EFFECTS OF GROWTH STIMULANTS ON PROTEIN REQUIREMENTS OF FEEDLOT CATTLE

A. DiCostanzo and C. M. Zehnder
Department of Animal Science
University of Minnesota, St. Paul

ABSTRACT

Feedlot performance and diet composition data were collected from a survey of finishing steer experiments (347 kg average initial weight; data excluded Holstein steers) conducted in the U.S. and reported in refereed and university publications between 1988 and 1995. Data were analyzed by weighted (observations/mean) analyses of variance to determine effects of protein intake and implanting strategy on feedlot performance (ADG, DMI and kg DM required/kg gain). Implanting strategies were defined according to prevalent or last implant type used: no implant (None); medium-potency implants (Medium): zeranol 72 mg/dose, steroid-based implants (Synovex-S or Compudose) or trenbolone acetate (TBA) alone; high-potency implants (High): TBA in combination with either steroids or zeranol. Regression procedures were utilized to estimate CP and DIP, or MP requirements. Protein accretion was estimated by formulae provided in the literature and regressed on MP intake to estimate MP requirements for maintenance. Implant effects were independent of dietary protein effects and included faster ($P < .05$) gains at higher intakes ($P < .05$) that resulted in improved ($P < .05$) feed efficiencies (gain and efficiency ranking: High > Medium > None). Steers responded to higher dietary CP by increasing intake ($P < .05$) which resulted in faster ($P < .05$) and more efficient ($P = .09$) gains. Total MP requirement for a given rate of gain in steers implanted with high-potency implants was lower than that in steers implanted with medium-potency implants or that in steers not implanted. When diets contain high dietary CP, DIP may increase to 68% of CP in steers implanted with high-potency implants or those not implanted. Maintenance MP requirements of nonimplanted steers were greater than those of implanted steers but similar to MP requirements established by NRC (1996). At relatively low protein intakes, steers in medium-potency strategies accrued more empty body protein. This finding indicates that diets of steers implanted with high-potency implants must be supplemented to contain more than 7.5 g MP/kg $BW^{.75}$/d, especially at heavy (>450 kg) initial BW, to maximize implant response.

INTRODUCTION

Renewed interest in effects of growth stimulants on nutrient requirements has been prompted by several findings that indicate that cattle implanted with a combination of trenbolone acetate and steroids or zeranol, respond to higher dietary protein concentrations (Galyean, 1996). Also, greater protein requirements are suspected because genetic manipulation of cattle has led to production of leaner, later-maturing cattle types. However, defining protein requirements for implanted cattle is further complicated by effects of implants on DMI (Anderson and Botts, 1995), diets fed (e.g., source of grain and source of protein, Zinn, 1995) and environments (NRC, 1996) under which cattle are fed. Using the concept of metabolizable protein, we have summarized effects of growth stimulants on performance and modeled protein requirements.

Materials and Methods

Feedlot performance and diet composition data were collected from a survey of finishing steer experiments (347 kg average initial weight; data excluded Holstein steers) conducted in the U.S. and reported in refereed and university publications between 1988 and 1995. Based on initial and final BW, breed type information, diet composition and DMI, dietary energy (TDN, NE_m, NE_g) and protein fractions (DIP, MP and CP) were estimated using procedures contained in the software of the Nutrient Requirements of Beef Cattle (NRC, 1996; tabular system, level 1). Composition of feeds provided in the software was altered only as needed according to information provided in published material. Because most publications did not provide weather information data or effects of weather on cattle, a standard exposure to a 5-kph wind, a temperature of 20° C (previous or current), no night cooling or heat stress on steers with .5 cm clean and dry hair coats was utilized. Although this assumption biased estimates of protein requirements, it had no effect on estimates of protein supply.

Data were analyzed by weighted (observations /mean) analyses of variance to determine effects of protein intake and implanting strategy on feedlot performance (ADG, DMI and kg DM required/kg gain). Implanting strategies were defined according to prevalent or last implant type used: no implant (None); medium-potency implants (Medium): zeranol 72 mg/dose, steroid-based implants (Synovex-S or Compudose) or trenbolone acetate (TBA) alone; high-potency implants (High): TBA in combination with either steroids or zeranol. A more thorough comparison of steer performance responses to implant type or sequencing is beyond the scope of this paper.

