J. Dairy Sci. 99:1–6
http://dx.doi.org/10.3168/jds.2015-10338

Short communication: Individual cow variation in urinary excretion of phosphorus

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ABSTRACT

Some dairy cows excrete large amounts of P through their urine; thus, it was speculated that a genetic defect related to their efficiency in uptake of P or recirculation of P could cause such an effect. This speculation was pursued in a cross sectional study on 139 cows (103 Holstein and 36 Jersey) from an experimental herd using repeated sampling of urine (301 samples) to investigate sources of variation in urinary P concentration (Pu). Urine samples were taken on 6 testing sessions spread over 2 mo. Each sample was obtained by mild manual stimulation of the rear udder escutcheon area. The samples were immediately assayed for pH, stored frozen, and assayed for inorganic P and creatinine. Concentrations of P and creatinine in urine, the ratio of Pu to creatinine, and pH were analyzed using a linear mixed model. The model included fixed effects of breed, parity number, and sampling session. Stage of lactation was fitted as Wilmink-type lactation curves. Random effects included additive polygenic ancestry, permanent animal effects, and residual. The distribution of Pu approximated normality except for a single sample with very high Pu and very low pH. This sample came from a cow diagnosed independently with ketosis. For the remaining samples, it was shown that Pu has low to moderate heritability (0.12) and is only moderately repeatable (0.21). Based on a small data set, it is tentatively concluded that individual differences between cows exist in their Pu, and individual differences presumably result from genetic differences. However, it remains unclear if cows with genetically lower or higher Pu will perform better on a low-P diet.
Key words: phosphorus retention, urine samples, dairy cows

Short Communication

The main P excretion route for adult cattle is through feces, but excretion of aberrantly high amounts of P through urine in individual animals has been reported in the scientific literature (reviewed by Breves and Schröder, 1991). However, reports on phenotypic and genetic variation in urinary P excretion are scarce; therefore, the current paper focuses on phenotypic variation between individual dairy cows in urinary excretion of P.

Urinary excretion of P in ruminants is usually insignificant due to efficient renal reabsorption of filtered P. Model estimates of the urinary P excretion from lactating dairy cows fed dietary P close to their requirement are 0.002 g/kg of BW (NRC, 2001) or 1% of absorbed P (Hill et al., 2008) corresponding to 1.0 to 1.4 g of P/d. Lower and higher urinary P excretions have been measured with lower respectively higher quantities of dietary P. Dietary P concentrations from 2.3 to 3.4 g/kg of DM did not influence the urinary P excretion in a long-term study with lactating dairy cows (0.038 g/d; Puggaard et al., 2014). In a short-term study with lactating dairy cows fed varying feed forage particle size and dietary urea at a low dietary P concentration (2.5 g/kg of DM) urinary P excretion was 0.035 g/d (Puggaard et al., 2013). Urinary excretion was 0.27 to 0.43 g of P/d in dairy cows 3 to 11 wk in lactation when fed 0.34% dietary P, 0.58 to 1.63 g of P/d when cows were fed 0.51% dietary P, and 2.26 to 6.08 g of P/d when cows were fed 0.67% dietary P (Knowlton and Herbein, 2002). Similar effects of dietary P on mean urinary P excretion were observed in more studies (Morse et al., 1992; Wu et al., 2001), although a lower excretion was found in other studies (Odongo et al., 2007; Ferris et al., 2010).

Urinary P excretion can become quantitatively significant in case of high plasma P concentrations (approximately 2 mmol/L) or if saliva secretion is inhibited by feeding diets low in physical fiber (Scott et al., 1985; Scott, 1988; Scott and Buchan, 1988; Knowlton

Received September 1, 2015.
Accepted February 11, 2016.
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and Herbein, 2002; Bravo et al., 2003; Wu, 2005; Hill et al., 2008). Several studies have reported the occurrence of one or a few experimental animals with exceptionally high urinary P excretion not related to any of the mentioned causes (reviewed by Breves and Schröder, 1991). Manston and Vagg (1970) concluded that a small proportion of cows have a tendency to excrete relatively large amounts of phosphate in the urine, and similar observations were reported in newer studies with high-yielding dairy cows (Wu et al., 2000). Genetic variation in urinary P was detected in an experiment with 4 sets of triplet lambs (Field et al., 1984; Field and Woolliams, 1984) and individual differences were reported by Sato (1981) in sheep and goats. A genetic predisposition to deviating high urinary P might be caused by single gene mutations or be caused by polygenic quantitative genetic variation. In either case, individual animals will have urine P concentrations that are less variable compared with randomly taken samples, and concentrations are therefore repeatable.

