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Exploring How Maternal Phosphorus Status Affects Calf Growth and Performance

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Cover Page Footnote

Elizabeth Lafferty is a May 2021 honors program graduate with a major in Animal Sciences with a preprofessional concentration. Beth Kegley, the faculty mentor, is a Professor in the Department of Animal Science. Brittni Littlejohn is an Assistant Professor in the Department of Animal Science. Jeremy Powell is a Professor in the Department of Animal Science.

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Meet the Student-Author

Elizabeth Lafferty

I am originally from Rosston, Arkansas, where I grew up on a small cattle farm helping out where my dad would let me. From these experiences, I developed a passion for large animals. I began my undergraduate career at the University of Arkansas as a major in Animal Sciences with a preprofessional concentration. I was a member of the pre-vet club and an active volunteer at local animal shelters throughout my college years. I have also had the opportunity to gain hands-on experiences through my research and work as a veterinary technician. In February of 2020, I began my research on beef nutrition. I graduated Cum Laude and plan to obtain my doctor of veterinary medicine degree. My time at the University of Arkansas has been made possible by many individuals. I would like to thank Dr. Beth Kegley for serving as my honors mentor and for her confidence in me and continual support throughout this project. I also would like to thank Dr. Jeremy Powell and Dr. Brittni Littlejohn for serving on my thesis committee and for their help throughout this process. To my family, thank you for your continual encouragement and support while achieving my goals.

Elizabeth stands next to the centrifuge that is used to process blood samples. It was generously funded by the Honors Program Equipment Grant.

Research at a Glance

- Phosphorus is an important mineral in beef cattle nutrition and is thought to be linked to calf growth and performance.
- Data did not show any negative effects of supplementing excess phosphorus in free-choice minerals but was not advantageous in regard to calf growth or performance.
- Producers in the area where pastures have been fertilized with livestock manure could purchase minerals with or without phosphorus.

Exploring How Maternal Phosphorus Status Affects Calf Growth and Performance

Elizabeth Lafferty, Beth Kegley,† Brittni Littlejohn,§ and Jeremy Powell‡*

Abstract

Phosphorus is an important component of bodily functions and is critical for adequate growth and development. This experiment evaluated the effect of maternal phosphorus intake on the growth and health of the calves. Treatments were 1) a free-choice mineral containing no supplemental P or 2) a free-choice mineral with 4% supplemental phosphorus. Primiparous, or pregnant for the first time, crossbred Angus beef cows (n = 36) were stratified by body weight and pregnancy status (bred by artificial insemination or natural service) then assigned to pasture groups (4 groups, 2/treatment, 9 heifers/group). These bred heifers had been receiving these same dietary treatments from 30 days after weaning until confirmation of pregnancy. Eighteen bred heifers from each treatment were selected randomly to continue into this experiment. At calving, colostrum and blood samples were collected from a subset of 12 heifers/treatment (6/group). Body weights were obtained for all cattle. Data were analyzed using the MIXED procedure of SAS. Cows grazed mixed grass pastures; monthly forage samples ranged from 0.28% to 0.36% P. There were no differences ($P > 0.10$) for cow body weight during gestation, calf birth weight, or calf weight at an average age of 21 days. There were also no differences ($P > 0.10$) in colostrum components (fat, protein, lactose, and IgG) or in the serum IgG or plasma mineral concentrations for both cows and calves 48 hours after birth. All calves were sampled at approximately 21 days of age, and there were no treatment differences ($P > 0.10$) in serum IgG concentrations. There were no benefits to supplementing gestating heifers with phosphorus when they grazed pasture with a history of fertilization with livestock manure.

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Introduction

The beef cattle industry is always looking for ways to increase gain performance and improve the fertility of developing heifers and cows. The goal of this study is to evaluate phosphorus supplementation on primiparous (or pregnant for the first time) cows and the effect on colostrum quality, calf growth, performance, and health. Colostrum is one of the main sources of minerals for newborn calves, especially calcium and phosphorus (Kume and Tanabe, 1993). In dairy calves, colostrum with high immunoglobulin concentrations led to weight gain in calves from birth to four days old, while low immunoglobulin concentrations led to weight loss (Nocek et al., 1984). If the same rationale can be applied to beef cattle, high immunoglobulin concentrations will increase weight gain during the first 4 days of life. Similar to immunoglobulin concentrations, colostrum with greater mineral content, phosphorus included, led to a decrease in calf mortality (Salih et al., 1987). Therefore, an increase in minerals, including phosphorus, could lead to greater immunoglobulin concentrations and, in return, an improved immune response and increased calf survival rate.

