Article

Digestibility, fecal characteristics, and plasma glucose and urea in dogs fed a commercial dog food once or three times daily

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Abstract — Digestibility, fecal characteristics, and levels of glucose and urea in the plasma were determined in 8 dogs that received 2 different dog foods once or 3 times daily. One dog food (A) was 5 times more expensive than the other (B). Fecal pH and consistency, digestibility of dry matter (DM), organic matter (OM), crude protein (CP), and crude fiber (CF) were determined. Blood samples were taken from 30 min before to 60 min after a meal. Digestibilities of DM, OM, and CP, and fecal consistency were higher, and daily fecal excretion and fecal pH were lower when dogs were fed food A ($P < 0.001$). The feeding schedule had no effect on plasma glucose and urea. Neither feeding frequency nor food × frequency interactions was significant for the parameters studied.

Résumé — **Digestibilité, caractéristiques fécales, glycémie veineuse et urée chez les chiens nourris une fois ou trois fois par jour avec de la nourriture commerciale pour chiens.** La digestibilité, les caractéristiques fécales et les taux de glucose et d'urée dans le plasma ont été déterminés chez 8 chiens qui ont reçu 2 types différents de nourriture pour chiens 1 fois ou 3 fois par jour. Une nourriture pour chiens (A) était 5 fois plus dispendieuse que l'autre (B). Le pH et la consistance des fèces, la digestibilité des matières sèches (MS), des matières organiques (MO), des protéines brutes (PB) et des fibres brutes (FB) ont été déterminés. Des échantillons de sang ont été prélevés entre 30 minutes avant le repas et 60 minutes après le repas. La digestibilité des MS, des MO et des FB et la consistance fécale étaient supérieures et les excrétions fécales quotidiennes et le pH fécal étaient inférieurs lorsque les chiens étaient nourris avec la nourriture A ($P < 0,001$). L'horaire d'alimentation n'avait aucun effet sur la glycémie veineuse ni l'urée. Ni la fréquence d'alimentation ni la nourriture × les interactions de fréquence n'étaient significatives pour les paramètres étudiés.

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Introduction

The broad varieties of commercial dry dog foods in the marketplace have wide price ranges and are composed of numerous ingredients of different qualities. The apparent digestibility of the food relates to the proportion of nutrients absorbed in the gastrointestinal tract and digestibility trials are used to determine this. Huber et al (1) compared low-priced and high-priced dry dog foods with identical label guaranteed analysis and found that that the low-priced ones had lower dry matter digestiby.

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Digestibility can also be affected by feeding frequency; it has been reported that an increased eating frequency was positively correlated with digestibility coefficients in pigs (2,3). Differences in food digestibility are also associated with differences in fecal characteristics. Highly digestible diets result in low fecal outputs and firm fecal consistencies, characteristics that are of interest to pet owners (4).

Feeding frequency is also related to the management of pathologies such as diabetes mellitus and kidney diseases. In fact, several small meals per day together with insulin result in minimal glycemic responses (5,6). Additionally, postprandial plasma urea levels increase as greater amounts of protein are consumed (7), and postprandial blood urea levels could be reduced by supplying the protein requirements in 2 or 3 small meals per day, rather than in only 1 meal (8). It is therefore of interest to study physiological consequences of feeding frequencies.

The aim of this research was to evaluate whether or not the feeding frequency of 2 commercial dry dog foods with different market prices affects the apparent digestibility, fecal parameters, and plasma glucose and urea in dogs.

Materials and methods

Eight healthy adult cocker spaniels (5 female and 3 male) with body weights (BW) of 10.4 ± 1.5 kg were used. The animals

Table 1. Dry matter (DM), organic matter (OM), crude protein (CP), and crude fiber (CF) contents of dry dog foods A and B used in this study

	Food A	Food B
DM (g/kg)	883.0	889.0
OM (g/kg DM)	938.4	866.0
CP (g/kg DM)	292.0	186.0
CF (g/kg DM)	33.3	94.6

were housed in 2.0 m × 2.0 m individual cages located in the Canine Nutrition Experimental Unit (Facultad de Veterinaria, UdelaR, Montevideo, Uruguay). All procedures were approved by the Bioethics Committee of the Facultad de Veterinaria. The dogs were fed 2 commercial dry dog foods (A and B) once or 3 times daily. Food A was 5 times more expensive than food B. The chemical composition of the foods is presented in Table 1. The dogs were allotted randomly to feed in a double 4 × 4 Latin square design. Each square consisted of 4 dogs allotted randomly to 4 feeds (A once, A 3 times, B once, B 3 times) during 4 consecutive periods. Both Latin squares were carried out independently and simultaneously. Hence in each period, 2 dogs received the same feed sequence and all the dogs received all feed sequences throughout the experiment. Each experimental period consisted of a 5-day diet adaptation phase, followed by 3 d for collection of feces, and 1 d for blood sampling. The animals were fed 43 g DM/kg $BW^{0.75}$/d of each food. Daily rations were offered at 08.00 h when feeding frequency was once daily (A1, B1) or divided into 3 equal meals and offered at 0800 h, 1400 h, and 1800 h, when feeding frequency was 3 times daily (A3, B3). Dogs had free access to fresh water, and all food was completely consumed throughout the experiment.

