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Effect of feed forage particle size and dietary urea on excretion of phosphorus in lactating dairy cows

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ABSTRACT

Thirty six multiparous Danish Holstein cows, 222 days from calving with a standard deviation (±) of 102 days, 627 ± 7 kg of body weight, and 32 ± 3 kg/d energy corrected milk were used to investigate the effect of forage particle size (FPS) and dietary urea supplementation on excretion of phosphorus (P) in feces and urine when cows were fed P below requirement. Dietary P content was 2.5 g P/kg DM in all treatments. Treatments (CONTROL, SHORT and LOW-N) were all based on the same content of forage ingredients but varied in FPS and dietary urea content. In CONTROL and SHORT rumen degradable protein was optimized according to the Nordic protein evaluation system by supplementing dietary urea, whereas urea was excluded in LOW-N in order to obtain a supply of rumen degradable protein below requirements. It was hypothesized that dietary factors that reduce saliva secretion via reduced chewing activity will reduce the inevitable loss of endogenous P (IL) of P and that dietary factors that reduce the supply of rumen degradable protein in the form of dietary urea will result in a decrease in rumen microbial incorporation of P and in turn increase digestibility of P and hereby reduce IL of P. In SHORT FPS of grass hay was reduced to a theoretical particle size of 3 mm, as compared to 40–60 mm in CONTROL and LOW-N. Rations were fed for *ad libitum* intake for 16 d and balance trials were conducted on d 15 and 16. Indigestible neutral detergent fiber was used as an internal marker to estimate fecal output and total tract digestibilities. The obtained negative P balances confirmed that dairy cows were fed below P requirement, indicating that treatment effects on fecal P excretion mainly originated from variations in IL. Fecal P excretion was not reduced with reduced forage particle size despite reduction in chewing time. Fecal excretion of P was not affected by reduced dietary urea supply below requirement despite a reduction in digestibility of OM. Therefore, the results of the present study do not support the concept that fecal loss of endogenous P is affected by FPS. Nor do the results support the concept that fecal loss of endogenous P is affected by supply of rumen degradable protein.

1. Introduction

Phosphorus is an essential mineral for production and health of dairy cows and for rumen microbial protein synthesis (Breves and Schröder, 1991). A significant part of P absorbed in the gastrointestinal tract is being recycled to the rumen via saliva (Puggaard et al., 2011; Reynolds et al., 1991), and the secretion of endogenous P via salivary glands accounts for a substantial amount for the rumen microbial P supply. Kebreab et al. (2005) reported that on average 45% of P entering the rumen is supplied via saliva, and Kincaid and Rodehutscord (2005) suggested that more than 50% of ruminal P supply is secreted via saliva. Net rcycling of inorganic phosphate (P_i) accounted for 30–38% of total ruminal P input in a study by Puggaard et al. (2011). Urinary excretion of P is usually insignificant due to an efficient renal reabsorption of filtered P (Sehested, 2004) and fecal P is

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therefore the quantitatively most important excretion route in cattle. However, urinary P excretion may be excessive if saliva secretion is inhibited by feeding diets low in physical fiber (Scott and Buchan, 1988). Total P in feces originates mainly from non-reabsorbed endogenous P secreted via saliva (85%) and unabsorbed dietary P (15%) (Bravo et al., 2003). A small proportion of endogenous P is originating from intestinal cells and other digestive secretions than saliva (Scott et al., 1985). The inevitable fecal loss of endogenous P (IL) is defined as the fecal loss of endogenous P when P is supplied at or below true requirements (NRC, 2001). It is generally accepted to express IL as a function of DMI (Rodehutscord et al., 2000), and IL is estimated to be 1 g/kg DMI for dry and lactating dairy cows (Spiekers et al. 1993). Endogenous P, which has been built into microbial matter, is suggested to constitute about 50% of IL, and factors that stimulate rumen microbial growth, *i.e.* intake of digestible organic matter, will consequently increase IL (Bravo et al., 2003; NRC, 2001) due to increased incorporation of P into microbial components such as nucleic acids (Rodehutscord et al., 2000). In support, Rodehutscord et al. (2000) concluded that IL of P via feces depends on the digestible fraction in the diet rather than on the indigestible fraction. In a recent study by Sehested et al. (2012a) intestinal digestibility of rumen microbial P was estimated to be only 43% supporting that increased incorporation of saliva P into microbial P will result in increased IL. Another effect of DMI on IL is that salivary secretion of P is considered dynamic and dependent on feed intake (NRC, 2001; Ternouth, 1989). The hypotheses of the present study are that (1) dietary factors that reduce saliva secretion via reduced chewing activity will reduce the IL of P and (2) a reduced supply of rumen degradable protein in the form of dietary urea will decrease microbial incorporation of P and thereby increase small intestine (SI) digestibility of P and reduce the IL of P. The objective of the study was to measure fecal excretion of P in lactating dairy cows fed below P requirement in relation to feed parameters expected to affect (1) chewing activity and hereby production of saliva or (2) the microbial P incorporation and SI digestibility of P. Therefore, the effect of forage particle size (FPS), and the effect of dietary urea content on excretion of P was tested.

