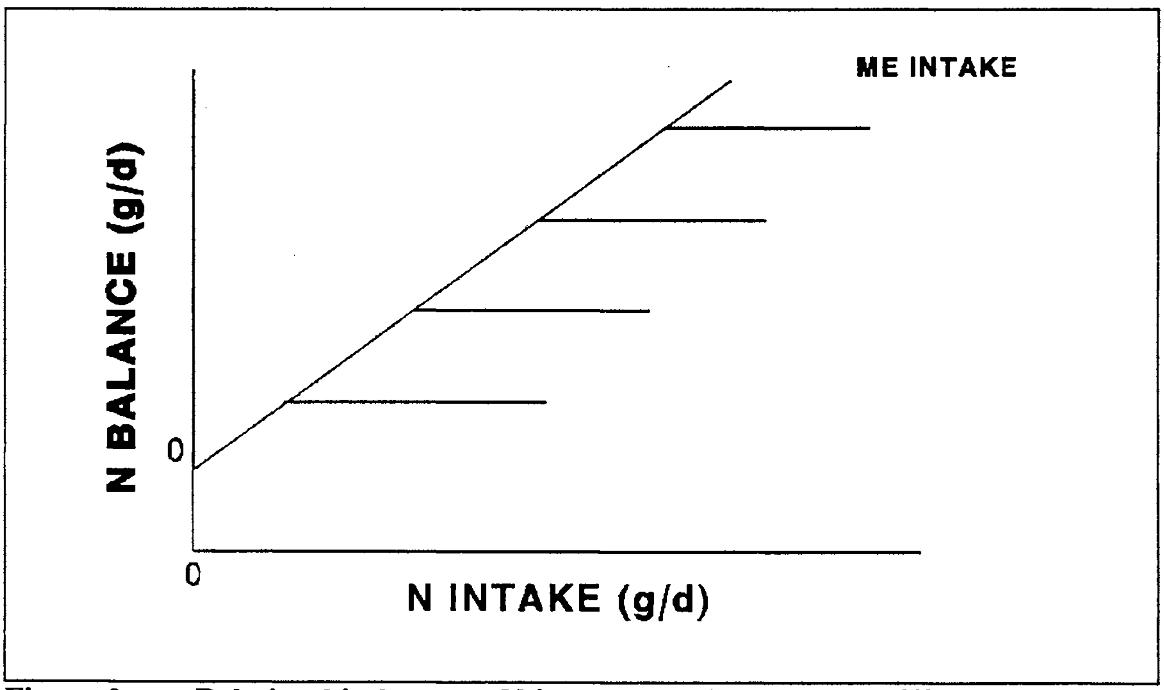

Figure 2. Relationship between N intake and N balance at different ME levels. Black and Griffiths (1975).

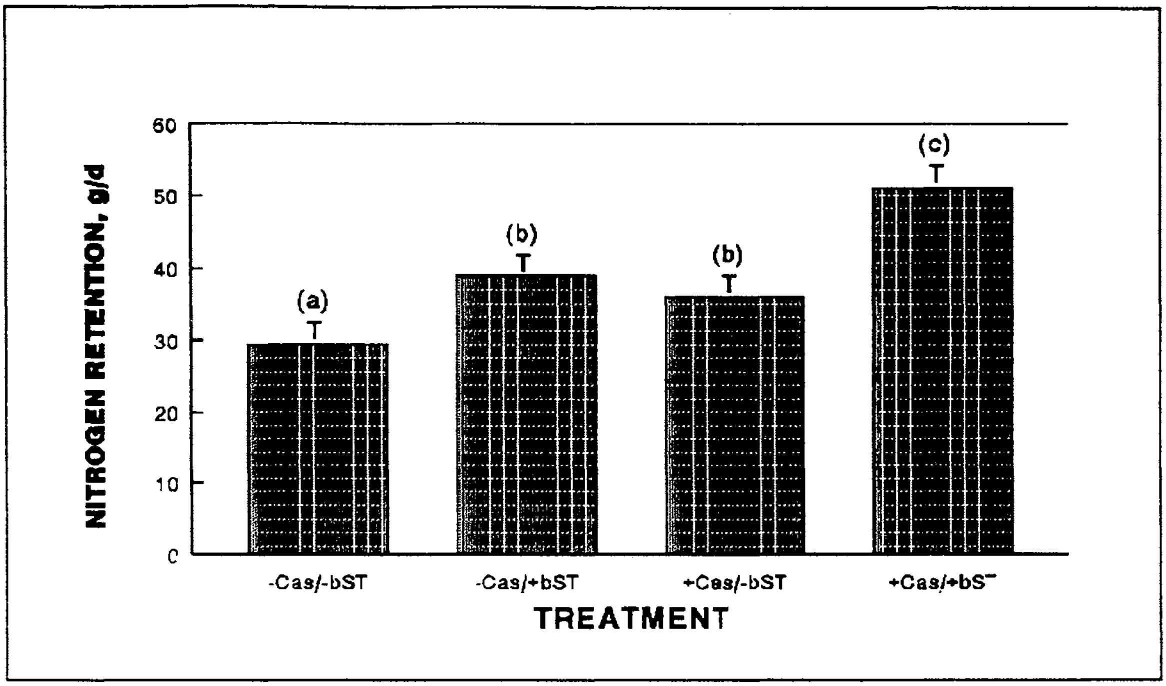

Figure 3. The effect of casein infusion and somatotropin treatment on nitrogen retention of cattle. Houseknecht et al. (1990).

