Livestock Science 159 (2014) 18–28

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Long term effect of reduced dietary phosphorus on feed intake and milk yield in dry and lactating dairy cows

L. Puggaard [a], P. Lund [a], A. Liesegang [b], J. Sehested [a,*]

[a] Department of Animal Science, AU Foulum, Aarhus University, DK-8830 Tjele, Denmark
[b] Institute of Animal Nutrition, Vetsuisse Faculty, University of Zurich, CH-8057 Zürich, Switzerland

ARTICLE INFO

Article history:
Received 7 February 2013
Received in revised form
13 August 2013
Accepted 4 October 2013

Keywords:
Dairy cow
Phosphorus
Dry matter intake
Milk yield
Bone markers

ABSTRACT

Eighteen multiparous Holstein cows were used to study the long term effect of reducing dietary P concentration on intake of DM and milk yield, on blood levels of inorganic phosphate (P_i), Ca, vitamin D_3, parathyroid hormone (PTH) as well as assessing bone turnover by the use of bone formation marker osteocalcin (OC) and bone resorption marker cross-linked carboxy-terminal telopeptide of type I collagen (CTX). Treatments were initiated 3 weeks before expected calving, and cows were followed until week 36 after calving. In dry period treatments were Low P (LP) (1.7 g P/kg of DM), Medium P (MP) (2.1 g P/kg DM) and High P (HP) (2.5 g P/kg DM). After parturition and throughout lactation treatments were LP (2.3 g P/kg DM), MP (2.8 g P/kg DM) and HP (3.4 g P/kg DM). Differences in dietary P were obtained by adding 0.60 and 1.19% mono-sodium phosphate per kg DM to MP and HP, respectively. The cows were fed restrictively pre-partum and for ad libitum intake from one week before expected calving and throughout the experiment. Due to a high number of health problems, LP treatment was terminated after sampling in week 12, and cows were shifted to HP and continued on this treatment until week 36. Reduction in P concentration from 3.4 to 2.3 g P/kg DM reduced DMI, milk yield, milk protein yield and plasma P_i concentration, and increased serum concentration of CTX, but did not affect serum concentration of OC in early lactation. Reduced dietary P concentration from 3.4 to 2.8 g P/kg DM did not affect DMI or milk production in early lactation. Dry matter intake and milk yield were not affected by dietary P concentration in late lactation. Plasma Ca increased in LP, whereas there was no effect on serum concentration of PTH or on plasma concentration of vitamin D_3 pre-partum, in early or late lactation. Despite an estimated mobilization of P in early lactation, on the basis of results of CTX and OC, it is not possible to reduce P concentration from 3.4 to 2.3 g P/kg DM in dairy cows in this period without compromising DMI and milk production. The results indicate a potential for reducing P concentration in early and late lactation from the current recommendations of 3.4 to 2.8 g P/kg DM without effects on performance, but this level of dietary P might not allow for repletion of bone P mobilized in early lactation.

1. Introduction

Phosphorus (P) is an important nutrient involved in a number of functions in the organism. However, P is poorly utilized in dairy cattle, and efficiency averages at 31% on a production cycle basis (Poulsen, 2009). Phosphorus plays an important role in the production and health of cattle

* Correspondence to: Department of Animal Science, Faculty of Science and Technology, Aarhus University, Blichers Allé 20, PO Box 50, DK-8830 Tjele, Denmark. Tel./fax: +45 8715 7893.
E-mail address: Jakob.Sehested@agrsci.dk (J. Sehested).

1871-1413/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.livsci.2013.10.009

and is an essential nutrient for growth and function of ruminal microbes. Rates of ruminal fermentation, protein synthesis and digestibility of organic matter (OM) have been found to be impaired by insufficient supply of dietary P (Müschen et al., 1988; Kincaid and Rodehutscord, 2005).

Several studies have investigated the effect of dietary P concentration on feed intake and milk production, but only few studies have investigated the long term effect including the transistion period of reducing dietary P (Valk and Sebek, 1999; Wu et al., 2000; Elizondo Salazar et al., 2012), and there is a shortage of long-term studies on reduction of dietary P significantly below the recommendations (NRC, 2001; Sehested, 2004; Nielsen and Volden, 2011). Low dietary P intake result in impaired milk production in both lactating dairy cows and goats (Müschen et al., 1988; Valk and Sebek, 1999; Wu et al., 2000), but also reduced feed intake, reduced plasma concentration of inorganic phosphate (P_i) (Tomas et al., 1967) as well as increased body weight loss (Call et al., 1987) have been found. Nonetheless, a decrease in milk yield may not be the primary response to low P intake, as Valk and Sebek (1999) found that milk production was not suppressed in the ongoing lactation period when dietary P was reduced from 3.4 (corresponding to Dutch recommendation) to 2.8 or 2.4 g/kg DM from week 17 of lactation.