We hypothesized that urinary P concentrations (**Pu**) would be normally distributed except if some individual animals have aberrantly high Pu. The objectives of the present study were to estimate individual and genetic cow variation in Pu, and to detect cows with aberrant Pu.

This experiment used repeated sampling of urine from a cross section of cows at the Danish Cattle Research Centre (Foulum, Denmark; Table 1). The cows were sampled during 6 testing sessions (January to March 2009, 2-wk intervals) with the aim of obtaining on average 2 samples per cow to allow for studying repeatability. Each sample only took few minutes to obtain and each testing session lasted less than 2 h, during which as many cows as possible were sampled. The lactating cow herd (5–391 DIM) contained 2 groups of Holsteins (103 sampled cows) and 1 group of Jerseys (36 cows sampled). Each group was assigned to an automated milking system (VMS, DeLaval, Tumba, Sweden). All cows were fed a partially mixed ration, which was fed ad libitum (DM composition: 36.7% maize silage, 35.5% grass silage, 11.4% rolled barley, 8.9% soy expeller, 5.8% canola expeller, 1.7% mineral and salt mix), and supplementary concentrates during milking restricted to total 3 kg/d. The total feed intake from the mixed ration (Insentec, RIC-system, Marknesse, the Netherlands) and of concentrates provided to cows was 19.4 ± 5.9 kg of DM/d (mean ± SD for all cows across breeds) containing 4.04 g of P/kg of DM. The P content in feed was determined from composition and assayed content in ingredients. Daily milk yield on each test day was used as a reference trait to compare with urine-based traits.

Urine samples from 139 cows were used for the present study, covering all stages of lactation and parities from 1 to 5 (Table 1). Urine samples (100 mL) were obtained following mild manual stimulation of the rear udder escutcheon area, or in some cases without stimulation. Sampling sessions lasted up to 2 h. Urinary pH was measured immediately after sampling (HI-98127, Hanna Instruments Inc., Woonsocket, RI), before aliquots were transferred to 5-mL tubes (Sarstedt AG & Co, Nümbrecht, Germany), and stored frozen (−25°C) until assayed.

Table 1. Data overview and estimates of fixed effects and random variance parameters for concentrations of P and creatinine in urine of dairy cows

				Fixed effects[1]							
Item	Grouping	n	Mean ± SD	Breed	Parity	β_1	β_2	β_3	Sampling date	Repeatability t ± SE	Heritability h^2 ± SE
Cows	All	139									
	Holstein	103									
	Jersey	36									
DIM	All	300	174 ± 110								
Live weight (kg)	All	300	599 ± 100								
	Holstein	233	640 ± 69								
	Jersey	67	456 ± 41								
Phosphorus (mmol/L)	All	300	0.069 ± 0.029	NS	NS	NS	NS	*	NS	0.21 ± 0.07	0.12 ± 0.17
Creatinine (mmol/L)	All	300	5.56 ± 2.18	***	**	***	*	NS	***	0.38 ± 0.07	0.05 ± 0.17
P-to-Creatinine ratio	All	300	1.37 ± 0.71	NS	***	NS	NS	NS	NS	0.13 ± 0.08	0.11 ± 0.16
pH	All	297	8.03 ± 0.13	***	NS	NS	NS	NS	***	0.16 ± 0.07	0.08 ± 0.14
Milk yield (kg/d)	All	300	32.6 ± 11.9	***	***	***	***	**	**	0.49 ± 0.07	0.36 ± 0.29
		233	35.4 ± 11.4								
		67	22.8 ± 7.9								

[1]F-test for fixed effects.

$*P < 0.05$, $**P < 0.01$, $***P < 0.001$.