While phosphorus could lead to improved immune response and increased calf survival rate, phosphorus supplements may have a negative impact on the environment. When over-supplementation occurs, many nutrients are passed into the environment through manure and then into water sources. This process is unsustainable as it can ruin water sources for future farming and/or cities. Such is stated by researchers from the University of Nebraska's Department of Animal Science, "removal of phosphorus supplements are important nutritional management options to help feedlots become more environmentally sustainable" (Klopfenstein and Erickson, 2002). As phosphorus is introduced to water systems, algae begin to grow at an increased rate. Many water ecosystems are not readily prepared to counteract the increased growth rates of algae, and it leads to decreased oxygen levels in the water, thus lowering the water quality and the amount of aquatic life that can be supported in that body of water. Therefore, this experiment investigated the effect of maternal phosphorus intake on the growth and health of the calves.

Materials and Methods

The following procedures were reviewed and approved by the University of Arkansas Animal Care and Use Committee (IACUC) before the project began. For this experiment, heifers (n = 64) weaned in May 2019 from the University of Arkansas System Division of Agriculture's Experiment Station Beef Cow/Calf Research Unit near Fayetteville were used. Approximately 30 days after weaning, heifers were weighed, stratified by body weight, and divided randomly into 8 groups (8 heifers/group). Each group was then assigned randomly to one of two dietary treatments (Table 1): 1) supplemented with phosphorus (4% in a free-choice-mineral mix) and 2) not supplemented with phosphorus in an otherwise identical free-choice-mineral mix formulated to meet all other mineral and vitamin requirements. Heifers were allowed to graze 8 mixed grass pastures (2.4 ha each) and received supplemental soybean hulls (0.5% of body weight each day adjusted after each weigh day). Soil phosphorus concentrations in pastures ranged from 130 to 259 mg/kg of soil.

In November of 2019, heifers were synchronized and bred by artificial insemination (AI), followed by natural service. Data were collected by H. Hilfiker for her University of Arkansas Honors research project at that time and have been previously reported (Hilfiker, 2020). In February 2020, a portion of the heifers with a confirmed pregnancy continued onto this trial. Bred heifers were stratified by body weight and reassigned randomly within treatment to 1 of 2 groups (9 heifers/group). Each treat-

Table 1. Composition of free-choice mineral mixes used to deliver dietary treatments.

Ingredient	Control	Supplemental P
Calcium, %	20	20
Phosphorus, %	0	4
Salt, %	24 to 26	24 to 26
Magnesium, %	0.2	0.2
Potassium, %	0.1	0.1
Copper, mg/kg	2,500	2,500
Selenium, mg.kg	26	26
Zinc, mg/kg	10,000	10,000
Vitamin A, IU/kg	440,000	440,000
Vitamin D3, IU/kg	22,000	22,000
Vitamin E, IU/kg	22	22

ment had a similar number of heifers, 18, confirmed pregnant by either artificial insemination or natural service, and had similar average body weight. Pregnant heifers continued receiving the same dietary treatment to which they were originally assigned. Available forage, hay (when offered), and soy hulls were sampled monthly.

The heifers began calving in August of 2020. Two weeks prior to the anticipated calving date, heifers were moved nearer the working facility to smaller (0.45 ha) grass lots. A subset of heifers (12 heifers/treatment, 6 heifers/group) were selected for additional sample collection. At the time of birth, a pooled colostrum sample from all four quarters was collected from each of these heifers. The colostrum samples were evaluated for the following: 1) colostrum phosphorus concentrations and other minerals, 2) colostrum immunoglobulin G (IgG) concentrations, and 3) percentages of fat, protein, lactose, ash, and solids not fat, and a somatic cell count. Subsamples of colostrum were frozen at -20 °C for later mineral and immunoglobulin analyses, and a subsample for proximate analysis was placed in a sample vial provided by the commercial lab that contained a pellet of preservative, mixed thoroughly, and stored at room temperature until shipped to the Mid-South Dairy Records Laboratory (Springfield, Missouri).

At 48 hours after birth, blood samples were collected from these cows and calves by jugular venipuncture. Blood for the serum to be used to evaluate IgG concentrations was collected in vacuum tubes with a clot-activating compound. Blood for plasma mineral determinations was collected in vacuum tubes manufactured for trace mineral determinations. Anticoagulated whole blood samples for complete blood count analysis were collected in vacuum tubes containing EDTA. Blood was refrigerated until centrifuged at 2,100 × g for 20 min, then serum and plasma were stored frozen at -20 °C. Whole blood was refrigerated for up to 48 hours before being evaluated for white and red blood cell values using an automated analyzer (HemaVet HV950; Drew Scientific, Miami Lakes, Florida).