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

Thirty six multiparous Danish Holstein cows, 222 with a standard deviation ($\pm$) of 102 days from calving, 627 $\pm$ 7 kg of body weight, and 32 $\pm$ 3 kg energy corrected milk (ECM) were used to measure fecal and urinary excretion of P. In order to avoid excessive feed P in feces, dietary P content of all three rations was 2.5 g P/kg DM, which is below recommendations (NRC, 2001; Sehested, 2004). The thirty six cows were blocked according to milk yield and randomly assigned to one of three dietary treatments (CONTROL, SHORT and LOW-N; Table 1), which were all based on the same ingredients but varied in FPS and content of dietary urea. In CONTROL and SHORT rumen degradable protein was optimized according to the Nordic protein evaluation system, which is based on the AAT/PBV system described by Madsen et al. (1995) by adding urea, where AAT is the amount of amino acids absorbed in SI and PBV is protein balance in the rumen. In LOW-N, as compared to CONTROL, urea was excluded in order to obtain a supply of rumen degradable protein below microbial requirements. Thus, planned PBV was −13, 6 and 6 g/kg DM in LOW-N, CONTROL and SHORT, respectively. Compared to FPS of grass hay of 40–60 mm in CONTROL and LOW-N, FPS of grass hay was reduced in SHORT by using a Cormall tractor cutter, 10 mm mesh (Cormall A/S, Sønderborg, Denmark), followed by President hammer mill, 3.0 mm mesh (President milling, Herning, Denmark) according to Storm and Kristensen (2010). The rations were fed as total mixed ration which were mixed daily prior to morning feeding and fed for *ad libitum* intake in two equal sized portions at 0830 and 1530 h. Orts were removed and registered daily at 0700 h. Cows were kept in tie stalls with wood shavings as bedding. Cows were milked at 0500 and 1600 h. Treatments were fed for 16 d and cows were sampled on d 15 and 16.

Indigestible neutral detergent fiber (INDF) was used as an internal marker to estimate fecal output and total tract digestibilities. Feed samples were collected once on d 14.

Table 1
Ingredients and nutrient composition of experimental diets (g/kg of DM if not otherwise noted).

	Treatment[a]		
	SHORT	CONTROL	LOW-N
Ingredients			
Concentrate premix[b]	300	300	302
Maize silage[c]	309	309	311
Sugar beet molasses	185	185	187
Grass hay, 40–60 mm[d]	–	199	200
Grass hay, 3 mm[d]	199	–	–
Urea	6.6	6.6	–
Nutrients			
DM, %	58.8	58.8	58.7
OM	929	931	931
NDF	314	311	313
Crude protein	137	144	133
Crude fat	29.2	29.6	29.8
P	2.5	2.5	2.5
PBV[e]	6	6	−13
DE, MJ/kg DM[f]	15.0	14.7	14.0
NE_L, MJ/kg DM[g]	8.6	8.4	8.0

[a] Experimental diets had the same composition of ingredients with the exception of chopping length of hay, and the addition of rumen degradable protein.
[b] Ingredient composition of concentrate premix (g/kg of DM): sugar beet pulp, 557; soybean meal, 291; sugar beet molasses, 101; rapeseed oil, 40; feed salt, 3; mono-sodium phosphate, 4; mineral and vitamin premix (VM 1, Vitfoss, Gråsten, Denmark).
[c] Chemical composition of maize silage (g/kg of DM): ash: 35, CP: 95, NDF: 232. DM (g/kg): 361
[d] Chemical composition of grass hay (g/kg of DM): ash: 63, CP: 136, NDF: 563. DM (g/kg): 869.
[e] PBV regulated according to the AAT/PBV system described by Madsen et al. (1995).
[f] Digestible energy, calculated according to Møller et al. (2005).
[g] Net energy, calculated according to Møller et al. (2005).