The literature survey yielded 171 treatments with means as shown in Table 1. Use of high grain diets is quite evident from this table. Most diets were corn-based; thus, DIP percentages are fairly low. Compared to NRC (1984) requirements, dietary CP and CP intake are much higher; this is a reflection of researchers trying to assure that crude protein supply does not limit performance of feedlot cattle.

Regression procedures were utilized to estimate CP and DIP, or MP requirements. In either instance, full models containing ADG as the dependent variable and DMI, initial BW, NE_g and DIP and CP, or MP and their quadratic components were reduced by a backward elimination procedure (SAS, 1994) until all variables remaining in the model were significant ($P < .10$). Where appropriate, discrete variables were utilized (usually DMI only) to test for effects of implants. Estimates of DIP and CP, or MP requirements were made by solving the resulting equations for these protein fractions. This step prevented modeling dietary protein fraction intake alone.

A further attempt to estimate protein requirements for maintenance and gain was made. Protein accretion was estimated by formulae provided by Owens et al. (1995). In their review, Owens et al. (1995) suggest that a logical approach to modeling growth should utilize degree of maturity. This approach accounts for differences between sexes, breed types, diets and

Table 1. Weighted means (observations/mean) for dietary characteristics and feedlot performance data according to implant strategy[a]

	Implant strategy		
Item	None	Medium	High
No. means	30	35	106
NE_g, Mcal/kg DM	1.38	1.36	1.38
Implant doses	0.0	1.6	1.2
CP, % DM	12.78	12.39	12.71
DIP, % CP	60.02	59.56	60.90
CP intake, g/d	1,116	1,165	1,238
Initial BW, kg	350	330	361
Final BW, kg	533	541	565
ADG, kg	1.33	1.50	1.63
DMI, kg/d	8.75	9.40	9.76
DM/kg gain, kg	6.61	6.34	6.03

[a] Prevalent or last implant used. None: no implant; Medium: zeranol 72 mg/dose, steroid-based or trenbolone acetate (TBA) only implants; High: combinations of TBA and steroid- or zeranol-based implants.

implant strategies. Equations to predict empty BW and empty body protein from BW and empty body ADG and maturity, respectively, were utilized: Empty body protein gain, (g/d) = 87.7 + 72.5EBADG^2 - 92Maturity^2, $R^2 = .91$; where EBADG = Empty body ADG, and Empty BW (kg) = .917shrunk BW - 11.39. Maturity was estimated by dividing percentage empty body fat by 36 (Owens et al., 1995). The denominator, 36, corresponds to empty body fat at protein maturity (when protein accretion reaches zero). Earlier findings using D_2O dilution techniques indicated that average maturity of cattle not exposed to implants was 60% and that of those exposed to low or medium-potency implants was 55% (Lemieux et al., 1988, 1990; Solis et al., 1989). In this paper, 55 or 60% maturity was used for cattle with or without implants, respectively. Body weight obtained from data survey was used as shrunk BW, although in research reports surveyed BW was obtained after only partial or no shrink.

Protein gain (g/kg BW$^{.75}$/day) was regressed on MP intake (g/kg BW$^{.75}$/day) within each implant strategy. Discrete variables were used to model effects of implant. In this regard, medium-potency strategies included effects of steroids, zeranol or trenbolone acetate implants. Resulting equations yielded estimates of MP requirements for maintenance and gain for defined implant strategies.

Effects of Protein Concentration and Implant Strategy on Feedlot Performance

Feedlot performance of steers under various implant strategies is listed in Table 2. Implant strategy affected ($P < .05$) ADG, DMI and kg DM required/kg gain. Steers implanted with high- potency implants gained fastest, while those not implanted gained slowest (1.63 vs 1.32 kg/d). Steers implanted with medium-potency implants were intermediate (1.56 kg/d). Differences in ADG between implanted and not implanted cattle may be explained by differences ($P < .05$) in DMI. Steers implanted with high-potency implants had the highest DMI, those not implanted had the lowest, while those implanted with medium-potency implants were intermediate (9.65; 8.92; 9.63 kg/d, respectively). As a result, feed efficiency followed similar trends. Steers implanted with medium-potency implants required the least kg DM/kg gain ($P < .05$), while those not implanted required the most (6.79 vs 5.99); steers implanted with medium-potency implants were intermediate (6.20).

