Use of Net Carbohydrate and Protein System model to estimate phosphorus fecal excretion

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Introduction

Dairy cattle requires an adequate supply of phosphorus for bone growth, milk production, energetic metabolism, fatty acid transport, synthesis of phospholipids, metabolism of aminoacids and protein synthesis. Of all dietary essential minerals for dairy animals, phosphorus represents the greatest potential risk if excess is released into the environment contaminating surface waters and causing eutrophication (NRC, 2001). Typically, most phosphorus excretion is found in feces, representing about 69% of ingested P. Milk contents about 30% of ingested P and 1% is found in urine (Amaral, 2000).

There has been an important development of tools aimed to estimate nutritional parameters in relation to environment and animal welfare. One of them is the model *Net Carbohydrate and Protein System* (CNCPS 5.0), developed by Fox et al. (2003). This model produces environmental estimations such as feces and urine production and chemical composition in terms of N and P.

The aim of this work is to study the effect of phosphorus content in concentrates supplied to dairy cattle on fecal excretion and milk production and compare the results obtained to the estimated values by CNCPS.

Keywords: dairy cow, phosphorus, faeces, CNCPS

Material and methods

Animals and diets

Three Holstein Friesian cows in their first lactation, with 257±12 milking days; 644±8 kg BW and 27±3 kg of milk, were selected from the experimental dairy herd in the Milk Production Unit at the IES (La Granja, Cantabria, Spain). They were confined to metabolism stalls for control of feed intake and feces. Diets contained 52% of forage, which consisted of: corn silage (28%); alfalfa hay (24%). The concentrate was supplied at three levels, named P5; P6.5 and P8 g/kg DM (Table 1). The concentrate was a mixture of dehydrated lucerne (22, 21.2 and 20.5% for P5; P6.5 and P8 respectively), 9.7% beet pulp; 30.1% cracked barley; 10% cracked maize; 12.8% soya-bean meal; 11.7% bean meal; limestone 1.78%; 0.89% vitamin and mineral corrector and 0, 0.8 and 1.51% of dicalcium phosphate ($CaHPO_4 2H_2O$) respectively for the concentrates. Animals had free access to water and stones for mineral supply during the assay.

Experimental procedure

The experiment was conducted as a 3 by 3 Latin Square design: 3 cows x 3 phosphorus concentrations during 3 feeding trials of 15 days (allowing an adjustment period of 11 days). Feed was offered to produce 10% orts and supplied as a mixed diet at two times of the day (9.0 a.m. and 17 p.m.). Milk production was recorded and samples were collected twice a day (8 a.m and 6.30 p.m). Milk samples were preserved with

2-bromo-2-nitropropane-1,3 diol. Feces were weighed following a.m. milking, and a 300 g sample was taken for analysis. Samples were stored at -20ºC until measurement. During the 2 consecutive days at the end of each experimental period, feed composition was analysed. Details of the diets are given in Table 1.

Table 1. Composition of the diets used

Ingredient, % DM	Corn silage	Alfalfa	P 5 g/kg DM	P 6.5 g/kg DM	P 8.0 g/kg DM
DM, %	40.08	87.8	88.5	88.5	89.1
Ash, g/kg DM	35.8	84.7	83.8	94.5	99.8
CP, g/kg DM	81.5	157.4	185	183	187
P, g/kg DM	2	2.1	5	6.5	8.5

DM: dry matter; CP: crude protein; P: phosphorus

Analytical measurements for feed, milk and feces

Dry matter was calculated after drying simples in oven at 80 ºC for 24 hours. Ash was determined by calcination at 550ºC. Total N as N-Kjeldahl using Kjeltec™ 2300. Phosphorus by the colorimetric method based on nitro-molibdo-vanadate using FIAstar 5000 analyser. Crude protein in milk samples (N x 6.38) was measured by Milko-Scan 4000 in the Laboratorio Interprofesional Lechero in Santander. Phosphrous milk content (g/d) was estimated using INRA's reference value for P content in milk (2.17 kg P_2O_5/1000 kg).

Model considerations

Data used of CNCPS validation were divided into two categories: "animal", including milk production, chemical composition, life body weight, feed intake, lactation number and days of lactation. The second category, "feed", included ash, crude protein, neutro detergent fiber, acid detergen fiber, neutron detergent fiber insoluble protein, acid detergent fiber insoluble protein, lignine, fat, starch, soluble protein, non proteic nitrogen, phosphorus and non fibrous carbohydrates.

Statistical analyses

All statistical analyses were performed using the SPSS 11 (2002). Means of nutrient intake, fecal chemical composition, excretion and digestibility were partitioned by orthogonal constrasts and compared by the least significant difference test. When no statistical significant differences were observed, data were analysed by analysis of varianze using the model: $Y_{ijkl} = \mu + V_i + P_j + T_k + (P_i - P..) + e_{ijklm}$; where Y_{ijklm} is the dependent variable; μ is population mean; V_i is the effect of cow; P_j the effect of period; T_k the effect of treatment; P_i – P is the mean intake of phosphorus as covariable and e_{ijklm} is the experimental error.

Results and Discussion

Table 1 shows the chemical composition of the diets. Phosphorus concentrations ranged from 3.6 to 5.5 g/kg DM, higher than the one indicated by NRC (2001), with 3.5 g. Phosphorus intake increased linearly (P<0.001) with treatments, and the highest dry matter consumption (P<0.01) was found when P6.2 g/kg DM was offered (Tabla 2). No significant differences were found between observed and estimated data for dry matter intake and phosphorus intake (Table 3).

