Asian-Aust. J. Anim. Sci.
Vol. 21, No. 2 : 220 - 224
February 2008

www.ajas.info

Increasing Dietary Phosphorus Level for Finishing Yearling Holstein Steers*

A. M. Brokman and J. W. Lehmkuhler**

Department of Animal Sciences, University of Wisconsin, Madison, 53706, USA

ABSTRACT : The need for refining dietary nutrient levels and limited information regarding Holstein steer and phosphorus supplementation led to the objective of examining the response of removing supplemental dietary phosphorus from a corn-based finishing diet offered to yearling Holstein steers. Two groups of yearling Holstein steers were utilized to study responses of increasing dietary phosphorus level during the finishing period. In Exp. 1, 96 Holstein steers (419 kg) were blocked into four weight groups. Dietary treatments included no additional phosphorus (NDC) or the inclusion of dicalcium phosphate (DCP) to achieve 0.30% phosphorus (P) in the complete diet. Daily gain, DMI and carcass traits were not different ($p>0.05$). Overall gain efficiency was slightly lower for NDC ($p<0.05$). Exp. 2 consisted of 78 Holstein steers (491 kg) blocked into two weight groups. Steers were harvested on d 84 and 112 d on test with carcass data collected following a 48-h chill. No differences ($p>0.05$) were detected for DMI, ADG, or gain efficiency. No differences ($p>0.05$) were detected in carcass characteristics in this experiment. Percent bone ash, calcium, P, and bending moment also did not differ among treatments ($p>0.05$). Removing supplemental phosphorus in the feedlot diet did not produce adverse effects on steer performance, carcass, or rib bone characteristics for yearling Holstein steers. (**Key Words** : Carcass, Feedlot, Holstein, Phosphorus, Ruminant, Steer)

INTRODUCTION

Nutrient management, with an emphasis on phosphorus (P), has become more important for cattle producers. Utilization of grain-based co-products increases dietary phosphorus levels and subsequent intake which can impact nutrient management plans. Previous research suggests that the P requirement of finishing yearling beef steers (386 kg) is less than 0.14% of diet DM (Erickson et al., 1999). Erickson et al. (2002) further determined that the P requirement of beef calves (265 kg) was less than 0.16% of diet DM. These suggested levels are below that of a standard corn-based ration. Limited data exists with respect to Holstein steers regarding phosphorus requirements. Zinn et al. (2002) determined the optimal P level to be 0.35% for lightweight Holstein steer calves (average BW = 121 kg). These experiments were conducted to determine the response of yearling Holstein steers to the removal of supplemental dietary phosphorus from corn-based finishing diets.

* This work was supported by USDA CSREES HATCH.

** Corresponding Author: Jeff Lehmkuhler. Tel: +1-608-263-4300, Fax: +1-608-262-5175, E-mail: jwl@ansci.wisc.edu

Received July 7, 2007; Accepted September 29, 2007

MATERIALS AND METHODS

These experiments were conducted under approval of the Animal Care and Use Committee of the College of Agricultural and Life Sciences, University of Wisconsin, Madison.

Experiment 1 utilized 96 Holstein steers (419±38 kg) which were previously grazing cool-season grass:legume mixed pastures. Steers were stratified by weight and assigned to four weight blocks. Twelve steers were then assigned to one of eight pens within an open front concrete-floored finishing barn. Pens within block were randomly assigned to a treatment of no supplemental P (NDC) or supplemental P (DCP) in the form of dicalcium phosphate. Dicalcium phosphate was added to provide 0.30% P in the complete diet which was expected to mimic traditional dietary P levels utilized for growing/finishing diets. Steers were adapted to a high concentrate diet over a period of approximately 28 d prior to initiation of the trial. Diets (Table 1) were mixed daily and the fresh total mixed ration was offered once daily near 0800. Intakes were managed such that no orts were observed in the morning with DMI expected to be 95-98% of *ad libitum* consumption. On d 0, steers were implanted with 200 mg progesterone and 20 mg

Table 1. Diet composition (% DM) offered to Holstein steers to evaluate response to removing supplemental dietary phosphorus[1]

