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Effects of Matching Protein to Requirements on Performance and Waste Management in the Feedlot

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Decreasing dietary protein to not exceed requirements predicted by the 1996 NRC computer model decreased nitrogen excretion and improved nitrogen balance.

Summary

Four experiments were conducted, two with calves in the winter/spring and two with yearlings during the summer, to evaluate the effects of decreasing protein levels on nutrient balance in the feedlot. The control diet was formulated for 13.5 percent protein; the experimental diets were formulated using the 1996 NRC model to predict protein requirements. Nutrient balances for organic matter (OM) and nitrogen (N) were measured. Nitrogen intake and subsequent excretion were decreased with steers fed the experimental treatment. During the summer more N was removed from pens on the experimental treatment since OM excretion was greater which led to decreased N volatilization. N losses were lower in the winter/spring feeding periods when expressed as percentage volatilized.

Introduction

With the concentration of the feedlot industry into fewer acres and fewer producers, waste management is becoming an increasingly important issue. Feedlot design has advanced to handle the nutrient concentration from manure in these feedlots, particularly surface runoff and leaching. From a cost perspective, minimizing total manure production and removal time is advantageous. Since manure has been and will continue to be used as a crop fertilizer in feedlot areas, concentrations of nitrogen (N) and phosphorus (P) are critical. In particular, the N:P ratio is important as most crops require a 5:1 ratio although most manure contains a 2:1 ratio or less.

When manure is used as a fertilizer, either excess P is applied to the land base or extra fertilizer N needs to be applied to optimize crop yields. The reason the ratio is typically much lower than 5:1 is because 50 to 70 percent of the N volatilizes from the pen after excretion in either the feces or urine, whereas phosphorus does not volatilize. Increasing the N or decreasing the P will add value to the manure relative to crop needs. From an environmental perspective, decreasing total N and P excretion would be advantageous to improve the sustainability of the industry.

The animal's requirement changes with age and time on feed. Calves have a higher requirement for MP than yearlings. At the same time, calves require less MP at the end of the finishing period than at the beginning. Therefore, if the diet is to meet requirements, it must change between calves and yearlings as well as with time on feed. This is commonly referred to as "phase feeding." Understanding this system allows nutritionists to more effectively optimize performance without overfeeding nutrients.

Our objective was to balance a diet to meet the DIP and UIP requirements without overfeeding protein and phosphorus, and to determine the effects on animal performance and, more importantly, waste management in the feedlot.

Procedure

Four experiments were conducted, two with 96 yearling steers fed through the summer months and two with 96 calves fed through the winter/spring months. Steers were randomly assigned (eight head/pen) to either the control (CON) or the experimental treatment (EXP). Yearlings were fed for an average of 137 days from May to October and implanted twice with Revalor-S, with the second implant approximately 70 days from slaughter. Yearlings were stepped-up on energy in 21 days with four diets containing 45, 35, 25 and 15 percent alfalfa hay which were fed for three, four, seven and seven days respectively. The control diet (Table 1) was formulated to provide 13.5 percent crude protein and 0.35 percent phosphorus (P) with all supplemental protein from urea. The control diet was considered typical for this region, based on three published surveys. The experimental diet was formulated using the 1996 NRC model to not exceed DIP and UIP requirements. Since protein from HMC is lower in UIP and the requirement for UIP is also lower for yearlings, DRC was used in CON whereas the EXP contained HMC to minimize overfeeding of UIP. Likewise since both DRC and HMC contain 0.25 to 0.30 percent P and the requirement is 0.23 percent P, the EXP treatment also contained corn bran (0.10 percent P) to meet, but not exceed, the P requirement predicted by the NRC model. Since the P requirement changes with days on feed, EXP finishing diets 1, 2 and 3 were fed for 28, 28 and an average of 54 days, respectively, with corn bran replacing HMC.

In the two calf trials, steers were fed for an average of 192 days from November to May. Steers were implanted twice

Table 1. Diet composition (percent of DM) for yearlings and calves.

