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Periparturient Responses of Multiparous Holstein Cows Fed Different Dietary Phosphorus Concentrations Prepartum

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ABSTRACT

Our objective was to compare the effects of different prepartum dietary phosphorus concentrations on periparturient metabolism and performance. Forty-two late pregnant multiparous Holstein cows were fed 0.21, 0.31, or 0.44% P (dry basis) for 4 wk before expected calving. After parturition, all cows were fed a common lactation diet (0.40% P). In the prepartum period, cows fed 0.21% P had lower blood serum P concentrations compared with cows fed 0.31 or 0.44% P. However, serum P concentrations of all cows were within the normal range (4 to 8 mg/dL) until the day of calving when average concentrations dropped below 4 mg/dL. From 3 to 14 d postpartum, serum P of cows fed 0.21% P was greater than that of cows fed 0.31 or 0.44% P. No cows presented with or were treated for clinical hypophosphatemia in the periparturient period. Total serum Ca was lower before calving through 2 d postpartum for cows fed 0.44% P compared with those fed 0.21 or 0.31%. Prepartum dietary P treatments did not alter blood osteocalcin, hydroxyproline, and deoxypyridinoline, indicators of bone metabolism, or concentrations of parathyroid hormone or 1,25-dihydroxyvitamin D_3. Energy-corrected milk yield and milk composition (first 28 d of lactation) were not affected by prepartum dietary P concentrations. It is concluded that feeding 0.21% P (34 g of P/cow daily) prepartum is adequate for periparturient multiparous Holstein cows with high metabolic demands and genetic potential for milk production. No adverse effects on periparturient health, dry matter intake, or 28-d lactation performance resulted.
(**Key words:** phosphorus requirement, periparturient cow, serum phosphorus)

Abbreviation key: 1,25(OH)$_2$D$_3$ = 1,25-dihydroxyvitamin D_3, **BEB** = base excess, **DPD** = deoxypyridinoline, **ECD** = expected calving date, **ECM** = energy-corrected milk, **iCa** = ionized calcium, **OC** = osteocalcin, **OHP** = hydroxyproline, **PTH** = parathyroid hormone.

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INTRODUCTION

New dietary P requirements and ration recommendations for late-pregnant, nonlactating dairy cows were advanced by NRC (2001). The new recommendations are lower than those of earlier editions (NRC, 1978, 1989). This is largely because of changes in the way the maintenance requirement for P is estimated and changes in estimations of the absorption coefficients of dietary P. The earlier estimated absorption coefficients were 0.55 (NRC, 1978) and 0.50 (NRC, 1989), regardless of P source. In contrast, NRC (2001) used absorption coefficients for dietary P of 0.64 for forages and 0.70 for concentrates, and supplemental mineral sources were each assigned a different absorption coefficient. The new total ration P requirement is based on the absorbed P requirement for late-pregnant dairy cows. However, this new requirement has not been evaluated. Few studies have compared the effects of different prepartum dietary P concentrations on cows during the periparturient period. Two previous reports described the effects of varying prepartum dietary P concentrations on responses of plasma P, Ca, Mg, and vitamin D metabolites around parturition (Kichura et al., 1982; Barton et al., 1987). The study of Barton et al. (1987) examined dietary P concentrations that were all well above the estimated requirement. The study of Kichura et al. (1982) used Jersey cows that were limit-fed experimental diets composed of semipurified ingredients. Thus, these studies were not with contemporary Holstein cows with greater metabolic demands and genetic potential for milk production.

Late stages of gestation and early lactation contribute to changes in both Ca and P metabolism (Liesegang et al., 2000). Increased bone resorption occurs because of skeletal mineralization of the fetus in late gestation and milk production during early lactation (Brommage and DeLuca, 1985; Fukuda and Iida, 1993). Milk production requires an available supply of P, and bone resorption was estimated to supply 500 to 600 g of P during the first few weeks of lactation (Wu et al., 2000).

A large portion of P mobilized from bone tissue may be a direct consequence of Ca mobilization for Ca homeostasis in early lactation (Horst, 1986; Wu et al., 2000). Three biochemical bone markers have been evaluated in multiparous cows: osteocalcin (**OC**), a marker of bone formation (Naito et al., 1990; Liesegang et al., 1998, 2000); and deoxypyridinoline (**DPD**; Liesegang et al., 1998, 2000; Naito et al., 1990) and hydroxyproline (**OHP**; Goff et al., 1989; van Mosel and Corlett, 1990), both markers of bone resorption. Effects of dietary P concentrations on plasma OC concentrations were evaluated in sheep (Corlett and Care, 1988; Scott et al., 1994). However, the effects of prepartum dietary P concentrations on serum OC, OHP, and DPD concentrations around parturition in dairy cows have not been reported and these markers may be useful indicators of changes in bone metabolism.