The skeleton contains a large amount of P as well as Ca, and is a metabolically active tissue that undergoes constant, but regulated, degradation and renewal (Delmas, 1993). Therefore, P present in the skeleton functions as an important reservoir for resorption in times where requirement of the body is not met by P intake. It is known that bone mineral mobilization occurs in early lactation irrespective of sufficient P concentration in the diet (Knowlton and Herbein, 2002), which is most likely due to a rapid increase in the demand of Ca for milk production (Ramberg et al., 1970; Liesegang et al., 1998). It is assumed that up to 30% of P in bone tissue is mobilized in early lactation (Knowlton et al., 2001). The dynamics of bone metabolism in lactating dairy cows is possible to asses by measuring the bone formation marker osteocalcin (OC) and the bone resorption marker cross-linked carboxy-terminal telopeptide of type I collagen (CTX), which have been verified as relevant biochemical markers (Liesegang et al., 1998; Holtenius and Ekelund, 2005).

In the present experiment it is hypothesized that intake of DM and milk yield are not reduced when reducing dietary P concentration in early lactation due to a concomitant increase in mobilized bone P. It is furthermore hypothesized that bone mobilization is increased when dietary P concentration is reduced indicated by changes in serum concentration of the bone markers CTX and OC. The objective of the present experiment was to investigate the long term effect of reducing dietary P concentration in dry and lactating dairy cows on intake of DM and milk yield, on blood levels of P_i, Ca, vitamin D_3, parathyroid hormone (PTH) as well as assessing bone turnover by the use of the bone formation marker OC and bone resorption marker CTX.

2. Materials and methods

The present experiment complied with the Danish Ministry of Justice Law no. 382 (June 10, 1987), Act no. 726 (September 9, 1993) concerning experiments with animals and care of experimental animals.

2.1. Animals, design, feeding, and samplings

Eighteen dry, multiparous Danish Holstein cows, 688 ± 80 kg of body weight (BW), and 43 ± 13 days from actual calving were used in an experiment with 3 treatments (6 cows in each treatment group) and all cows were followed from before parturition until week 36 after calving. Cows were blocked according to expected calving date and randomly assigned to 1 of 3 treatment groups. Treatments were initiated 3 weeks before the first cow was expected to calve, and therefore not all cows were sampled in week −4 before expected calving. In the dry period (DRY) treatments were Low P (LP, 1.7 g P/kg DM), Medium P (MP, 2.1 g P/kg DM) and High P (HP, 2.5 g P/kg DM). After parturition, the treatment continued as a lactation ration and treatments were LP (2.3 g P/kg DM), MP (2.8 g P/kg DM) and HP (3.4 g P/kg DM). Due to a high number of health problems, the LP treatment was terminated after the cows completed sampling in week 12, and cows were shifted to Former LP (FLP; 3.4 g P/kg DM, corresponding to HP) and continued on this treatment until week 36. High P lactation diet met the recommendations of 3.4 g P per kg DM by NRC (2001) as well as current Danish recommendations (Sehested, 2004; Nielsen and Volden, 2011).

Concentrate mix with a low P content (no supplemented mono-sodium phosphate) or a high P content (supplemented 11.9 g mono-sodium phosphate/kg DM; Table 1) of dietary P was pre-made. The concentrate mix with medium P was obtained by mixing 50% of concentrate premix with low P content and 50% of concentrate premix with high P content, thus containing 6.0 g mono-sodium phosphate/kg DM. The rations were fed as TMR and the dry period rations were lactation rations diluted with barley straw (Table 2).

Table 1
Ingredient composition of concentrate premix (g/kg DM).

Item	Concentrate premix[a]	
	LP	HP
Ingredient		
Sugar beet pulp	605	597
Soybean meal	231	228
Sugar beet molasses	88.8	87.7
Rapeseed oil	48.2	47.6
Urea	19.3	19.0
Feed salt	3.3	3.3
Mono-sodium phosphate	–	11.9
Mineral premix[b]	2.4	2.4
Red suplex[c]	2.4	2.4

[a] Experimental concentrate premix of low P (LP) and high P (HP) had the same composition of ingredients with the exception that HP premix concentrate contained 1.19% of DM mono-sodium phosphate.

[b] Mineral and vitamin premix (Vitfoss, Gråsten, Denmark) contained (per kg): Ca, 180 g; P, 4 g; Mg, 65 g; Na, 80 g; S, 30 g; vitamin A, 693 kIU; vitamin D, 146 kIU; α-tocopherol, 4620 mg; Mn, 3080 mg; Cu, 693 mg; Co, 19 mg; Zn, 3460 mg; I, 173 mg; Se, 38.5 mg.

[c] Red suplex (Vitfoss, Gråsten, Denmark) contained: Ca: 17.2%; P: 0.32%; Mg: 0.04%; Na: 0.1%; Vitamin A, 5 kUI (international kg units; vitamin D, 0.2 KUI; α-tocopherol, 9100 mg/kg and Se, 10 mg/kg.