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Faecal dry matter excretion per se affects faecal calcium and phosphorus losses in dogs

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Abstract

The study aimed to investigate the effect of faecal dry matter (DM) excretion on faecal losses of calcium (Ca) and phosphorus (P) without potentially confounding factors. Dogs were fed two levels of the same basal diet (cooked pork, rice, gelatine; 8.5 ± 0.7 and 12.6 ± 1.2 g DM/kg BW). Mineral supplements were added separately for identical Ca and P supply independent of DM intake (Ca 226 and P ~170 mg/kg BW). Digestion trials (10 days adaptation, 5 days quantitative faecal collection) were carried out. Digestibility of DM averaged 87% in both trials. Faecal DM and mineral excretion increased highly significant (DM 1.1 ± 0.3 to 1.7 ± 0.2 g/kg BW, $p = 0.00005$; Ca 185 ± 34 and 233 ± 22 mg/kg BW, $p = 0.00119$; P 99 ± 23 to 127 ± 12 mg/kg BW, $p = 0.00212$), revealing a highly significant correlation. Apparent digestibility of Ca was positive in the first trial and negative in the second leading to a slightly negative Ca retention in the latter one. The results suggest that in dogs (i) factors influencing Ca and P absorption can only be compared if faecal DM excretion is identical and (ii) Ca requirements may be affected by DM intake and digestibility.

KEYWORDS

calcium metabolism, faecal dry matter excretion, mineral digestibility, phosphorus metabolism

1 | INTRODUCTION

In previous retrospective studies, an increase in faecal Ca excretion with increasing faecal dry matter (DM) excretion was demonstrated in dogs (Kienzle et al., 2006, 2017) as well as in cats (Prola et al., 2009). In two of these studies, the increase in faecal DM excretion was due to addition of fibre. Therefore, it was not clear whether this was a fibre or a DM excretion effect. In the third retrospective study, digestion trials with prepared wet and dry dog food were evaluated (Kienzle et al., 2017). In prepared dog food, a high faecal DM excretion could be due to high fibre but also to an increased percentage of bone meal. Bone meal contains a lot of ash and has a low digestibility (Dobenecker et al., 2010). This could be a confounding factor. Therefore, in the present study, dogs were fed two levels of the same basal diet. Mineral supplements were added separately to ensure the same amount of Ca and P supply with different DM intake of the same diet. The hypothesis was that in the absence of a variation in calcium and phosphorus intake, faecal DM excretion is the main parameter influencing the faecal excretion of Ca. Given the rather constant ratio of faecally excreted Ca and P in dogs (Mack et al., 2015), it was expected that the same would be true for P.

2 | ANIMALS, MATERIALS AND METHODS

Eight healthy adult foxhound-crossbred (FBI) dogs were involved in the study (24–32 kg, two neutered males, one intact male, five intact females, age of 3–5 years). The dogs were pair-housed in climate-controlled indoor pens with sufficient resting places with bedding material. Every day of the year, they had access to outdoor runs of about 50 m^2 equipped with kennels as well as trees or awning in established groups of 4–7 animals for at least 6 h during the day. The dogs were fed separately and their individual food intake was measured daily. Additionally, the dogs were walked on a leash and clicker-trained in regular intervals. During the digestibility trials, they were walked at least twice daily. The indoor pens had natural and artificial light for a minimum of 8 h per day, depending on the season. Humidity varied between 40% and ~70%. Fresh air was provided through a ventilation system throughout the year. The indoor temperature was kept above 16°C. Standard procedure was adopted to the digestion trials (3 days dietary change to test diet, 10 days adaptation, 5 days sampling period, one meal per day). The dogs were housed individually during the 5 days of total faecal collection. Water was provided ad libitum at all times. Between the trials with the same type of food fed in different levels (Table 1) was a 2-week wash-out period.

At the lower intake level (N), lard was added in small amounts to animals with an energy requirement which exceeded the feed allowance to prevent weight loss. At the higher level (HI), weight gain was considered acceptable. The mineral-vitamin mixture (Supporting Information: Table S1) was not mixed into the feed but given into each dog's daily ration to ensure absolutely identical intake of Ca (Table 2). This led to slight differences in the mineral content of the diet in each individual dog.

After total collection, faeces were lyophilised and ground. Calcium levels in food and faeces were analysed by flame-emission photometry (Eppendorf Flammenphotometer EFOX 5,053, HJG Spezialmesssysteme) after acid hydrolysis and wet digestion in a microwave (Janßen et al., 2006). Phosphorus was determined photometrically with ammonium molybdate and ammonium vanadate in HNO_3 (GENESYS 10 UV, Thermo Spectronic). Two means were compared by paired *t*-test after testing normal distribution of data (Shapiro–Wilk test). The significance levels were set at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$. Linear regression analyses were carried out between faecal DM and Ca excretion and between faecal P and Ca excretion.