Item	Exp. 1		Exp. 2	
	DCP	NDC	DCP	NDC
Whole shelled corn	74.0	74.0	81.0	81.0
Corn silage	18.0	18.0	6.0	6.0
Alfalfa	-	-	5.0	5.0
Supplement				
Soybean meal	2.56	2.56	2.56	2.56
Corn	2.45	2.45	2.45	2.45
Limestone	1.03	1.30	1.03	1.30
Urea	0.26	0.26	0.26	0.26
Dicalcium phosphate	0.26	-	0.26	-
Salt	0.22	0.22	0.22	0.22
Trace mineral[2]	0.04	0.04	0.04	0.04
Vitamins A, D, E[3]	0.04	0.04	0.04	0.04
Vitamin E[4]	0.04	0.04	0.04	0.04
Rumensin[5]	0.15	0.15	0.15	0.15
Tylan[6]	0.15	0.15	0.15	0.15
Choice white grease	0.12	0.12	0.12	0.12
Diet composition				
No. of samples analyzed[7]	11	11	7	7
DM (%)	67.6 (1.4)	68.1 (1.8)	74.5 (3.2)	73.2 (1.8)
CP (%)	11.0 (0.4)	11.1 (0.4)	12.3 (0.2)	12.6 (0.2)
Phosphorus (%)	0.36 (0.26)	0.31 (0.12)	0.34 (0.08)	0.30 (0.13)
Calcium (%)	0.74 (0.08)	0.65 (0.08)	0.76 (0.05)	0.77 (0.05)

[1] DCP = Supplemental phosphorus in the form of dicalcium phosphate, NDC = No supplemental phosphorus.
[2] Trace mineral mix contains 24.9% Ca, 6.0% S, 60,000 ppm Zn, 40,000 ppm Mn, 6,000 ppm Cu, 200 ppm Co, 1,000 ppm I, 200 ppm Se, 10,000 ppm Fe.
[3] Premix contains 1,200,000 IU vitamin A, 400,000 IU vitamin D, 1,600 IU vitamin E.
[4] Premix contains 20,000 IU vitamin E. [5] Premix contains 14.3 g/kg monensin.
[6] Premix contains 6.05 g/kg tylosin. [7] Standard deviation in parenthesis.

estradiol benzoate (Synovex S®, Fort Dodge, Overland Park, KS). Initial and final weights were based on weights collected on two consecutive days obtained immediately prior to feed delivery. Single-day intermittent weights were recorded every 28 d prior to feeding. Thirty-four steers from the heaviest weight block and half from the second heaviest weight block were harvested after 126 d, and the remaining steers were harvested after 137 d on test at a USDA inspected commercial packing facility. Carcass traits were collected by trained individuals following a 24-h chill and included hot carcass weight, backfat, longissimus muscle area, kidney, pelvic, and heart fat (KPH), and marbling score. USDA Yield Grade was calculated as Yield Grade = 2.5+(hot carcass weight, lb×0.0038)+(backfat, inches×2.5)+(percent kidney, pelvic and heart fat×0.2)-(longissimus muscle area, square inches×0.32).

Experiment 2 included 78 Holstein steers (491±39 kg) that had previously grazed cool-season grass:legume mixed pastures and were blocked by weight into a light and heavy weight group. Steers were then assigned to one of eight pens. Pens within block were randomly assigned to one of two treatments with two replicates per block. Management and diets offered were similar to Exp. 1. However, low corn silage quality was affecting intake primarily due to chop length and dryness resulting in sorting and refusal. Corn silage inclusion was reduced and alfalfa haylage included to ensure adequate roughage consumption. On day 0, steers were implanted with 200 mg progesterone and 20 mg estradiol benzoate (Synovex S®, Fort Dodge, Overland Park, KS). Heavy steers were harvested at a commercial processing plant after 84 d and light steers following 112 d on trial to avoid heavy carcass discounts. Carcass data were collected by trained individuals following a 48-h chill. Due to removal of the kidneys and visceral fat immediately after slaughter, USDA yield grades could not be calculated as no estimate of kidney, pelvic and heart fat could be determined. A ventral portion of the sixth rib bone measuring ~10.2-15.2 cm was collected from 33 steers in the second harvest group, sealed in plastic bags, and stored frozen.

Sample collection and analysis

Samples of diets (NDC and DCP) were collected weekly and frozen. All samples were dried in a forced-air oven at 55°C and then ground through a 1-mm screen using a cross-beater mill (Retsch SM 100, F. Kurt Retsch GmbH and Co. K. G, Germany). Ground samples were composited on a weight basis to provide diet representation at approximately two week intervals. Composited diets were analyzed in duplicate for DM (AOAC, 1990). Phosphate P was determined colormetrically by a molybdovanadate assay (AOAC, 1980) using a Stasar II spectrophotometer (Gilford Instrument Laboratories, Inc., Oberlin, Ohio).

