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Phosphorus Requirement of Finishing Feedlot Calves

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Based on performance and bone characteristics, phosphorus requirements of feedlot calves are lower than previously thought, therefore, corn-based feedlot diets contain adequate phosphorus for optimum performance without supplementation.

Summary

Feedlot calves were individually fed to determine the phosphorus required for optimum performance during a 204-day experiment. The base diet consisted of high-moisture corn and corn starch/fiber with P treatments of 0.16, 0.22, 0.28, 0.34, and 0.40% of diet DM. Calves fed 0.16% P had the lowest plasma P but it was adequate (5.7 mg/dL). Bone mineral was not influenced by treatment, suggesting that dietary P was adequate to meet performance needs. Supplementation of P is unnecessary because requirements are less than 0.16% of the diet DM.

Introduction

Livestock operations are becoming increasingly aware of the challenges associated with nutrient management. Perhaps the largest challenge will be managing phosphorus when concentrated at livestock operations. One factor that may help alleviate the challenges of proper P management is diet modification, in particular, decreasing dietary P to not exceed cattle requirements. However, requirements are not well established for beef feedlot cattle weighing between 550 to 1,250 lb. Phosphorus requirements of yearling steers (850 lb) were evaluated previously, and we concluded that the requirement was less than 0.14% of diet DM or 70% of NRC predicted requirements (*1998 Nebraska Beef Report*, pp. 78-80). Other research has focused on light calves (< 500 lb) which have a higher P requirement than typical feedlot cattle. Therefore, P requirements for typical feedlot calves (> 550 lb) fed high-energy diets need to be evaluated to allow producers to decrease dietary P without compromising performance. Our objectives were to determine 1) the P requirement of finishing calves for optimum performance and 2) the impact of decreasing dietary P on bone metabolism and plasma inorganic P.

Procedure

Diets

A base diet was formulated to contain high concentrations of NEm and NEg yet low concentrations of P. Because corn contains 0.32 $\pm$ 0.04% P based on 3,500 samples analyzed across the country, only 34.5% of diet DM consisted of high-moisture corn (Table 1). Brewers grits, which is primarily corn starch, and corn bran, which is the digestible fibrous component of corn, were added to provide a high-energy, low-P substitute for corn. Dietary P treatments evaluated were 0.16 (contained no supplemental P), 0.22, 0.28, 0.34, and 0.40% of diet DM. Dietary P was increased by "top-dress" addition of NaH_2PO_4 (0 to 130 grams/day) directly to each day's aliquot of feed in the bunk. Therefore, P was

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replacing all of the diet (in small quantities) when added to the bunk instead of the supplement carrier. The dry meal supplement was formulated to meet or exceed the metabolizable protein requirements predicted by the 1996 NRC. Blood meal was gradually decreased because less UIP in the diet was required to meet the protein requirements as the experiment progressed. Diet CP concentrations for the three phases were 13.0, 12.6, and 11.8% of diet DM.

Animals

Calves were purchased from one commercial ranch in Nebraska and were managed similarly prior to weaning. At weaning, calves were transported to the University of Nebraska Agricultural Research and Development Center near Mead, Neb. Following a 25-day receiving period and a 14-day training period, calves were limit-fed (12 lb of DM/steer) 50% alfalfa hay and 50% wet corn gluten feed for seven days for accurate initial weights. Initial weights were based on weights taken on three consecutive days prior to morning feeding.

Forty-five, crossbred steer calves (584 $\pm$ 37 lb) were assigned randomly to one of five levels of P, either 0.16, 0.22, 0.28, 0.34, or 0.40. Steers were adapted to high-energy diets by limiting intake (8 lb DM initially) and gradually increasing DM offered at a rate of 0.5 lb/day until ad libitum intakes were achieved. This adaptation scheme required approximately 21 days. Steers were fed once daily and implanted on day 1 with Synovex-S followed by Revalor-S on day 84. Two-day weights were taken every 28 days for sampling and performance purposes. Steers were on the experiment for 204 days, from Feb. 2, 2000 to Aug. 24, 2000. At slaughter, hot carcass weights were recorded and two bones from the lower front leg (phalanx and metacarpal) were collected. Following a 24-hour chill, fat depth, loineye area, and marbling measurements at the 12th rib were collected. Final weight was calculated from hot carcass weight divided by a common dressing percentage (62).

Table 1. Diet composition (% of diet DM). At time of feeding, target levels of P were added as top-dress of NaH_2PO_4 to achieve added increments of 0.06%.