	Yearlings				Calves								
		Exp				Exp							
Item[a]	CON	1	2	3	CON	1	2	3	4	5	6	7	8
DRC	81.3				82.5	82.5	82.5	82.5	82.5	59.5	35.0	4.5	
HMC		67.4	64.6	61.4						16.5	36.5	61.0	57.5
C.bran		17.2	19.9	23.1						6.5	11.0	17.0	25.0
Liq-32	6.2				5.0								
Molasses						5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fat		3.0	3.0	3.0									
Alfalfa	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Suppl.	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	.52	.76	.76	.76	.29	.83	.88	.91	.96	.87	.75	.62	.60
FM					1.40	1.60	1.15	.75	.18				
BM					.18	.20	.14	.10	.02				
Dical P	.48				.47	.10	.04						
CP (%)	13.6	11.2	11.9	11.5	13.4	12.7	12.4	12.1	11.7	11.5	11.2	10.8	10.9
UIP (%)[b]	4.48		3.67		5.16	5.51	5.23	4.99	4.64	4.11	3.68	3.11	3.02
P (%)	.34	.24	.24	.22	.35	.26	.25	.24	.24	.23	.22	.21	.20

[a]CON is control, EXP is experimental, DRC is dry-rolled corn, HMC is high-moisture corn, c. bran is corn bran, Liquid-32 is a molasses based supplement, FM is feather meal, and BM is blood meal.
[b]The EXP finishers for yearling trials and EXP 8 finisher for calf trials unavoidably contained more UIP than required.

with Revalor-S, with the second implant approximately 85 days from slaughter. Cattle were adapted to finisher diets (7.5 percent alfalfa) similar to the yearling trials except each diet was fed for seven days. The control diet was formulated to provide 0.35 percent P and 13.5 percent crude protein; however, supplemental CP was from urea, 1.4 percent feather meal (FM), and 0.18 percent blood meal (BM) on a DM basis to provide UIP throughout the 192 days. The experimental diet was formulated using the 1996 NRC model to meet changing calf requirements. The first seven finishers were fed for 14 days each and finisher eight was fed until slaughter. Since calves initially require more UIP as a percentage of total protein fed, DRC was used and gradually switched over to HMC by finisher seven. Likewise, the P requirement also decreases with increasing weight of the animal so DRC and HMC were gradually replaced with corn bran to prevent overfeeding of P. During the second year, calves were placed on finisher two and finisher one was skipped due to heavier initial weights than in year one.

Initial weights were an average of weights on two consecutive days following a five-day limit-feeding period. At slaughter, hot carcass weights and liver scores were recorded. Quality grade, yield grade and fat thickness at the twelfth rib were recorded following a 48-hour chill. Final weights were calculated as hot carcass weight divided by a common dressing percentage (62).

Steers were fed in 12 waste management pens. Soil in pens was core sampled (0 to 6 inches) before the trial to estimate nutrient concentration on the pen surface. The animals were then fed in those pens for an average of 132 days over the summer or 183 days over the winter/spring, after which pens were cleaned. Manure was sampled during removal and pen soil samples were again collected to estimate nutrient balances after the feeding period. Soil sampling allows adjustment for inevitable cleaning differences from pen to pen. These pens also contain runoff collection basins to determine total runoff from pens on different treatments. Due to pen design, two pens drain into one pond; therefore dietary treatments were assigned in blocks of two pens. All samples including feed and orts were analyzed for N and OM.

Table 2. Performance of calves and yearlings fed either conventional protein levels (CON) or the experimental diets (EXP) combined across both years.