Estimating diet ME (Table 2) at observed or similar body weight (composition) indicated improvements in energetic efficiency ranging from 5 to 8% (observed weight and composition) or from 3 to 6% (similar weight and composition). This suggests an improvement in energetic efficiency in response to implanting.

Table 2. Effects of implant strategy[a] on feedlot performance of steers

	Implant strategy			
Item	None	Medium	High	MSE[b]
No. means	30	35	106	
Dietary CP, %	12.1	12.1	12.1	
Initial BW, kg	354	356	356	
Final BW, kg	526	556	565	
ADG[c], kg	1.32	1.56	1.63	.023
DMI[c], kg	8.92	9.63	9.65	.289
DM/kg gain[c], kg	6.79	6.20	5.99	.252
Calculated diet ME				
Direct	3.18	3.34	3.44	
Composition adjusted	3.18	3.28	3.36	

[a] Prevalent or last implant used. None: no implant; Medium: zeranol 72 mg/dose, steroid-based or trenbolone acetate (TBA) only implants; High: combinations of TBA and steroid- or zeranol-based implants.

[b] Mean square error.

[c] Implant effect ($P < .05$).

Table 3. Effects of dietary protein concentration on feedlot performance

	Dietary CP, %		
Item	11	13	MSE[a]
No. means	66	105	
Dietary CP, %	11.4	13.3	
Initial BW, kg	355	356	
Final BW, kg	545	553	
ADG[b], kg	1.47	1.53	.023
DMI[b], kg	9.31	9.50	.289
DM/kg gain, kg	6.38	6.27	.252
Diet ME, calculated	3.30	3.34	

[a] Mean square error.

[b] Protein effect ($P < .05$).

Crude protein concentration averaged 11.2 or 13.4% for two groups created by dividing the data set into trials with either a high (> 12%) or a low (< 12%) CP concentration. This concentration was chosen because it was at the upper limit of NRC (1984) CP requirements for steers of this type and BW. Only two observations reported crude protein concentrations below 10%. Eliminating these concentrations from the data set did not change the results or conclusions.

Crude protein concentration affected ($P < .05$) feedlot performance independent of implant strategy (Table 3). Steers fed high protein diets consumed more feed ($P < .05$), gained faster ($P < .05$) and tended ($P = .09$) to be more efficient than steers fed low protein diets (1.53 kg/d, 9.50 kg/d, 6.27 vs 1.47 kg/d, 9.31 kg/d, 6.38). Estimates of diet ME (Table 3) indicate that protein effects gain through an intake response.

Lack of a significant implant by dietary protein concentration interaction ($P > .538$) indicated that implanted steers do not have higher CP requirements, but merely respond to increased dietary CP as nonimplanted steers do. Regression analyses confirm this finding.

Modeling CP, DIP and MP Requirements

Regressing ADG on DMI, DIP and CP resulted in a model that contained a significant quadratic component for DMI and linear components for DIP and CP (Table 4). Solving for DIP at the dietary CP concentrations, DMI and ADG observed in the survey resulted in estimates of DIP requirements that were dependent on implant strategy (Table 4).

When no implant was used, DMI and ADG were low; therefore, diets with high DIP were sufficient to meet protein requirements. It is quite surprising that at ADG and DMI observed, steers in a high-potency implant strategy fed high CP diets could be fed relatively high DIP diets. In contrast, steers in a medium-potency implant strategy fed high CP diets required less DIP (higher UIP requirement). This would indicate that at similar intakes, diets of steers implanted in a medium-potency implant strategy require more UIP and, therefore, more MP than those of steers in a high-potency implant strategy. In all instances, if dietary CP was limiting, then the maximum DIP permitted in the diet fell to between 55 and 63% to compensate for low dietary CP. These findings substantiate earlier observations (Milton and Brandt, 1994; Berger and Merchen, 1995; DiCostanzo, 1995) that urea concentration in high moisture, whole or dry-rolled corn diets must not exceed 1% of dietary DM. In a previous analysis of data obtained in this survey (DiCostanzo, 1995), steers fed diets containing 5% soybean meal or .8% urea had similar performance. When dietary CP or DMI is not limiting (later in the feeding period), dietary DIP may be increased to between 69 and 73% in diets of steers not implanted or those of steers in a high-potency implant strategy.