Fecal P excreted increased as P concent in the concentrate increased following a cuadratic relationship. No significant relationships were found for fecal production on a dry basis (Table 2). Nevertheless, fecal production (kg DM/d) and P fecal content (g/d) were overestimated by CNCPS (5.0) (Table 3). Such difference between observed and estimated values can be attributed to the lower digestibility of the dry matter estimated by CNCPS (5.0). That is, 67% *vs* 83%, while fecal P excretion was quite similar between observed and measured values (Table 3). Besides, CNCPS underestimated phosphorus and nitrogen apparent digestibility (29.4% estimated *vs* 65.6% observed value for phosphorus and 58% estimated *vs* 79% observed value for nitrogen). Fecal N excretion was also overestimated (P<0.001) (Table 3). The observed phosphorus digestibility was closer to 46% in dairy cattle fed with grass silage and supplemented with 3.6 kg of concentrate (Salcedo, 2007).

Table 2. Intake, excretion and milk chemical composition

	Phosphorus content				Sig.		Contrasts	
	5	6.5	8.0	P	P intake	P*C	L	C
DM, kg/d	18.7	20	19.2	**	***	***	ns	ns
N, g/d	477	499	458	***	***	***	ns	ns
P intake, g/d	69	89	103	***	-	-	***	ns
Faeces (fresh weight), kg/d	16.2	18.4	18.8	**	***	**	ns	ns
DM faeces, kg/d	3.02	3.73	3.30	ns	ns	ns	ns	ns
N faeces, g/d	90	100	97	ns	**	ns	ns	ns
dN_{vivo} , %	81	79	78	ns	ns	ns	ns	ns
P faeces, g/d	21	37	29	ns	***	ns	***	***
P faeces, g/kg DM	7.4	10.1	9.2	ns	ns	ns	**	**
dP_{vivo}, %	69	57	70	ns	ns	ns	ns	***
Balance P, g/d	27	28	52	**	***	ns	***	***
Milk, kg/d	22.4	23.6	21.4	ns	**	ns	ns	ns
CP milk, g/kg	32.3	33.2	34.6	ns	ns	ns	**	ns

P: probability; P intake: Phosphorus consumption (covariable); P*C: interaction of phosphorus x concentration; L: lineal effect, C: cuadratic effect; dN: In vivo N apparent digestibility; dP: In vivo P digestibility; CP: crude protein in milk; *P<0.05; **P<0.01; P<0.001; ns: non significant

Table 3.Comparison of observed and estimated values using CNCPS

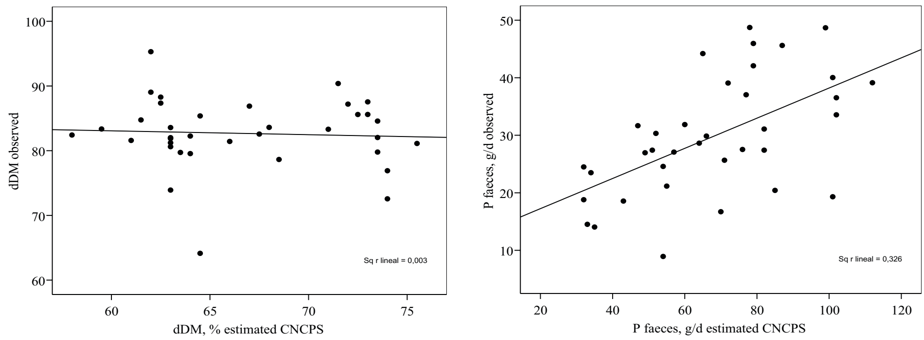
	Observed	CNCPS	sd	Sig
DM, kg/d	19.3	20	0.22	ns
P intake, g/d	87	93.7	2.4	ns
N intake, g/d	478	506	7.79	ns
Faeces (fresh weight), kg/d	17.8	35.1	1.17	***
DM feces, kg/d	3.34	6.65	0.23	***
dN_{vivo}, %	79	58	1.35	***
N faeces, g/d	96	212	7.5	***
P faeces, g/d	30	67	3.04	***
P faeces, g/kg DM	8.8	10	0.03	ns
dP_{vivo}, %	65.6	29.4	2.4	***
Balance P, g/d	36.6	-2.6	2.74	***
Milk, kg/d	22.5	30	0.58	***

Sd; standard deviation Sig: significance; *** P<0.001; ns: non significant

The percentage of fecal phosphorus excreted with respect to P intake was underestimated by CNCPS, with 34.3% and 52.5% for estimated and observed values. Both of them are lower to the one reported bye Amaral (2000), with 69%. CNCPS (5.0) estimated a negative phosphorus balance, estimated as [P intake, g/d – (P feces, g/d + P milk, g/d)]. This was explained by the lower digestibility of the dry matter as estimated by CNCPS.

Low relationships were found between dry matter digestibility and fecal phosphorus excretion either observed or estimated (Figure 1).

Figure 1. Relationship between dry matter digestibility (left) and fecal phosphorus content observed and estimated by el CNCPS (right)



A high percentage nitrogen content of milk protein is found in casein, as phosphocaseinate. Wu *et al*. (2000) observed positive relationships between P intake and milk protein content. In contrast, we have found a low relation between protein content and P intake (r^2=0.15 P<0.01), with an slope of 0.046 g CP/g P. This value was previously observed by Salcedo (2007). Milk production was dependent on feed intake (P<0.01), as observed by Arriaga et al (2006) for commercial dairy farms in the Basque Country, but it was not different with respect to P content in concentrates.

Conclusions

CNCPS overstimates daily fecal excretion of P due to the lower estimation of the dry matter.

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