3 | RESULTS

All animals remained healthy throughout the study. Apparent digestibility of DM was not affected by the level of food intake; it averaged 87% in both trials (Table 2). Faecal DM excretion increased highly significant in trial HI compared to trial N ($p = 0.00005$). The same was true for faecal Ca excretion which was higher by nearly 50 mg/kg BW in trial HI than in trial N ($p = 0.00119$). The resulting apparent digestibility of Ca was positive in trial N and negative in trial HI. In trial N, there was a considerable amount of apparently digested ("retained") Ca, in the second trial with higher DM intake, this parameter was negative. There was a highly significant positive relationship between faecal DM excretion and faecal Ca excretion (Figure 1; $p \leq 0.001$). There was also a highly significant correlation between faecal organic matter excretion (*x*; g/kg BW) and faecal Ca excretion (*y*; mg/kg BW): $y = 101.8 + 144.3x$; $R^2 = 0.80$, $p \leq 0.001$). Faecal P excretion also increased significantly with increasing faecal DM excretion (Table 2, Figure 2; $p = 0.00212$). The increase of faecal P excretion with increasing faecal DM excretion was less marked though than the increase of faecal Ca excretion. Apparent P digestibility was positive in both trials. In trial, HI apparent P digestibility was significantly reduced compared to trial N but the difference was less marked than in apparent Ca digestibility. The apparently digested

TABLE 1 Composition of the diets fed to eight foxhound crossbred dogs

	Unit	Diet N	Diet HI
Ingredients, basal diet	%	76.9 pork (rump with rind and fat, heart) 19.2 rice 3.9 gelatine	76.9 pork (rump with rind and fat, heart) 19.2 rice 3.9 gelatine
Dry matter, basal diet	g/kg	368	368
Gross energy, basal diet	MJ/kg DM	24.6	23.2
Crude protein, basal diet	g/kg DM	411	430
Crude fat, basal diet	g/kg DM	164	149
Crude fibre, basal diet	g/kg DM	6	9
NfE[a], basal diet	g/kg DM	406	396
Intake basal diet	g DM/kg BW	5.6 ± 0.6	11.3 ± 1.2
Intake lard	g DM/kg BW	1.5 ± 0.9	No lard
Intake mineral supplement[b]	mg DM/kg BW	1389 ± 35	1357 ± 34
Vit D_3, daily intake, total ration	IU/kg BW	13.9 ± 0.4	13.6 ± 0.4

[a]Nitrogen free extract.

[b]See Supporting Information: Table S1.

TABLE 2 DM intake, digestibility, and faecal DM excretion

Diet	Unit	N	HI	*p*-values
Total DM intake	g DM/kg BW	8.5 ± 0.7	12.6 ± 1.2	0.00005
Faecal DM excretion	g/kg BW	1.1 ± 0.3	1.7 ± 0.2	0.00005
Apparent DM digestibility	%	87 ± 3	87 ± 2	0.39
Apparent energy digestibility	%	94 ± 2	93 ± 1	0.31
Ca intake	mg/kg BW	226 ± 6	226 ± 6	0.25
Faecal Ca excretion	mg/kg BW	185 ± 34	233 ± 22	0.00119
Apparently digested Ca	mg/kg BW	41 ± 32	−8 ± 21	0.001
Apparent Ca digestibility	%	18 ± 15	−3 ± 9	0.0015
P intake	mg/kg BW	172 ± 6	168 ± 7	0.00012
Ca/P in diet	g/g	1.32/1	1.35/1	-
Faecal P excretion	mg/kg BW	99 ± 23	127 ± 12	0.00212
Apparently digested P	mg/kg BW	73 ± 20	41 ± 11	0.0013
Apparent P digestibility	%	43 ± 12	24 ± 6	0.00185

Abbreviation: DM, dry matter.

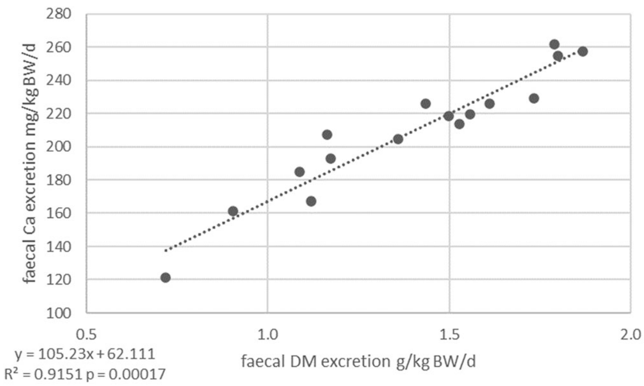

FIGURE 1 Faecal calcium (Ca) excretion vs. faecal dry matter (DM) excretion in eight dogs fed different amounts of DM