It is hypothesized that feeding a prepartum ration to supply between 30 and 35 g of P/cow daily for multiparous Holstein cows is sufficient to meet periparturient requirements without adverse effects on metabolism or early lactation performance. Therefore, the objective of this experiment was to compare the effects of different prepartum dietary P concentrations on periparturient mineral and acid-base status and lactation performance of multiparous Holstein cows.

Table 1. Ingredient and analyzed chemical composition[1] of prepartum dietary treatments with different P concentrations (% of dietary DM).

	Treatment		
	0.21%P	0.31%P	0.44%P
Ingredients			
Alfalfa silage	17.5	17.5	17.5
Corn silage	27.0	27.0	27.0
Beet pulp pellets	27.0	27.0	27.0
Cornstarch	9.14	9.14	9.14
Corn, ground	9.01	9.01	9.01
Mineral-vitamin mix[2]	3.28	3.28	3.28
Supplement[3]	2.11	2.11	2.11
Rice hulls	1.81	1.29	0.90
Blood meal	1.08	1.08	1.08
Biuret[4]	0.86	0.86	0.86
Urea	0.77	0.65	0.52
Ammonium chloride	0.39	0.39	0.39
Monoammonium phosphate	0.00	0.52	1.03
Chemical composition			
CP	15.0	15.1	14.5
ADF	25.3	24.9	24.8
NDF	38.6	38.4	38.1
Ca	0.78	0.80	0.79
P	0.21	0.31	0.44
Mg	0.36	0.37	0.37
K	0.93	0.97	0.96
Na	0.07	0.07	0.07
Cl	0.49	0.48	0.47
S	0.24	0.25	0.25
DCAD[5]	–2.00	–1.30	–1.30
NE_L[6]	1.58	1.58	1.58

[1]Individual ingredients were sampled every other week, dried (60°C), ground through a 2-mm screen, and made into a composite across the entire prepartum period for analyses.

[2]Composition (DM basis): soybean hulls = 91.4%; magnesium sulfate = 8%; manganese sulfate = 0.14%; zinc sulfate = 0.11%; copper sulfate = 0.06%; Se 0.99% = 0.06%; cobalt sulfate = 0.001%; ethylenediaminodihydroiodide (EDDI) = 0.001%; vitamin A, 488,000 IU/kg; vitamin D_3, 71,000 IU/kg; and vitamin E, 2490 IU/kg.

[3]Supplement: SoyChlor 16-7, West Central Soy, Ralston, IA.

[4]Biuret, Moorman's Manufacturing Company, Quincy, IL.

[5]DCAD = Dietary cation-anion difference: mEq[(Na + K) – (Cl + S)]/100 g of dietary DM.

[6]NE_L (Mcal/kg of DM) = 0.0245 × total digestible nutrients (% of DM) – 0.12 (NRC, 1989).

MATERIALS AND METHODS

The experiment was conducted under a protocol approved by the Michigan State University All-University Committee on Animal Use and Care.

Cows and Experimental Design

Forty-two multiparous, pregnant Holstein cows scheduled for dry-off at the Michigan State University Teaching and Research Center were stratified by expected calving date (**ECD**), blocked by upcoming parity (2, 3, and 4+), and randomly assigned to 1 of 3 prepartum dietary treatments. After dry-off, cows were kept in individual tie-stalls from 60 d before ECD until parturition was imminent. Then, they were moved to individual maternity pens with drinking cups and their respective experimental ration just before parturition. Cows typically spent less than 12 h in these pens before being moved to tie-stalls in a barn with other lactating cows.

Treatments and Diets

Cows were fed the same diet (containing 0.31%P) during the standardization period from 60 to 28 d before ECD (Table 1). From 28 d before ECD to parturition, each cow was fed a different dietary treatment formulated to contain 0.18, 0.30, or 0.42% P (DM basis). Based on actual final P analyses of the diets (described subsequently), the treatments will be designated henceforth as 0.21%P, 0.31%P, and 0.44%P (dry basis), respectively. Treatment 0.31%P was the midconcentration of the 3 treatments formulated to supply the dietary requirement (34 g/d) of a 765-kg cow at 250 d of gestation consuming 11.4 kg of DM daily. Treatments 0.21%P and 0.44%P were intended to be an equal concentration difference (0.12%) lesser and greater than that of treatment 0.31%P. All dietary treatments contained the same concentrations of corn silage, alfalfa silage, beet