ITEM	% diet DM	Ingredient % P
High moisture corn	33.5	0.32
Corn bran	20.0	0.08
Brewers grits	30.0	0.08
Cottonseed hulls	7.5	0.11
Fat	3.0	—
Supplement[a,b]	6.0	0.09
Composition		
Crude protein	12.5	
Calcium	0.62	
Potassium	0.75	

[a]Supplement fed in three phases with decreasing amounts of blood meal to meet or exceed predicted metabolizable protein requirement.
[b]All diets contained 27 grams/ton Rumensin and 10.4 grams/ton Tylan

Table 2. Effects of dietary P on finishing performance and carcass characteristics for calves fed varying levels of P.

	Phosphorus, % of DM[a]						P-Value		
ITEM	0.16	0.22	0.28	0.34	0.40	SE	F-test	Linear	Quad
P intake, g/day	14.2	20.2	23.4	31.7	35.5	0.7	0.01	0.01	
Initial wt., lb	591	584	582	581	582	13	0.98	0.61	0.75
Final wt., lb	1275	1273	1185	1304	1244	24	0.02	0.69	0.33
DMI, lb/day	19.7	19.8	18.1	20.4	19.5	.5	0.03	0.92	0.32
ADG, lb/day	3.35	3.38	2.95	3.54	3.24	.09	0.01	0.86	0.28
Feed conversion[a]	5.85	5.85	6.13	5.75	6.02	—	0.30	0.65	0.79
Fat depth, inches	.38	.51	.46	.46	.46	.05	0.42	0.41	0.25
Ribeye area, inches^2	17.4	17.1	16.3	16.4	16.8	.4	0.44	0.19	0.21
Marbling[b]	529	533	516	566	571	31	0.67	0.25	0.57

[a]Analyzed as gain to feed (ADG ÷DMI) which is the reciprocal of feed conversion
[b]Marbling score where small 50 = 550 and slight 50 = 450.

Sample collection and analysis

Feed ingredients were sampled weekly for DM determination, ground through a Wiley Mill (1-mm screen), and composited by month for analysis. Feed refusals were collected when necessary (minimum of weekly), dried in 60°C forced air oven for DM determination, composited by steer, and ground through a Wiley Mill (1-mm screen) for analysis. Composited feed ingredients and refusals were analyzed for P by a common procedure, alkalimetric ammonium molybdophosphate method.

Blood samples were collected initially and every 56 days thereafter as well as the day of slaughter. Blood was collected in heparinized tubes, transported to the laboratory on ice, centrifuged, and plasma separated. Plasma samples from calves fed 0.16 and 0.40% P from day 0, 56, 112, and 204 were transported to Michigan State University for analysis of osteocalcin concentration using an enzyme-linked immunosorbent assay according to manufacturer's instructions (Novo-Calcin®, Metra Biosystems, Inc., Mountain View, Calif.). Once osteocalcin analysis was complete, those samples were shipped back to Nebraska for plasma inorganic P analysis. Plasma samples from all days and treatments were analyzed for inorganic P using colorimetric procedures (no. 670; Sigma Diagnostics, St. Louis, Mo.).

Results

Based on DMI and P concentration in diets versus orts samples, P intake ranged from 14.2 to 35.5 grams/day. Gain and DMI were variable; however, feed conversion expressed as DMI/ADG was not different across P treatments (Table 2). Because of variable gains, final weights were also variable but did not increase linearly or quadratically as dietary P increased. Figure 1 depicts the

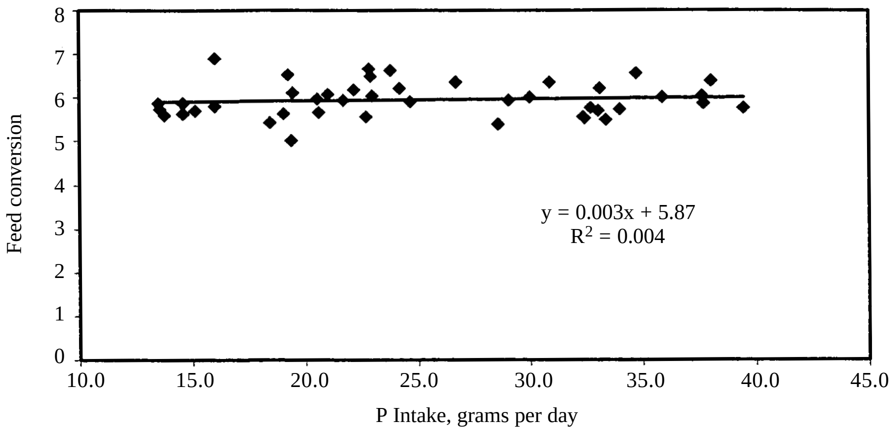

Figure 1. Scatterplot diagram for the relationship between feed conversion measured as DMI/ADG and P intake in grams per day. Each dot represents the average conversion for each steer averaged across the entire 204-day experiment.