All calves were weighed and bled at approximately 21 days of age. There were three sampling dates: 14 September, 2 October, and 21 October, and actual calf age ranged from 15 to 36 days of age. Blood was handled similarly, and serum was used to determine IgG concentrations.

Forage and supplement samples were composited and dried in a forced-air oven, then ground using a Wiley Mill (Thomas Scientific, Swedesboro, New Jersey) through a 1-mm screen. Mineral mix samples were dried but not ground. All samples were prepared for mineral analysis by standard procedures and analyzed by inductively coupled plasma spectroscopy (Model 3560, Applied Research Laboratory, Sunland, California) at the University of Arkansas System Division of Agriculture's Altheimer Laboratory (Fayetteville, Arkansas).

Colostrum and serum immunoglobulin concentrations were determined by commercial anti-bovine IgG radial immunodiffusion kits (Immunology Consultants Laboratory, Inc., Portland, Oregon). The intra-assay CV was 7.3%, and the inter-assay CV was 2.5%.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, North Carolina) with pen set as the experimental unit. Compound symmetry was specified as the covariance structure. For heifer data, treatment was the only fixed effect, and replicate was the random effect. For calf growth performance data, treatment was the only fixed effect, and replicate and sex were specified as random effects. Kenward Rogers was specified as the degrees of freedom selection method in the mixed procedure. Mineral intake data were analyzed as a repeated measure, and the model included treatment, period, and the treatment by period interaction. Non-normal data were log-transformed before further statistical analysis to improve normality. For the purpose of this study, $P < 0.1$ was considered significant.

Results and Discussion

In this study, both groups of heifers grazed similar pastures and were offered identical rations of soyhull pellets. Each group's treatment of 0% or 4% phosphorus was delivered via free-choice mineral. The mineral offered was designed for a 113 g/day intake. Of this offered amount, each heifer consumed approximately 100 g/day. There was no effect ($P = 0.46$) of treatment on average mineral intake, with control averaging 99 g/day and supplemental phosphorus averaging 90 g/day. However, there was a treatment × period interaction ($P = 0.01$; Fig. 1) for mineral intake with the greatest intake of mineral (121 g/day) by the control heifers in the final period of the trial.

First-calf heifers that are approximately 464 kg require 0.13% to 0.18% of their diet to contain phosphorus (dry matter intake) throughout gestation and lactation (Nutrient Requirement Tables, 2018). The phosphorus concentrations of the mineral provided to both treatments were well over the minimum requirements for gestating and lactating first-calf heifers (Table 2). The control group was offered 0.28%, while the phosphorus group was offered 3.44% phosphorus in the mineral supplements. In addition to the mineral mix, the forages, hay, and soyhull pellets contributed to phosphorus concentrations ensuring that heifers were well over their minimum requirements. The majority of the heifers' diet was supplied as forage. Each month of forage had phosphorus concentrations greater than the minimum requirements for each heifer.

Calves were weighed at birth and at approximately 21 days postpartum to evaluate calf performance and average daily gain (ADG). Actual calf ages ranged from 15 to 36 days of age. The expected ADG for fall calves is 1.4 kg/day (UA-

DA-CES, 2016). Calves from each treatment performed similarly.

Normal protein percentages of colostrum can range from 16.8% immediately following birth to 6.3% at 12 hours after calving. Percentages of fat composition are less volatile and change more slowly. For fat, normal ranges are from 6.7% to 4.4%. Normal lactose concentrations are 2.9% to 3.9% (Puppel et al., 2019). Data for fat, protein, and lactose percentages (Table 3) were within the normal ranges as defined above. There were no differences between the control and the phosphorus group for percentages of fat ($P = 0.58$), protein ($P = 0.23$), and lactose ($P = 0.20$). Normal IgG concentrations for colostrum should be about 48 mg/ml (Sellers, 2001). Cows on each treatment had normal and nonsignificant results ($P = 0.38$).