Table 4. Estimated DIP[a] and MP[b] requirements for gains achievable with low and high CP diets at intakes observed in data surveyed.

Implant strategy	CP, %	DMI, kg/d	ADG, kg	DIP, %CP	MP, g
None	13.4	9.05	1.35	72.7	750
None	11.1	8.81	1.28	62.6	616
Medium	13.3	9.77	1.59	60.5	984
Medium	11.5	9.51	1.51	55.0	848
High	13.4	9.77	1.65	68.7	855
High	11.1	9.60	1.60	56.6	772

[a] Obtained by solving for DIP% in: ADG (kg/d) = -5.1054 + [DMI (kg/d) * Implant strategy coefficient (None: 1.2695; Medium: 1.1943; High: 1.2054)] + [DMI^2 (kg/d^2) * Implant strategy coefficient (None: -.0630; Medium: -.0541; High: -.0542)] - [DIP (%) * .0056] + [CP (%) * .0397]; $R^2 = .52$, CV = 21.2%.

[b] Obtained by solving for MP in: ADG (kg/d) = -5.4445 + [DMI (kg/d) * Implant strategy coefficient (None: 1.3722; Medium: 1.2665; High: 1.2839)] + [DMI^2, (kg/d^2) * Implant strategy coefficient (None: -.0720; Medium: -.0597; High: -.0604)] + [MP (g) * .00037]; $R^2 = .47$, CV = 22.3%.

When ADG was regressed on DMI and MP, the model contained significant quadratic components for DMI (Table 4). Solving for MP at the DMI and ADG observed in the survey resulted in estimates of MP requirements that were dependent on implant strategy (Table 4). When no implant was used, DMI and ADG were lowest; therefore, MP requirements were lowest. At similar DMI, steers in the medium-potency implant strategy required more MP, although they had lower ADG than steers in the high-potency implant strategy. Thus, steers implanted with combinations of TBA and steroids or zeranol appear to be more efficient at converting MP to daily BW gain. Estimates of efficiencies of MP to ADG averaged 51.84, 59.05 and 50.03 g MP/kg. Because these estimates of MP include requirements for maintenance and gain, it is not clear from this analysis whether medium-potency implants increase protein requirements for maintenance or gain or both.

Protein need for Maintenance

Regression of estimates of protein accretion on estimates of MP intake (Figure 1) indicated that nonimplanted steers have a higher maintenance requirement for protein and lower efficiency of conversion of MP to empty body protein. Maximum empty body protein deposition was achieved at 14.1, 9.1 or 11.8 g/kg BW$^{.75}$/d for none, medium or high potency strategies, respectively. This suggests that less protein is required for maximum gain when steers are implanted. At MP intakes observed in the survey, nonimplanted steers were, on average, 22 or 28% less efficient (MP intake/empty body protein gain) than steers implanted with medium- or high-potency implants. At low MP intakes (< 7.5388 g/kg BW$^{.75}$), steers implanted with medium-potency implants were more efficient. At high MP intakes (> 7.5388 g/kg BW$^{.75}$), steers implanted with high-potency implants were more efficient. This MP intake is equivalent to 736 g MP for an average steer BW of 450 kg (approximately 1099 g dietary CP supply). This finding suggests that when dietary, economic or management conditions limit MP supply to below 736 g (or dietary CP supply below 1099 g) for a feeding period, the strategy of choice may be a medium-potency implant.

By solving for zero empty body protein accretion, estimates of MP requirement for maintenance of steers under various implant strategies were obtained and are compared to similar NRC (1996) estimates (Table 5). Metabolizable protein requirements were corrected for efficiency of MP conversion to net protein. Because

Table 5. Estimated MP requirements for maintenance derived from the NRC (1996) equation[a] or data surveyed[b]

	NRC, 1996	Implant strategy		
BW, kg	All	None	Medium	High
350	307	308	199	230
375	324	325	210	243
400	340	341	220	255
425	356	357	230	266
450	371	373	240	278
475	387	388	250	290
500	402	403	260	301

[a] MP requirement for maintenance = 3.8 g MP/kg BW$^{.75}$.