Table 2. Performance characteristics of Exp. 1 and 2 finishing Holstein steers receiving supplemental (DCP) or no supplemental (NDC) P

Item	Exp. 1			Exp. 2		
	NDC	DCP	SE	NDC	DCP	SE
Pens	8	8		8	8	
Initial BW (kg)	420	418	4.4	498	493	4.9
Final BW (kg)	606	600	14.9	656	651	16.9
DMI (kg/d)	10.5	10.7	0.36	11.1	11.1	0.13
ADG (kg)	1.51	1.43	0.043	1.63	1.64	0.037
Phosphorus intake (g/d)	31.3[b]	37.2[a]	0.89	31.3[b]	35.8[a]	0.91
GE[1]	0.15[a]	0.14[b]	0.002	0.15	0.15	0.005

[a, b, c] Means with unlike superscripts differ ($p<0.05$). [1] GE = kg live weight gain per kg of dry matter intake

Table 3. Carcass data for yearling Holstein steers receiving corn-based diets without (NDC) or with (DCP) supplemental phosphorus for Experiments 1 and 2

	Exp. 1			Exp. 2		
	NDC	DCP	SE	NDC	DCP	SE
HCWT[a] (kg)	360	357	4.3	383	379	2.2
Backfat (cm)	0.54	0.49	0.038	0.56	0.51	0.041
LMA[2] (cm)[b]	72.9	73.2	0.849	80.6	79.7	2.08
Yield grade	2.8	2.7	0.05	NA[c]	NA	-
Marbling score[d]	595	583	21.9	584	594	27.1

No differences were detected ($p>0.05$).
[a] HCWT = Hot carcass weight. [b] LMA = Longissimus muscle area. [c] NA = Not available. [d] Marbling score where 400 = Slight 0, 500 = Small 0, etc.

Calcium (Ca) was analyzed using atomic absorption spectrophotometry (Perkin-Elmer 2280, Norwalk, CT). Diet N concentrations were determined using thermal conductivity (LECO FP 528 Nitrogen Analyzer, Leco Instruments, Inc., St. Joseph, MI) while NDF and ADF with α-amylase and Na_2SO_3 were determined following ANKOM procedures (ANKOM[200] Fiber Analyzer, ANKOM Technology Corporation, Fairport, NY). Ash content was measured following incineration at 500°C for 24 h in a muffle furnace.

To determine bending moment, percent ash, P and Ca content in rib bones, samples were partially thawed and cleaned of extraneous tissue. Care was taken not to scratch the cortical surface of the bones. The bones were kept hydrated with deionized water during dissection and testing. Mechanical properties were tested by a three-point bending test using an Instron 5566 instrument (Canton, MA). Load was applied to the midpoint of the bone specimen at a constant rate of 5 mm/s. The load deformation curve generated during each test was used to calculate bending moment. Bending moment (kg-cm) was calculated using yield load (kgf) according to methods described by Crenshaw et al. (1981).

After the three-point yield test was completed, bones were extracted in a Soxhlet apparatus in ethyl ether for 14 d. Bones were removed from the apparatus, allowed to air dry for 12 h, and then dried at 100°C for 24 h. The fat-free dry bone weight was determined and extracted bones were ashed at 750°C for 24 h. The dry fat-free ash percentage was calculated as g of ash/dry fat-free bone. Bone ash P and Ca content was determined as described above.

Statistics

Data were analyzed separately for each experiment as a randomized complete block design. Data analyses for performance and carcass traits were performed using the MIXED Procedure of SAS Release 8.0 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Period was included in the model as a fixed effect. Block was included as a random effect with block by treatment interaction included as a repeated effect. Spatial power was used to define covariance structure. Bone analyses used individual sample as the experimental unit using the GLM Procedure of SAS. The model included pen and the interaction of pen by treatment. Means were separated using the LSMEANS statement.

RESULTS AND DISCUSSION

Initial weights for treatments were similar for both experiments by design (Table 2). Reducing the dietary phosphorus had minimal impact on animal performance. Daily gain and DMI were not affected ($p>0.05$) in either experiment. Overall gain efficiency was slightly lower for DCP in comparison to NDC in Exp. 1. This small improvement in efficiency is likely a result of experimental error as no differences were observed in the second experiment. Erickson et al. (2002) suggested that the NRC (2000) recommended dietary P levels for finishing calves were above actual dietary P requirements and supplementation of grain-based diets was not necessary to maintain performance. Carcass variables measured are reported in Table 3. Carcass traits were not altered by the removal of dietary phosphorus ($p>0.05$). Erickson et al.