Normal colostrum phosphorus percentages are 0.235% (Puppel et al., 2019). The recorded phosphorus concentrations for both the control and the phosphorus group are below the presumed normal concentration with no significant difference (Table 4). However, there was a tendency ($P = 0.11$) for the phosphorus supplemented heifers to have greater phosphorus in their colostrum at the time of calving. Colostrum calcium concentrations varied between the two treatments ($P = 0.02$). Normal percentages of calcium in colostrum are 0.256 (Puppel et al., 2019). The control and the phosphorus treatments were both below this average. Excess P in the body interferes with calcium metabolism and could cause these lower than average per-

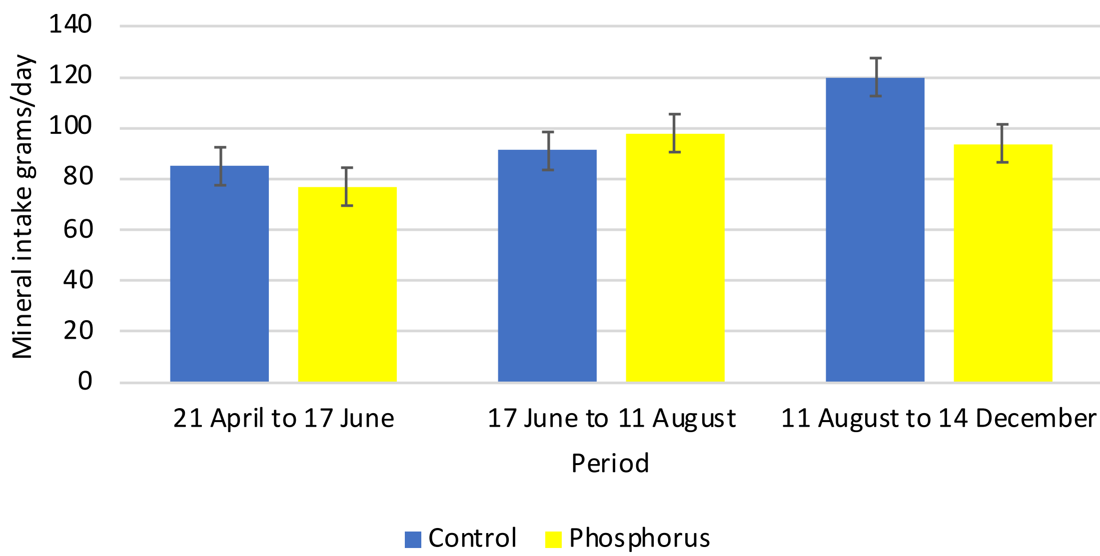

Fig. 1. Effect of phosphorus in the mineral offered on daily mineral intake as estimated by disappearance from the mineral feeders averaged across each period ($n = 4$, 2 groups/treatment; $P = 0.46$ for treatment and $P = 0.01$ for the treatment by period interaction).

Table 2. Mineral composition (DM basis) of minerals mixes, forage, hay, and soyhull pellets.

Feed	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu
	--------------------------------		(%)		--------------------------------		----------------	(mg/kg)	----------------	
Mineral with no added P	0.28	0.48	16.70	0.37	1.38	7.22	3,427	1,061	13,165	5,308
Mineral with supplemental P	3.44	0.30	16.36	0.24	1.07	7.11	6,213	1,091	8,197	4,760
Hay	0.36	1.58	0.49	0.38	0.14	0.03	72	162	57	6
Forage										
March, 2020	0.34	2.39	0.42	0.19	0.22	0.01	116	114	44	7
April, 2020	0.36	2.32	0.43	0.18	0.22	0.004	319	108	51	8
June, 2020	0.33	2.14	0.38	0.18	0.17	0.017	166	110	41	7
July, 2020	0.30	1.83	0.46	0.20	0.18	0.010	113	92	41	6
August, 2020	0.29	2.00	0.38	0.18	0.24	0.008	127	139	62	7
September, 2020	0.32	2.12	0.44	0.21	0.24	0.010	99	90	58	6
October, 2020	0.28	2.11	0.51	0.23	0.20	0.013	107	74	46	5
Soyhull Pellets	0.10	1.22	0.64	0.24	0.10	16.24	424	14	37	5

centages of calcium in the colostrum (Kidney Health Australia, 2017). However, it is unknown why the phosphorus-supplemented heifers colostrum calcium was greater than the control heifers.