[b] MP requirement for maintenance of nonimplanted steers or those of steers implanted with medium- and high-potency implants were: 3.81, 2.46 or 2.84 g MP/kg BW$^{.75}$, respectively. Requirements were derived by solving for MP in the equation: Empty body protein (g/kg BW$^{.75}$/d) = -.70208 + [MP (g/kg BW$^{.75}$/d) * Implant strategy coefficient (None: .4009; Medium: .6216; High: .5329)] + [MP^2 (g/kg BW$^{.75}$/d^2) * Implant strategy coefficient (None: -.0142; Medium: -.0343; High: -.0225)]; R^2 = .37; CV = 33.2%.

net protein was regressed on MP in the current analysis, a correction factor of 2.03 (1 / .492, the efficiency assumed by NRC, 1996) was applied to compare our results to other estimates. Maintenance MP requirements of nonimplanted steers were highest but surprisingly similar to those obtained by the NRC (1996). The equation adopted by the NRC (1996) was based on animal growth data and corroborated by nitrogen balance data (Susmel et al., 1993).

Estimates of maintenance MP requirements for steers in medium- or high-potency implant strategies were 36% and 25% lower, respectively, than those of nonimplanted steers. Reduced maintenance MP requirements of implanted steers may be indicative of reduced protein turnover and amino acid catabolism.

Wether lambs treated with TBA plus estradiol had reduced protein synthesis and degradation (Sinnett-Smith et al., 1983). When ewe lambs were treated with either TBA or zeranol, protein synthesis rates were decreased, but free cathepsin D activity, an indicator of protein degradation, was significantly decreased (Sinnett-Smith et al., 1983). Similar results were observed in steers treated with TBA plus estradiol (Lobley et al., 1985). Thus, it is apparent that TBA plus estradiol, or zeranol impact protein accretion by reducing protein synthesis and degradation; a larger impact on the latter enhances protein accretion and improves energetic efficiency.

However, previous metabolism studies on effects of TBA combinations with estradiol and estradiol only on protein synthesis and degradation do not shed a direct explanation as to a potential difference in MP requirement for steers treated with combinations of TBA or TBA, steroids or zeranol alone. Reports of effects of TBA- or steroid-based implants on energy requirements of steers fed high roughage diets in adverse environments indicate that steroids increase energy requirements while TBA reduces them (Hunter and Vercoe, 1987). Based on this finding, one would expect protein requirements to be affected similarly. However, energy retention and intake were not affected by implant status (a TBA-estradiol combination) in steers fed diets containing 15.75% CP to gain .8 kg/d (Lobley et al., 1985). Thus, energy requirements of steers implanted with TBA-based implants may not be altered when dietary conditions are adequate for moderate growth. In this study, the proportion of protein retention relative to energy retention increased under the influence of the implant. Therefore, increased maintenance requirements associated with increased protein mass in TBA-implanted steers fed for moderate growth may offset TBA-medicated effects on protein turnover and amino acid catabolism. Further study is required for clarification.

Using information derived from the relationship between empty body protein attrition and gain, empty body protein attrition was converted back to ADG and plotted at various average BW for a feeding period and implant strategy (MP intake was fixed for the feeding period at 750 or 850 g/d for nonimplanted or implanted steers, respectively, Figure 2). Average daily gain appeared to be virtually unchanged for nonimplanted steers in the range of average BW between 350 and 500 kg. This indicates that ADG or protein attrition is unaffected by average BW (a function of initial weight on feed) when steers are not implanted. When exposed to a constant MP intake, ADG of steers in either a medium- or high-potency strategy increased with increasing average BW (e.g., heavier initial BW). At heavier average BW (MP intake in g/kg BW decreases), the difference in ADG between medium- and high-potency implant strategies decreased. Metabolizable protein intake would average 8.04 g/kg $BW^{.75}$/d at average 500 kg BW. This intake is approaching 7.5388 g/kg $BW^{.75}$/d, the inflection point of the medium- and high-potency curves. These data are taken together to suggest for steers in a high-potency implant strategy that, as average BW increases, dietary protein concentration should increase to provide > 7.5 g MP/kg $BW^{.75}$/d during the feeding period to ensure maximum performance response.