Table 4. Sixth rib bone characteristics of Holstein steers fed diets with (DCP) or without (NDC) supplemental dicalcium phosphate during Experiment 2

Item	NDC	DCP	SE	P
No. bone samples	18	15		
Ash (%)	62.1	62.0	0.44	0.88
Calcium (mg/g ash)	395	392	1.8	0.24
Phosphorus (mg/g ash)	172	173	2.2	0.60
Bending moment (kg cm)	222	210	16.4	0.52

No differences were detected (p>0.05).

(1999) observed that carcass characteristics (backfat, hot carcass weight, marbling score) of steers initially weighing 385 kg and finishing at 567 kg were not adversely affected by a dietary P concentration of 0.14%.

The treatment diets averaged 68% DM and near 74% DM for Exp. 1 and 2. Variation in diet composition was noted in DM, CP, and P with differences between periods being observed which is attributed to daily variation of the basal ingredients and changes in nutrient density of the basal ingredients. Dry, whole shelled corn was purchased from a local grain elevator and delivered every 7-10 days which increased variability of diet nutrient density but was necessary due to grain storage limitations. Crude protein content of the diets also differed among periods in Exp. 1 ranging from 10.6% to 11.6% with Period III having the lowest dietary crude protein levels in both treatment diets. These levels were below that targeted and are due to lower protein levels in the corn utilized in these trials.

By design, DCP diets contained higher levels of P ($p<0.05$) in both experiments. Dietary P content varied among periods in Exp. 1 and 2 and ranged from 2.94 to 3.85 mg/g and 2.75 to 3.41 mg/g for Exp. 1 and 2, respectively. The lack of difference in performance and carcass characteristics with the removal of supplemental dietary phosphorus in these yearling Holstein steers agrees with recent findings for finishing beef steers and heifers (Erickson et al., 1999; 2002). This can be explained by comparing the estimated P requirement to the amount consumed. Using an average bodyweight over the finishing period of 535 kg and ADG of 1.53 kg, a daily P requirement was calculated. The NRC (2000) assumes a P maintenance and gain requirement of 16 mg/kg BW and 3.9 g of P/100 g of retained protein, respectively. Net protein was estimated to be 156 g/d and was in turn interpreted as the quantity of retained protein using the retained energy equations. Predicted P for maintenance was calculated to be 8.6 g/d and that required for gain at 6.1 g/d for 14.7 g/d total daily P needs. The NRC (2000) uses a 68% absorption coefficient resulting in a predicted dietary P requirement of 21.6 g/d. Calculated P intake based on observed intakes and diet analyses for NDC and DCP steers was 31.8 and 36.3 g/d or 132 and 140% of NRC (2000) recommended levels for Exp. 1 and Exp. 2 steers, respectively. Additionally, the P excreted by DCP is estimated to be 26% greater than NDC at 21.6 g/d versus 17.1 g/d P. Many states have implemented policies that restrict manure application rates based on both nitrogen and phosphorus with respect to soil nutrient tests, manure nutrient content and crop removal rates for concentrated animal feeding operations. In situations in which application rates are restricted due to high soil-test P levels, increasing manure P excretion results in a need for a larger land base to apply manure resulting in increased production costs.

Diet calcium intake levels ranged between 68.0 and 82.7 g/d diet DM. Dietary Ca:P ratios varied from 2:1 to 2.7:1 for these diets. Ricketts et al. (1970) concluded that performance of Holstein calves was adversely affected at a Ca:P ratio of 8:1. Wise et al. (1963) concluded that the optimum range of ratios for 114 kg calves was 1:1 to 7:1. The Ca:P ratio was within a normal range and was not considered as a confounding factor in performance or carcass characteristics.

Dietary treatment had no affect on sixth rib bone characteristics ($p>0.10$) as shown in Table 4. Erickson and co-workers (1999) reported that peak force values for rib bones were unaffected by P levels of 0.14% and 0.34%, again in agreement with our findings. Bieghle et al. (1994) determined the Ca, P, and percent ash in rib bones from 33 clinically normal steers, heifers, and cows of different breeds and ages which consumed alfalfa, grass hay, and corn. Percent ash for cattle 19 to 36 months was determined from analyses of three biopsies of ribs 9, 10, 11, and 12. The percent ash values near 62% reported in this study are similar to the values of 59.9±0.1 reported by Bieghle et al. (1994). Bieghle et al. (1994) also reported P and Ca of bone ash as 182±0.9 and 322±1.4 (mg/g ash), respectively, for cattle 19-36 months of age. Phosphorus content of ash was similar for the current study and believed to be within normal range based upon the previous literature. However, bone Ca content and Ca:P ratio from these yearling Holstein steers was greater than that reported by Bieghle et al. (1994). The Ca:P ratio of bone was 1.8:1 for cattle 19-36 months in the work performed by Bieghle et al. (1994) and 2.3:1 in this trial. Yearling Holstein steer rib bone values were also similar to values reported by Williams et al. (1990) in heifers and Wu et al. (2001) in dairy cattle. Therefore, the bone ash Ca concentrations and Ca:P ratios observed are within normal range and were not affected by dietary treatment.