The complete blood counts for the heifers were within normal limits and had no differences between heifers on the control and the phosphorus treatments (data not shown). All blood cell data for calves were within normal limits (data not shown), except for the percentage of red cell distribution width (RDW). The calves from the control treatment had RDW of 23.86%, while calves from the phosphorus treatment had 24.74% ($P = 0.04$). Varying data within the red cell distribution width can be caused by underlying anemia or iron deficiency, which can be explained due to collecting blood samples from young calves who have not yet received full passive immunity from colostrum [RDW (red CELL distribution WIDTH): Medlineplus medical test, 2020)]. Because no samples were taken later, it is unknown whether this difference remained; however, no calves were ever observed to be clinically anemic.

Normal IgG values in calves are 12.3 to 29.1 mg/mL at 24 hours after calving (Godden et al., 2009). At or before 12 hours postpartum, the calves from the control treatment and the phosphorus treatment had values within the parameters set above. The IgG concentrations of the calves from the control treatment and the phosphorus treatment at birth (Table 5) were similar ($P = 0.88$) and the IgG concentrations at day 21 had no significant difference ($P = 0.66$).

Normal cow plasma mineral concentrations of phosphorus are 5.6 mg/dL (McAdam and O'Dell, 1982). The heifers on the control treatment had 6.88 mg/dL of phosphorus, and heifers on the phosphorus treatment had 7.06 mg/dL. Heifers on both treatments had concentrations greater than average for phosphorus, likely because of the increased phosphorus concentrations in the pastures they were allowed to graze. While both concentrations were elevated, the heifers on the two treatments had no difference in phosphorus concentrations ($P = 0.62$). It is important to note that plasma magnesium concentrations for the heifers were different ($P = 0.02$). Heifers on the control treatment had magnesium concentrations at 2.58 mg/dL, and heifers on the phosphorus treatment had concentrations of 2.42 mg/dL. Normal magnesium concentrations are 2.01 mg/dL (McAdam and O'Dell, 1982). In general, as phosphorus concentrations in the diet rise, magnesium

Table 3. Effect of phosphorus concentration in the mineral offered to heifers on colostrum content.

Colostrum Components	Control	Phosphorus	Standard Error	*P*-value
Fat, %	5.05	5.93	--[a]	0.58
Protein, %	11.49	12.70	0.51	0.23
Lactose, %	3.06	2.58	0.18	0.20
Solids not fat, %	15.10	15.64	0.23	0.24
Somatic cell count, n x 1000/ml	7.24	7.20	--[a]	0.80
IgG, mg/ml	41	51	6.26	0.38

[a] Data were log transformed to improve normality, SE = 0.18 for the log-transformed percentage fat, and SE = 0.10 for the log-transformed somatic cell count.

Table 4. Effect of phosphorus concentration in the mineral offered on mineral concentrations in colostrum (n = 12/treatment).

Colostrum Minerals	Control	Phosphorus	Standard Error	*P*-value
Phosphorus, %	0.15	0.17	0.00	0.11
Potassium, %	0.14	0.12	0.01	0.36
Calcium, %	0.18	0.20	0.00	0.02
Magnesium, %	0.02	0.04	0.00	0.34
Sulfur, %	0.12	0.16	0.02	0.30
Sodium, mg/kg	891.92	1057.86	43.21	0.11
Zinc, mg/kg	22.90	35.28	3.79	0.14
Copper, mg/kg	0.10	0.13	0.01	0.23

Table 5. Effect of phosphorus concentration of heifers' colostrum on calf serum.

Colostrum Immunoglobulins	Control	Phosphorus	Standard Error (SE)	*P*- value
Birth IgG, % Log formation	19.0	19.6	--[a]	0.88
Day 21, % Log formation	11.0	12.0	--[a]	0.66

[a] Data were log transformed to improve normality, SE = 0.126 for the log-transformed birth IgG in ng/ml, and SE = 0.10 for the log-transformed IgG at day 21 in ng/ml.

retention decreases due to changes in electrolyte excretion by the kidney and absorption in the gut. Calf plasma mineral concentrations had no differences (data not shown).

Conclusions

The purpose of this study was to determine if the maternal phosphorus status of heifers affects the growth and performance of their offspring. Data collected over the course of this study indicates that offering phosphorus as a supplemental mineral to heifers throughout gestation does not affect the growth or performance of their calves. This study strongly indicates that when grazing forage is grown on soil that has adequate amounts of phosphorus, supplementation is not needed. Forages cattle grazed contained 0.28% phosphorus at minimum and 0.36% phosphorus at maximum, providing more than adequate levels of phosphorus for the heifers' diets. While offering minerals that include phosphorus has no negative effects on dams or calves, it is also not economically advantageous to farmers and may cause harm to the environment when used unnecessarily.

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