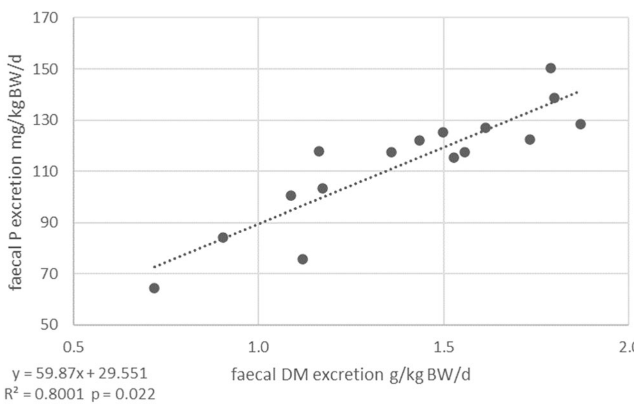

FIGURE 2 Faecal phosphorus (P) excretion vs. faecal dry matter (DM) excretion in eight dogs fed different amounts of DM

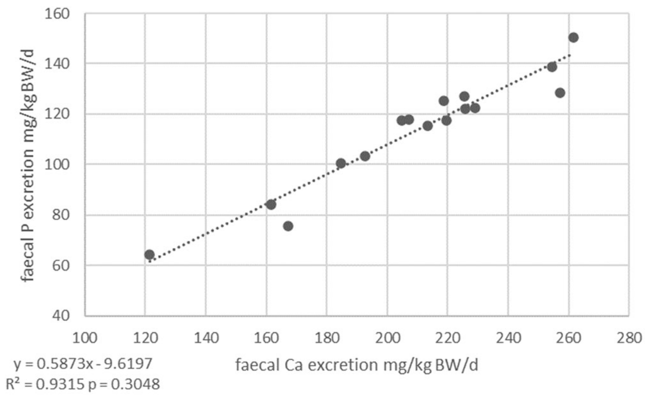

FIGURE 3 Faecal phosphorus (P) excretion vs. faecal calcium (Ca) excretion in eight dogs fed different amounts of dry matter

("retained") P amounted to 30 mg/kg BW on average. In both trials, P digestibility was higher than Ca digestibility. There was a highly significant relationship between faecal Ca and P excretion (Figure 3).

4 | DISCUSSION

The results of the study confirm the hypothesis that faecal DM excretion is a major determinant of faecal Ca excretion (Kienzle et al., 2006, 2017). The same is true for faecal P excretion. The relationship between faecal Ca and P excretion was confirmed again (Böswald et al., 2018; Mack et al., 2015). Mack et al. (2015), Böswald et al. (2018), and Schmitt et al. (2018) suggested that in dogs Ca absorption from the intestine is predominantly a passive transport. This is in excellent agreement with the results of Schünemann et al. (1989). These authors worked with dogs fitted either with an ileal or a colon fistula (methods see Brass & Schünemann, 1989). Schünemann et al. (1989) determined ileocecal flow of minerals as well as faecal excretion. The range of Ca intake was between 11 and 190 mg/kg BW. Ileocecal flow was even higher than the intake in most trials (Schünemann et al., 1989). There was very little net absorption in the small intestine, mostly a net secretion. Absorption of Ca mainly took place in the colon. There was a clear-cut positive relationship between Ca intake, ileocecal Ca flow and faecal Ca-excretion (Schünemann et al., 1989). Given the findings of Mühlum et al. (1989) who demonstrated that fat is digested nearly completely in the small intestine, this explains why Hallebeek and Hazewinkel (1997) did not see any effects of fat on Ca digestibility in dogs. The same was true in this study. The relationship between faecal DM and Ca excretion did not significantly differ ($p = 0.34$) between dogs eating extra lard and those without lard addition.

In the study by Schünemann et al. (1989), there was also a positive relationship between P intake, ileocaecal P flow and faecal P excretion, even though P was absorbed to a higher percentage in the small intestine. In addition, the ileocaecal flow of Ca and P and the faecal excretion of Ca and P were correlated, with the exception of one trial with extremely low Ca intake and an inverse Ca/P ratio (Schünemann et al., 1989). Schünemann et al. (1989) also found a relationship between the net absorption of Ca in the colon (calculated as percentage of ileocecal Ca flow) and the Ca concentration in ileal chyme. This suggests an effect of dilution on passive Ca absorption.

In the present study, faecal Ca excretion increased with increasing faecal DM excretion at a rate of about 100 mg Ca per g DM excretion (Figure 1). Even a relatively small difference of 0.6 g faecal DM excretion per kg BW increased faecal Ca excretion by 26% and reduced apparent Ca digestibility from 18% to negative. This finding is very important for research on Ca in dogs. Factors influencing Ca absorption can only be tested if the excretion of faecal DM is practically identical between experimental and control group, otherwise the researchers will just describe a faecal DM excretion effect. The results of the present study show that faecal DM excretion is an important factor for the estimation of Ca as well as to lesser extent P requirements in dogs because higher DM intake and/or lower DM digestibility increase faecal Ca and P losses.

5 | CONCLUSIONS

In conclusion, faecal DM excretion influences the faecal Ca and P positively and apparent Ca and P digestibility negatively. A high faecal DM excretion can therefore increase Ca and P requirements.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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