During the sample collection phase, all feces were removed from the cages 3 times daily after meals. Fecal consistency and fecal pH were determined immediately. Feces consistency was scored using a scale of 1 (liquid) to 5 (firm) as described by Strickling et al (9). Fecal pH of 1 g of feces in 10 mL of distilled water was measured using a digital pH meter (eChem Instruments Pte, Oakton, Singapore). Individual fecal samples were weighed, placed in plastic bags, and immediately frozen. At 0800 h of day 9 of each experimental period, blood samples were obtained every 15 min from the saphenous vein, beginning 30 min before the meal and finishing 60 min later. Blood samples were taken in 5 mL tubes containing sodium and potassium salts of EDTA and potassium fluoride in solution (Anticoagulant G, Wiener Laboratorios, Rosario, Argentina), and centrifuged at 1917 × *g* for 10 min to separate the plasma, which was stored at −18°C.

Fecal samples were later thawed and mixed so that pooled samples were representative of each dog and period. Food and fecal samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), and crude fiber (CF) (10). Apparent digestibility was calculated as:

$$\frac{\text{nutrient intake (g/d)} - \text{fecal nutrient output (g/d)}}{\text{nutrient intake (g/d)}} \times 100\%$$

Plasma samples were thawed and analyzed using enzymatic colorimetric kits for glucose (GLUCOSE liquicolor, Human Gesellschaft fur Biochemica und Diagnostica mbH, Wiesbaden, Germany) and urea (UREA/BUN-COLOR, BioSystems, S.A. Costa Brava 30, Barcelona, Spain).

Statistical analysis

Digestibilities (DM, OM, CP, CF), fecal consistency scores, wet fecal output, fecal DM, and fecal pH data were analyzed for the effects of commercial food type (A and B), feeding frequency (1 and 3), and food × frequency interaction using orthogonal contrasts. Plasma glucose and urea levels were analyzed by the PROC MIXED procedure and the model included as fixed effects: dry dog food, frequency and time and their interactions, and animal and period as random effects. The covariance structure was autoregressive order 1. All data were analyzed using Statistical Analysis System (SAS Institute, Cary, North Carolina, USA), with $P < 0.05$.

Results

All dogs remained healthy throughout the study. There were no differences in DM, OM, and CP apparent digestibilities when comparing feeding frequencies or the interaction between food × frequency (Table 2). However, differences between foods did exist for nutrient digestibility. Food A had higher digestibility of DM, OM, and CP (18.1%, 15.3%, and 7.4%, respectively) than food B ($P < 0.001$) for both feeding frequencies. Neither feeding frequency nor type of food affected the digestibility of CF.

The dogs had higher wet fecal output with lower fecal consistency scores when they ate food B (Table 3). Fecal DM content was not different between feed sequences. Fecal pH was lower when dogs ate food A. Neither feeding frequency nor food × frequency interaction had any effect on the fecal parameters studied.

Mean plasma glucose, and urea concentrations and the effects of food, feeding frequency, time of sampling, and their interactions are presented in Table 4. The basal plasma glucose and urea levels for all feed sequences were similar before the meal time (time −30 min to time 0; Figures 1 and 2). Both parameters increased after the meal, and only food × time interaction was significant for glucose. The maximum increases with respect to the basal values were 0.78, 0.88, and 0.54 mmol/L for A1, A3, and B1 feeds, respectively, at 60 min, and 1.05 mmol/L 45 min after the meal for feed B3. The shapes of the glucose curve for foods A and B were different as the interaction food × time was significant. Plasma urea concentrations tended to increase throughout the measurement period and higher values were registered 60 min after the meal for all feed sequences.

Discussion

A major finding in this study was that the apparent digestibility of the nutrients that were investigated were unaffected by feeding frequency for the intake level assigned to the animals. Likewise, Chastanet et al (11) found no differences in apparent gross energy digestibility or in DM digestibility in pigs fed once or twice daily. Other researchers (2,3) reported that an increase in the number of meals per day had a positive influence on the digestibility of nutrients at equal level of intake in pigs.