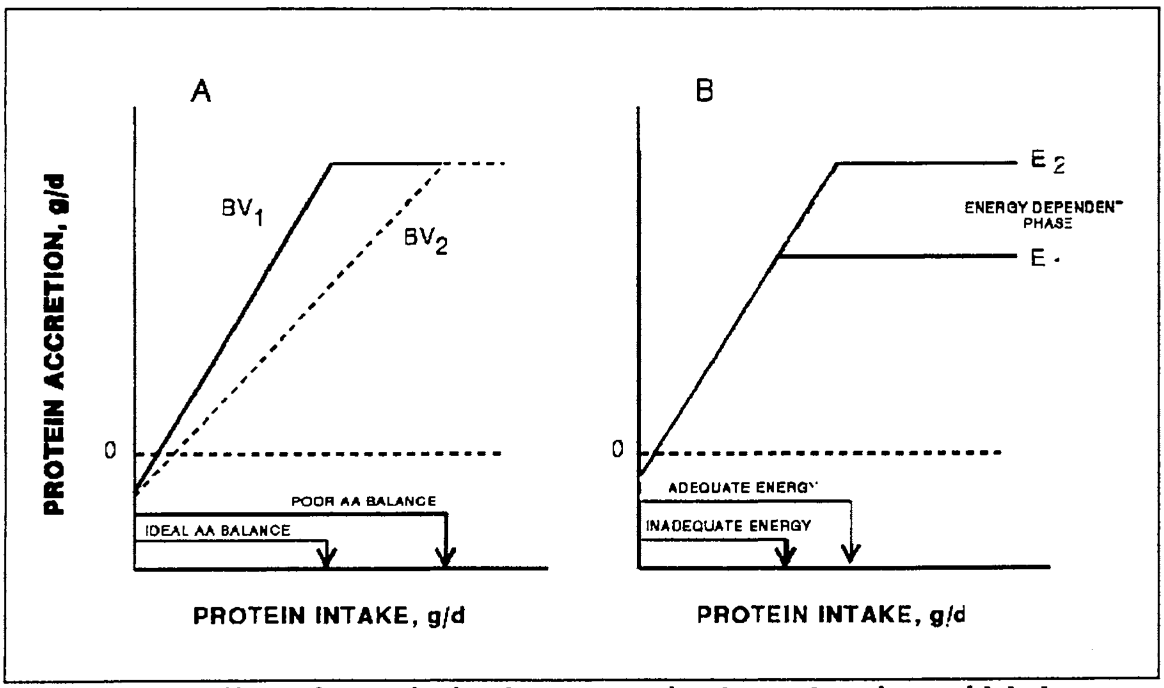

Figure 4. Effect of protein intake, energy intake and amino acid balance on protein accretion. Boyd et al. (1991).

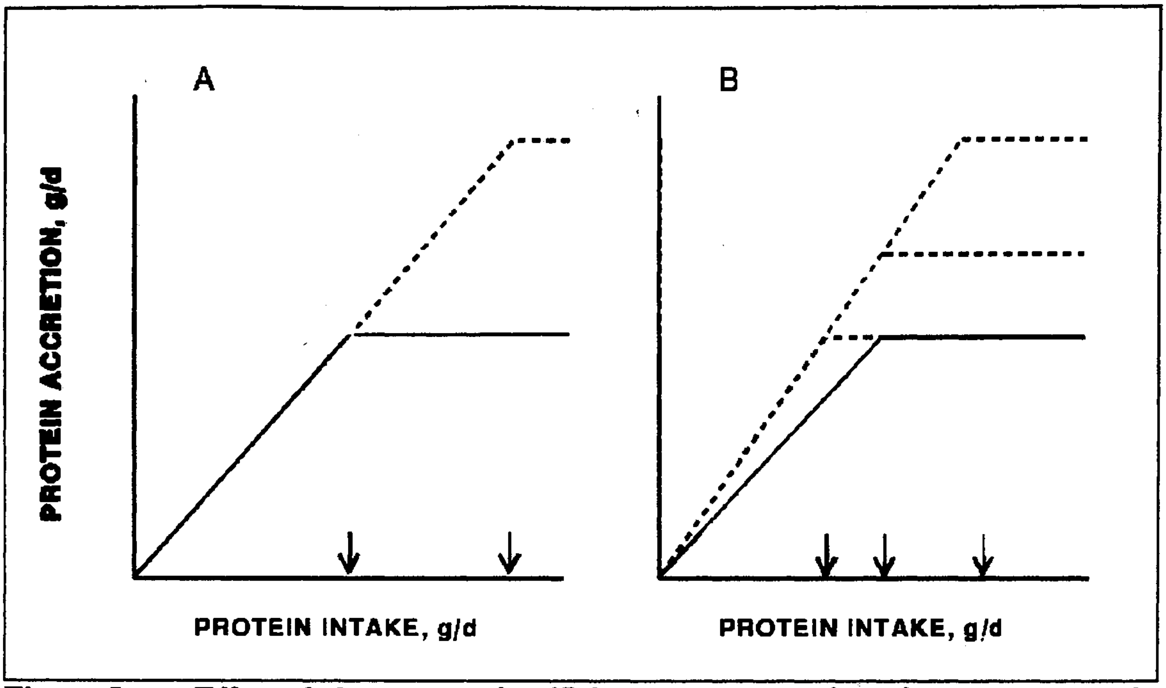

Figure 5. **Effect of altered protein efficiency on the relationship between protein intake and protein accretion. Boyd et al. (1991).**