Table 3. Effect of dietary P on phalanx and metacarpal bone ash from calf carcasses fed varying levels of P.

	Phosphorus, % of DM[a]						P-Value		
ITEM	.16	.22	.28	.34	.40	SE	F-test	Linear	Quad
Phalanx bone									
Total ash, g	27.8	29.3	27.8	30.9	27.6	1.1	0.19	0.72	0.23
Ash, g/100lb HCW	3.60	3.71	3.78	3.81	3.58	.09	0.46	0.87	0.08
Metacarpal bone									
Total ash, g	242	238	232	249	227	8	0.37	0.48	0.65
Ash, g/100lb HCW	31.5	30.2	31.6	30.8	29.5	.9	0.39	0.23	0.51

relationship between P intake in grams per day and feed conversion. The relationship in this experiment was poor (R^2 = 0.004). Carcass traits were also unaffected by P treatment suggesting that calves were all "finished." Fat depth, loin eye area, and marbling score are provided in Table 2.

The P requirement predicted by the NRC (1996) using actual performance of calves in this study was 18.7 grams/day or 8.4 lb over the 204-day finishing period. This calculation assumes maintenance requirement is 7.3 mg/lb of body weight (BW) and gain requirement is 3.9 grams of P per 100 grams retained protein. Based on retained energy calculations using ADG and average BW over the feeding period, retained protein was equal to 155 grams/day. Therefore, 6.7 grams/day of P for maintenance and 6.0 grams/day for gain is predicted as absorbed needs of the calves. NRC (1996) assumes a 68% absorption rate which means that dietary P requirements are 12.7 ÷ 0.68, or 18.7 grams/day. Despite using unique feed ingredients that are low in P such as brewers grits and corn bran, P intakes in this experiment were in the range of 76% to 190% of NRC-predicted requirements for P.

In these experiments, data suggest that current NRC recommendations are too high. The possible reasons are requirements for P are overestimated and/or the absorption coefficient is underestimated. The P maintenance requirements have been fairly well documented due to the ease of feeding cattle maintenance diets low in P. Only one study was found for estimating requirement for gain. The cattle used for whole-body analysis to define gain requirements were quite different than beef feedlot cattle fed today in terms of breed, body weight, age, and genetic potential. Furthermore, evidence exists that apparent P absorption is related to P intake because of changes in salivary flow of P. However, at low P intakes, true absorption of P from dietary ingredients may increase above 68%. Therefore, the two probable reasons for disagreement between the performance results in this study and the NRC-predicted requirements are inaccurate estimates of gain requirements and/or incorrect absorption estimates at low P intakes.

Phalanx bone ash expressed as total grams was not influenced by dietary P treatment (Table 3). Despite insignificant F-test, expressing phalanx ash as grams per 100 lb hot carcass weight tended (P = 0.08) to respond quadratically with percentage mineral being lowest for the 0.16% and 0.40% P treatments. Expressing mineral content of these bones as a percentage of carcasses should minimize any effects of bone size due to frame or BW differences. Metacarpal bone ash, expressed as either total grams or as a percentage of carcasses, was not influenced by dietary P treatment.

Based on the bone mineral results, calves were not resorbing P to meet their requirements for maintenance and gain. However, bones were collected at slaughter when P requirements are probably lowest relative to supply. Therefore, calves may have mobilized P from bone stores early in the feeding period when requirements were highest and replenished those stores once dietary supply was adequate to meet requirements. While bone mineral content is a critical assessment of P status of animals, osteocalcin in plasma from cattle on the lowest (0.16%) and highest (0.40%) P treatments was analyzed to gain insight into bone metabolism during the experiment. Osteocalcin is an indicator of bone turnover and/or formation. This protein is elevated in plasma during bone formation and turnover. Osteocalcin concentrations in plasma were similar on day 0, 56, 112, or 204 for calves on the 0.16% and 0.40% P treatments, suggesting that dietary P treatment did not alter bone turnover (Figure 2). Based on the osteocalcin and bone ash data, we conclude that dietary P was adequate to meet the requirements for maintenance and gain without compromising bone mineral accretion.