Table 2. Apparent digestibility of dry matter (DM), organic matter (OM), crude protein (CP) and crude fiber (CF) in dogs fed commercial dry foods once or 3 times daily

	Feed sequence					P		
Digestibility[a]	A1	A3	B1	B3	S_x	A versus B	1 versus 3	Interaction[b,a]
DM	81.8	84.9	71.0	70.1	1.66	< 0.001	ns	ns
OM	85.4	88.0	75.5	74.9	1.36	< 0.001	ns	ns
CP	86.8	88.3	81.5	81.6	1.18	< 0.001	ns	ns
CF	19.0	44.3	36.7	28.0	5.51	ns	ns	ns

[a] Values shown are mean percentages.
[b] Food × frequency.
A1 — food A fed once daily; A3 — food A fed 3 times daily; B1 — food B fed once daily; B3 — food B fed 3 times daily.
S_x — standard error of the mean; P — probability of a significant difference; A versus B — food A versus food B; 1 versus 3 — once versus 3 times daily; ns — not significant ($P > 0.05$).

Table 3. Wet fecal output, fecal dry matter, fecal consistency score and fecal pH in dogs fed commercial dry foods once or 3 times daily

	Feed sequence[a]					P		
	A1	A3	B1	B3	S_x	A versus B	1 versus 3	Interaction[b,a]
Wet fecal output (g/d)	123	115	217	209	13.4	< 0.001	ns	ns
Fecal DM (%)	33.6	33.0	34.0	35.6	0.78	ns	ns	ns
Fecal score	3.84	3.83	2.92	3.15	0.07	< 0.001	ns	ns
Fecal pH	6.52	6.66	7.03	7.07	0.10	< 0.001	ns	ns

[a] Values shown are means.
[b] Food × frequency.
Fecal consistency scores: on a 1 to 5 scale with 1 — liquid feces; and 5 — firm feces.
A1 — food A fed once daily; A3 — food A fed 3 times daily; B1 — food B fed once daily; B3 — food B fed 3 times daily.
S_x — standard error of the mean; P — probability of a significant difference; A versus B — food A versus food B; 1 versus 3 — once versus 3 times daily; ns — not significant ($P > 0.05$).

Table 4. Mean plasma glucose and urea concentrations in dogs fed commercial dry foods once or 3 times daily

	Feed sequence[a]				P			Interactions			
	A1	A3	B1	B3	Food	F[b]	T[c]	Food × F	Food × T	F × T	Food × F × T
Glucose (mmol/L)	4.47	4.48	4.31	4.52	ns	ns	< 0.001	ns	0.016	ns	ns
Urea (mmol/L)	5.61	6.19	6.11	6.75	ns	ns	< 0.001	ns	ns	ns	ns

[a] Values shown are means.
[b] F — meal frequency.
[c] T — time.
A1 — food A fed once daily; A3 — food A fed 3 times daily; B1 — food B fed once daily; B3 — food B fed 3 times daily.
P — probability of a significant difference; ns — not significant ($P > 0.05$).

As found herein, Huber et al (1) reported that low-priced dry dog foods had lower nutrient digestibilities than did high-priced ones. In contrast, Krogdahl et al (12) reported no association among price, nutrient content, and digestibility in commercial dog foods. The foods evaluated by Krogdahl et al (12), however, were uniform in composition independent of price category, with no CF higher than 3% and no ash content greater than 8%. The foods used in this study had important differences in CF and ash contents (Table 1); the higher level of CF in food B could have decreased its digestibility values and elevated the fecal consistency score. Researchers have reported a decrease in nutrient digestibility with increasing levels of fiber in the diet (13,14). There is a good explanation for this since fiber is indigestible for dogs (15), and high levels of fiber in the diet can decrease the transit time through the gastrointestinal tract (16,17), limiting the time of contact between feed and enzymes, and digestion products and absorptive surfaces (2).

Fecal consistency can be determined by either fecal consistency scores or fecal DM content (4). In this experiment when dogs were fed food B, fecal consistency scores were lower and wet fecal output was higher ($P < 0.001$); both parameters were unaffected by feeding frequency. In other publications, lower fecal consistencies were associated with lower fecal DM contents and lower digestibilities of OM (18–20). Zentek et al (21) reported that for dry diets, higher fecal consistency scores coincided with higher fecal DM content. However, in this study,

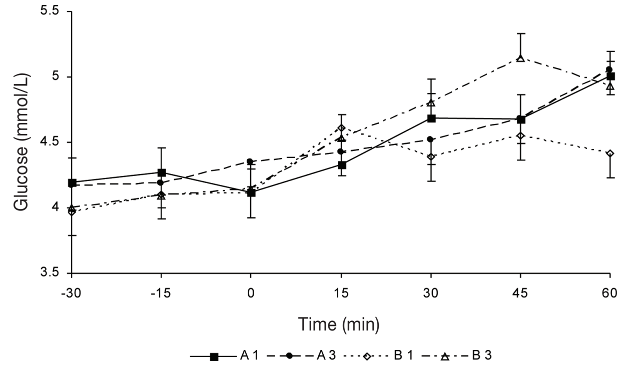

Figure 1. Plasma glucose concentrations in dogs fed commercial dry foods once or 3 times daily (mean ± standard error). 0 time indicates meal.