	Yearlings				Calves			
Item	**CON**	**EXP**	SE	P=	**CON**	**EXP**	SE	P=
Initial weight,lb	**694**	**697**	1.8	.17	**605**	**608**	1.7	.25
Final weight,lb	**1242**	**1256**	7.4	.17	**1264**	**1258**	8.5	.60
DM Intake,lb	**25.2**	**24.5**	.2	.03	**20.3**	**20.7**	.2	.21
ADG,lb	**3.98**	**4.07**	.05	.27	**3.45**	**3.40**	.04	.43
Feed/gain[a]	**6.33**	**6.02**		.01	**5.88**	**6.10**		.04
Fat thickness,in[b]	**.49**	**.50**	.01	.61	**.50**	**.47**	.01	.16
Quality grade[c]	**18.2**	**17.9**	.1	.26	**18.2**	**18.0**	.1	.12
Hot carcass wt.,lb	**770**	**779**	4.6	.17	**784**	**780**	5.3	.60

[a]Analyzed as gain to feed, the reciprocal of feed to gain.
[b]Fat depth at the twelfth rib in inches.
[c]Quality grades: Choice = 20; Choice$^-$ =19; Select$^+$ = 18; Select = 17

Results

Gain and carcass characteristics were unaffected by dietary treatment in both yearling and both calf trials (Table 2). Dry matter intake was reduced (P=.03) for EXP yearlings compared to CON yearlings which led to an improvement (P=.01) in feed efficiency for steers on the EXP treatment. This improved

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efficiency may have been due to the addition of corn bran, which replaced dietary starch, and may have decreased acidosis-related problems with EXP steers. Yearlings on the EXP treatment were also fed HMC which may have improved efficiency.

Although gain and DMI were unaffected by dietary treatment for the two calf trials, feed efficiency was poorer for calves fed the EXP. The increased feed to gain ratio is primarily due to year two where calf gains were reduced due to the wet, muddy winter and spring in 1998. The reduced efficiency in this scenario may be explained by the corn bran addition, and a lower benefit from corn bran in preventing subacute acidosis in the calves as compared to the yearlings. Corn bran decreases energy supply, but normally maintains gains due to the low inclusion rate (<20 percent) and a reduction in subacute acidosis from starch fermentation. With calves, the response to corn bran is normally lower than with yearlings, and combined with a higher maintenance energy requirement due to mud, feed efficiency was lower during year two for the EXP treatment. Total protein intake was considerably higher during year 2 due to ingredient composition compared to year one (no differences were observed in gain or efficiency) which leads us to believe that the response in efficiency is attributable to the energy differences between the two diets and not a result of feeding a lower protein diet. However, our goal was not to conduct a nutrition study to determine protein requirements but to maintain equal performance and illustrate how dietary nitrogen (protein) can be reduced and how this affects nitrogen balance in the system.

Nitrogen intake, expressed as total pounds per head, was reduced by feeding the EXP in yearling and calf trials (Table 3). Nitrogen retention in the animal was unaffected since gains were unaffected by treatment; however, calves retained more N than yearlings since more muscle tissue was deposited. Therefore, feeding EXP reduced N excretion by 13.5 pounds (.1 lb/d) in the yearling trials and 9 pounds (.05lb/d) in the calf trials. Organic matter excretion was increased by feeding EXP (Table 4) because corn bran, which is less digestible than corn grain, replaced part of the dietary corn. The increased OM excretion resulted in more OM and N to be removed in manure during the yearling summer trials. Manure N and OM were increased by 152 percent and 163 percent, respectively, by feeding less digestible OM in EXP relative to CON. No improvement in N captured in manure due to dietary treatment was observed during the winter calf trials. We believe the increased manure N during the summer is the result of increased OM on the pen surface. Also, the large amount of manure N removed in the spring following the calf trials is a function of the decreased losses due to the colder ambient temperature and more removed in the pen soil not excreted by the animal. Nitrogen volatilization was still 40 to 41 percent during the winter and was numerically lower (25 versus 29 lb) for EXP compared to CON treatment for calves. Nitrogen and OM leaving the feedlot via surface runoff are not large portions of total excretions (<3.5 and <7 percent for N and OM, respectively). Additionally, the majority of N losses from feedlot pens is via volatilization as ammonia and other N-containing gases during the summer, with estimates of 70.9 and 60.7 percent for CON and EXP, respectively. When expressed in pounds, EXP resulted in only 31 pounds of N

Table 3. Nitrogen (N) balance in the feedlot for the yearling and calf trials separated by dietary treatment (all values expressed as pounds per head over the entire feeding period).