Implications

Implants increase gains of finishing steers partly because of their effects on intake. Similarly, increasing dietary protein concentration increases intake, thereby resulting in faster gains. However, data analyzed herein indicated that implanted steers have a greater ability to respond to increased dietary protein concentration because of a reduced protein requirement for maintenance. Thus, the overall MP requirement for a given rate of gain is reduced in implanted steers. When high-potency implants (combinations of TBA with steroids or zeranol) are used, this requirement is reduced relative to when medium-potency implants (TBA, steroids or zeranol alone) are used. In heavy steers implanted with high-potency implants, MP supply must exceed 7.5 g MP/kg $BW^{.75}$/d to maximize implant response.

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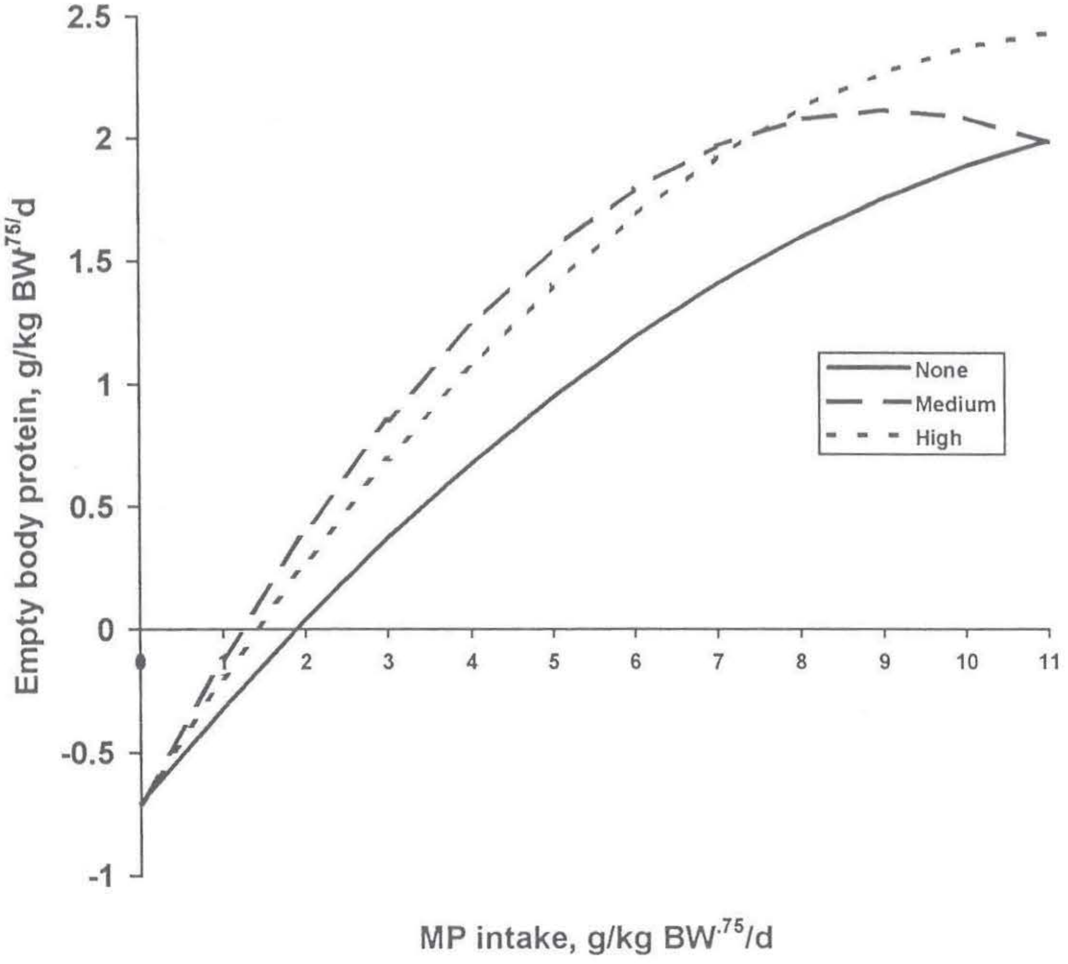

Figure 1. Relationship between estimated empty body protein gain and MP intake in cattle under various implant strategies. Empty body protein (g/kg $BW^{.75}$/d) = -.70208 + [MP (g/kg $BW^{.75}$/d) * Implant strategy coefficient (None: .4009; Medium: .6216; High: .5329)] + [MP^2 (g/kg $BW^{.75}/d^2$) * Implant strategy coefficient (None: -.0142; Medium: -.0343; High: -.0225)]; R^2 = .37; CV = 33.2%.