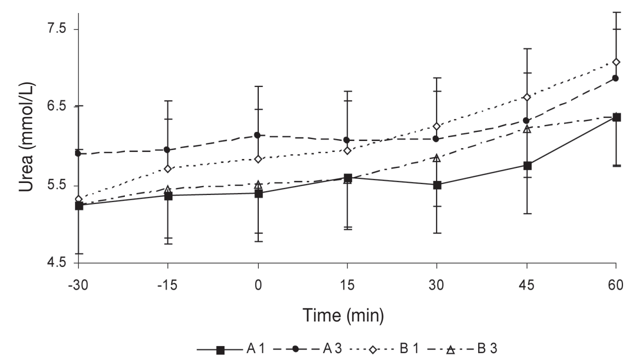

Figure 2. Plasma urea concentrations in dogs fed commercial dry foods once or 3 times daily (mean ± standard error). 0 time indicates meal.

fecal DM was not different for dogs on either type of food, and fecal consistency was significantly lower when dogs ate food B. This could be due to the high fiber content of food B and probably to the solubility of the fiber. Twomey et al (22), studying the effects of inclusion of soluble non-starch polysaccharides in diets of dogs, found that small variations in fecal DM can be associated with relatively large variations in the fecal consistency, and that fecal consistency score was a more sensitive method than DM content. Additionally, Sunvold et al (4) reported poor correlations between fecal DM and fecal consistency and concluded that fecal consistency score was more indicative of fecal characteristics than was DM content.

In this work, fecal pH was unaffected by feeding frequency and was lower when dogs received food A ($P < 0.001$), suggesting that a higher yield of organic acids in the hindgut may be due to a higher content of fermentable substrates. A reduction in fecal pH indicates increased fermentation in the colon (23) resulting in accumulation of lactic acid and short-chained fatty acids (22) that can be used as an energy source by colonocytes, contribute to normal large bowel function, and prevent pathology (24).

Plasma glucose peaks were not detected in this study. Values increased throughout the measurement period, which was not long enough to detect peaks. However, Nguyen et al (25) reported that glycemic peaks occurred, on average, 50 min after the ingestion of commercial dog foods, and the mean maximum glycemic increments were 1.11 mmol/L. Although there were no differences within feed sequences for glycemic responses herein, other researchers have reported that pigs fed several meals compared with 1 meal per day had lower postprandial blood glucose levels (3). Anderson and Edney (8) suggested that the postprandial plasma urea increment could be reduced by offering the daily protein requirements in 2 or 3 small meals instead of only 1. Nevertheless, in the present study there was no effect of feeding frequency or of type of food on postprandial plasma urea responses. As with glucose, the measurement period was not long enough to detect plasma urea peaks.

The results from the current study indicate that feeding 3 meals per day at this feeding level had no benefits on nutrient digestibility, fecal parameters, and plasma glucose and urea when compared with only 1 meal. The high-priced dry dog food had higher nutrient digestibility, less fecal output, more solid feces, and lower fecal pH values than the low-priced one. Further investigations are required to evaluate nutritional and metabolic parameters at different feeding levels. CVJ

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Book Review
Compte rendu de livre

Techniques in Large Animal Surgery, 3rd edition

Hendrickson DA, ed. Blackwell Publishing Professional, Ames, Iowa, USA. 2007. 312 pp. ISBN 978-0-7817-8255-5. $119.99

This classic surgical text has been updated and revised in the new edition. While the chapter order remains the same, new sections within certain chapters have been added.

The chapter on anesthesia has been updated, as has the section on instrumentation, and instruments that are less frequently used have been removed. The skin grafting chapter has been extended and now includes tunnel grafting and random pattern flaps as well as post-operative bandaging and graft care. The chapter dealing with suture materials and needles has been expanded and includes a table of commonly used suture material which is easy to read and allows rapid comparison between different suture types. Similarly the knots and ligatures section has been improved.

Advances in surgery, including arthroscopy for carpal joint surgery, laparoscopy for cryptorchidectomy, and laser techniques as they pertain to upper airway surgery are discussed.

This 3rd edition has the feel of a textbook, with important underlying principles as well as the technical step-by-step descriptions of how to perform the procedures, rather than simply being a technical manual. The illustrations, as with previous editions are a major plus. These, combined with the fact that this is a large animal surgical text (not simply equine) set it apart from other texts in this field and make this book well worth the purchase price.

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