It is acknowledged that the narrow dietary differences in P concentrations in these trials limits extrapolation of results. However, the corn-based finishing diets fed during these experiments provided P at levels greater than the recommended levels and the need for additional dietary phosphorus is not warranted when DMI and performance are near levels observed in these trials.

IMPLICATIONS

Performance and carcass results from this study agree with previous research conducted with beef cattle indicating that typical corn-based finishing diets provide adequate P for yearling Holstein steers with P intakes being greater than that recommended by the current NRC. Consideration of increasing dietary phosphorus concentration should be included in nutrient management plan and the costs associated with compliance of the nutrient management must be considered in assessing the value of a high P feedstuff. Alternatively, investigation into lower P containing feedstuffs is necessary to provide P at dietary levels closer to finishing steer maintenance and growth requirements as a strategy to reduce manure P concentrations and soil P accumulation.

REFERENCES

Bieghle, D. E., P. A. Boyazoglu, R. W. Hemken and P. A. Serumaga-Zake. 1994. Determination of calcium, phosphorus, and magnesium values in rib bones from clinically normal cattle. Am. J. Vet. Res. 55:85-89.

Bortolussi, G., J. H. Ternouth and N. P. McMeniman. 1999. Phosphorus repletion of cattle previously exposed to dietary nitrogen and phosphorus deficiencies. Aust. J. Agric. Res. 50:93-99.

Crenshaw, T. D., E. R. Peo, Jr., A. J. Lewis and B. D. Moser. 1981. Bone strength as a trait for assessing mineralization in swine: A critical review of techniques involved. J. Anim. Sci. 53:827-835.

Erickson, G. E., T. J. Klopfenstein, C. T. Milton, D. Brink, M. W. Orth and K. M. Whittet. 2002. Phosphorus requirement of finishing feedlot calves. J. Anim. Sci. 80:1690-1695.

Erickson, G. E., T. J. Klopfenstein, C. T. Milton, D. Hanson and C. Calkins. 1999. Effect of dietary phosphorus on finishing steer performance, bone status, and carcass maturity. J. Anim. Sci. 77:2832-2836.

Hoey, W. A., G. M. Murphy and R. J. W. Garner. 1982. Whole body composition of heifers in relation to phosphorus status with particular reference to the skeleton. J. Agric. Sci. Camb. 98:31-37.

Judkins, M. B., J. D. Wallace and E. E. Parker. 1982. Rib bone phosphorus levels in range cows. Proc. Ann. Meet. Am. Soc. Anim. Sci. West. Sect. 33:9-11.

Little, D. A. 1972. Bone biopsy in cattle and sheep for studies of phosphorus status. Aust. Vet. J. 48:668-670.

National Research Council. 2000. Nutrient Requirements of Beef Cattle: Update 2000 of 7th rev. ed. National Academy Press, Washington, DC.

Potash and Phosphorus Institute, PPI. 2001. Soil test levels in North America. Summary update. Tech. Bull. 2001-1. PPI/PPIC/FAR. Norcross, GA.

Ricketts, R. E., J. R. Campbell, E. E. Weinman and M. E. Tumbleson. 1970. Effect of three calcium:phosphorus ratios on performance of growing Holstein steers. J. Dairy Sci. 53:898-891.

Williams, S. N., L. A. Lawrence, L. R. McDowell, A. C. Warnick and N. S. Wilkinson. 1990. Dietary phosphorus concentrations related to breaking load and chemical bone properties in heifers. J. Dairy Sci. 73:1100-1106.

Wise, M. B., A. L. Ordoveza and E. R. Barrick. 1963. Influence of variations in dietary calcium:phosphorus ratio on performance and blood constituents of calves. J. Nutr. 79:79-84.

Wu, Z., L. D. Satter, A. J. Blohowiak, R. H. Stauffacher and J. H. Wilson. 2001. Milk production, estimated phosphorus excretion, and bone characteristics of dairy cows fed different amounts of phosphorus for two or three years. J. Dairy Sci. 84:1738-1748.

Zinn, R. A., M. Machado, A. Plascencia, S. A. Rodriguez, N. Torrentera and R. A. Ware. 2002. Dietary phosphorus requiremetns of calf-fed Holstein steers during the early growing period. J. Anim. Sci. 80: Supp. 2.