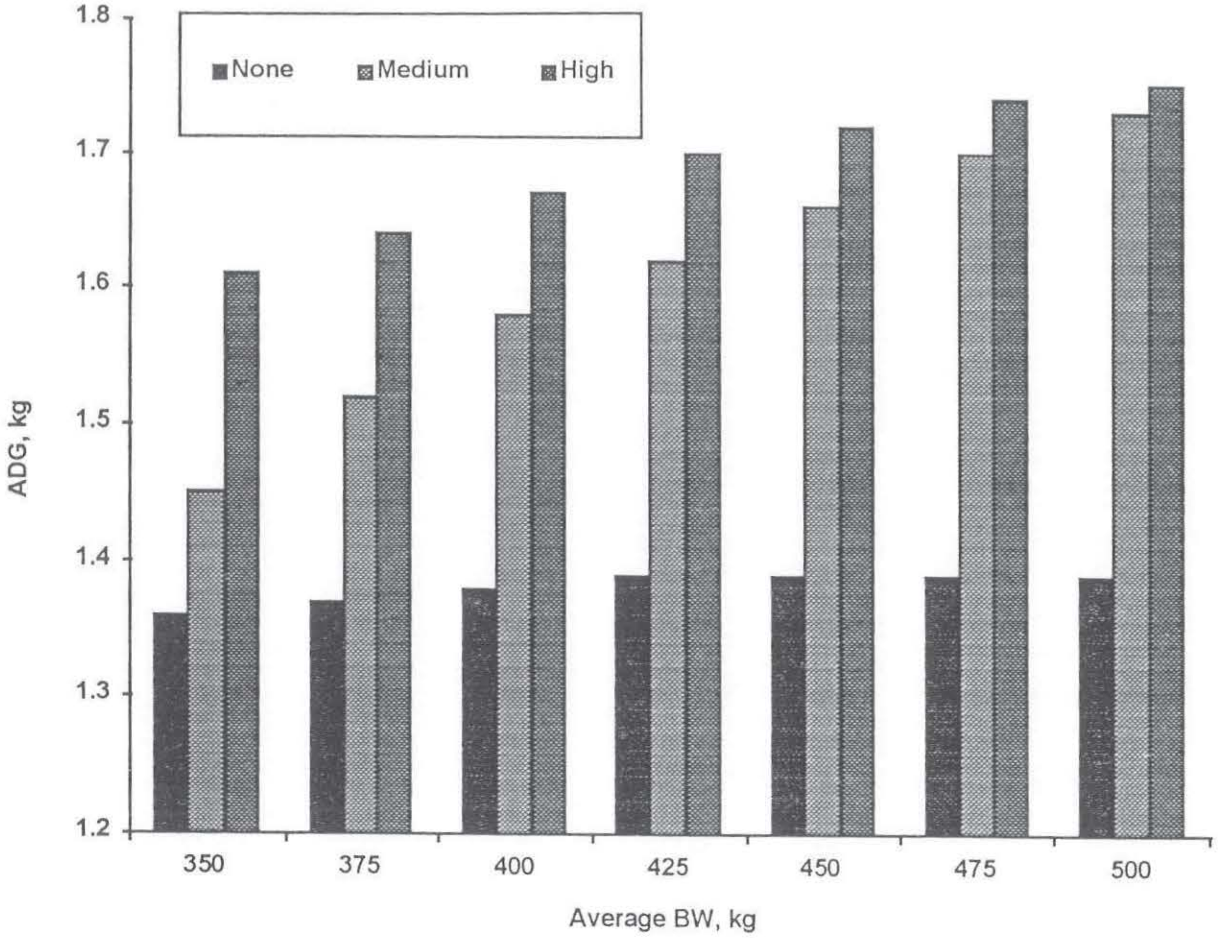

Figure 2. Estimated ADG for a feeding period given various feeding period average BW and MP intakes of 750 (nonimplanted) or 850 g (Medium or High implant strategies).