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Plasma inorganic P was measured every 56 days and did respond to P supplementation. Table 4 illustrates changes in plasma inorganic P due to dietary P treatment. When values are averaged for day 56, 112, 168, and 204, plasma P responded both quadratically (P < 0.01) and linearly (P < 0.01) with the lowest concentration in calves fed 0.16% P (5.71 mg/dL) compared to other dietary P treatments (average of 6.89 mg/dL). Numerous reports suggest that the threshold concentration is between 4.5 to 5.0 mg/dL. Based on average concentration from day 56 to 204 for the 0.16% P treatment, cattle were not deficient in P. However, because plasma P was 4.6 mg/dL on day 56 for the lowest level of P fed, those calves may have been marginally deficient. The plasma concentration for calves on the 0.16% treatment did increase past day 56 of the experiment which suggests that dietary supply relative to requirement was increasing. Plasma concentration of P can be a poor indicator of P status because bone resorption can maintain plasma concentrations above the lower threshold of 4.5 to 5.0 mg/dL. However, the data presented here suggest that calves fed the lowest level of P (0.16%) may have been marginally deficient at least during the first 56 days of the experiment.

Performance and bone data for the entire 204 days suggest calves were not deficient. However, performance and bone mineral data represent the entire 204 days and offer little insight when P requirements are presumably highest relative to supply. Plasma P data were quite variable in response to dietary treatment after the first 112 days. Interestingly, plasma collected on day 56 and day 112 from calves on the highest level of P (0.40%) contained less P than intermediate P treatments.

Dietary calcium was kept constant in this study at 0.62% of diet DM. Because % P varied from 0.16 to 0.40, calcium to phosphorus ratios ranged from 1.6 to 3.9. The ratios fed in this study should not have impacted performance or bone characteristics. Other research has demonstrated that cattle can tolerate Ca:P ratios between 1:1 and 7:1 assuming both calcium and phosphorus are included at or above requirements.

Phosphorus requirements for finishing calves are lower than previous estimates. Because requirements are less than 0.25% of diet DM, grain-based finishing diets contain adequate P to meet finishing cattle requirements for optimal performance and bone reserves. NRC-predicted requirements appear to be too high and should be modified. However, given the relatively large amount of P that grain-based finishing diets contain, requirements for feedlot cattle may be unimportant when using corn based diets. Supplementation of mineral P in finishing diets is an unnecessary economic and environmental cost for beef feedlot producers and should be discontinued.

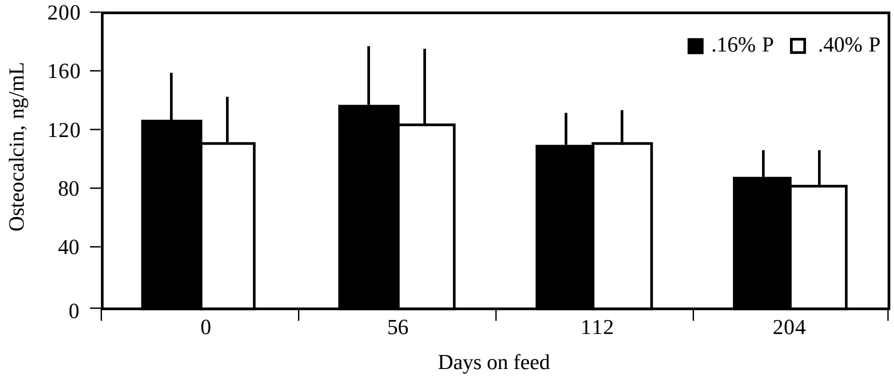

Figure 2. Osteocalcin (ng/mL) in plasma from calves fed either .16% or .40% P during the 204 day finishing experiment. Plasma was analyzed for day 0, 56, 112, and 204. Bars represent average of nine steers per level with standard deviation of the average osteocalcin.

Table 4. Effects of dietary P on plasma inorganic P (mg/dL)for calves fed varying levels of P from .16% to .40% of diet DM.

	Phosphorus, % of DM[a]						P-Value		
ITEM	0.16	0.22	0.28	0.34	0.40	SE	F-test	Linear	Quad
day 0	6.67	8.09	8.20	7.69	6.78	0.37	0.01	0.88	0.01
day 56	4.58	7.50	7.03	7.66	5.55	0.27	0.01	0.02	0.01
day 112	5.45	7.75	7.88	8.27	6.77	0.20	0.01	0.01	0.01
day 168	6.72	6.44	6.39	6.12	7.05	0.19	0.02	0.57	0.01
day 204	5.91	6.13	6.27	6.42	6.84	0.17	0.01	0.01	0.52
day 56 to day 204	5.71	6.95	6.89	7.19	6.55	0.12	0.01	0.01	0.01

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