	Yearlings				Calves			
Item	CON	EXP	SE	P=	CON	EXP	SE	P=
Intake	**72.82**	**59.39**	.59	.01	**81.40**	**72.23**	.84	.01
Retention[a]	**7.90**	**7.92**	.05	.80	**10.14**	**10.04**	.06	.28
Excretion[b]	**64.92**	**51.47**	.57	.01	**71.26**	**62.18**	.81	.01
Manure	**12.91**	**19.61**	.73	.01	**43.51**	**41.53**	2.64	.60
Soil[c]	**3.85**	**-.89**	1.42	.03	**-3.66**	**-6.46**	1.76	.28
Runoff	**2.12**	**1.51**	.22	.07	**2.10**	**2.21**	.23	.74
Volatilized[d]	**46.04**	**31.25**	1.62	.01	**29.31**	**24.91**	3.05	.32
% volatilized	**70.9**	**60.7**			**41.1**	**40.1**		

[a]N retention based on ADG, NRC equation for retained energy and retained protein.
[b]N excretion calculated as intake minus retention.
[c]Soil is core balance on pen surface before and after trial; negative values suggest removal of nutrient present before trial.
[d]Volatilized calculated as excretion minus manure minus soil minus runoff.

Table 4. Organic matter (OM) balance in the feedlot for the yearling and calf trials separated by dietary treatment (all values expressed as pounds per head over the entire feeding period).

	Yearlings				Calves			
Item	CON	EXP	SE	P=	CON	EXP	SE	P=
Intake	**3221.7**	**3080.5**	27.1	.01	**3322.6**	**3512.8**	36.7	.01
Excreted[a]	**665.6**	**920.2**	7.0	.01	**747.0**	**935.9**	9.0	.01
Manure	**242.3**	**395.4**	13.7	.01	**808.1**	**873.2**	51.8	.38
Soil[b]	**41.6**	**-73.9**	31.5	.02	**-74.5**	**-85.4**	37.2	.83
Runoff	**44.4**	**32.1**	4.8	.08	**18.4**	**27.5**	2.6	.02
Volatilized[c]	**337.3**	**566.5**	34.6	.01	**38.2**	**67.1**	55.0	.71

[a]OM excretion calculated from digestibility data from corn and corn bran diets.
[b]Soil is core balance on pen surface before and after trial; negative values suggest removal of nutrient present before trial.

volatilization versus 46 pounds per head for CON. This decrease can be primarily attributed to the decrease in N excreted by the steers and some improvement in N captured in manure.

Dietary N and indigestibility of dietary OM, rather than ingredient composition, runoff amounts and variation in pen cleaning, may be the largest factors influencing manure characteristics, because considerable differences from year one to year two were observed in all measurements for nutrient balance except the manure data. Averaged across both treatments, N in manure for the summer trials were 16.13 and 16.39 ± .73 lb per head for years one and two, respectively. Organic matter in manure was 323 (year 1) and 315 (year 2) ± 14 pounds per head for the summer. Likewise, N in manure from the winter/spring trials were 39.6 and 45.4 ± 2.6 pounds for years one and two, respectively.

It appears decreasing dietary protein to animal requirements will decrease nitrogen excretion. With less nitrogen excreted, nitrogen losses via volatilization can be minimized. However, it appears there is an interaction between OM and N on the pen surface. If OM excretion is increased, more N will be "trapped" in the manure and may eventually be utilized as fertilizer N, improving nutrient balance by decreasing losses from the feedlot. Volatilization is more of an issue during the summer months, due to ambient temperature, but some N losses occur year-round through volatilization or runoff (what little may occur).

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