Effects of diet on clinical signs of exocrine pancreatic insufficiency in dogs

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Objective—To assess the effects of dietary modification on clinical signs of exocrine pancreatic insufficiency (EPI) in dogs.

Design—Blinded randomized crossover study.

Animals—21 dogs with EPI.

Procedure—Dogs were fed the diet they received at home for 2 weeks. Thereafter, they received 3 special diets (a high-fat diet, a high-fiber diet, and a highly digestible low-residue diet) for 3 weeks each. Owners scored dogs daily for the last 2 weeks of each 3-week period for severity of 6 clinical signs including appetite, defecation frequency, consistency of feces, borborygmus, flatulence, and coprophagia. An EPI index was calculated for each dog by adding the daily scores for each clinical sign.

Results—Significant differences in daily EPI indices among diets were observed in 20 dogs. The original diet appeared to be the most suitable in 8 dogs, whereas the high-fat diet was most suitable in 5 dogs, the high-fiber diet was most suitable in 4 dogs, and the low-residue diet was most suitable in 2 dogs. In 1 dog, the lowest EPI index score was the same during the original diet and the high-fat diet feeding periods. One dog did not complete the feeding period for the high-fiber diet. Differences in mean EPI indices among diets were not significant.

Conclusions and Clinical Relevance—Results indicated that responses to different diets varied among individual dogs. Because responses to the feeding regimens were unpredictable, it is suggested that feeding regimens be individually formulated for dogs with EPI. (*J Am Vet Med Assoc* 2006;228:225–229)

In dogs with EPI, lack of pancreatic digestive enzymes causes the typical clinical signs of polyphagia, weight loss, voluminous feces with pulpy and loose consistency, coprophagia, steatorrhea, borborygmus, and flatulence.[1-4] Treatment for EPI includes providing supplementary enzyme extracts at each meal.[4,5] However, it is not possible to entirely compensate for lost exocrine pancreatic function with enzyme supplementation.[2,6] Absorption of nutrients, particularly fat and carbohydrates, remains diminished, and unabsorbed nutrients contribute to the severity of clinical signs.[2,7] Dietary modification has also been suggested to play an important role in the management of EPI.[5,7-9] However, results of clinical feeding studies[5,9-12] are not always in agreement regarding the benefits of special diets. Some authors[13] have suggested that most dogs with EPI do not require dietary modification but may be fed their regular diet. Because of these discrepancies in feeding recommendations for dogs with EPI, the study reported here was performed to assess the effects of dietary modification on clinical signs in dogs with EPI.

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Materials and Methods

The experimental protocol was approved by the ethics committee for animal experiments at the University of Helsinki, Finland. Medical records from January 1991 to December 1993 at the University Veterinary Teaching Hospital were reviewed, and owners of dogs with a diagnosis of EPI were contacted. The diagnosis of EPI was made on the basis of typical clinical signs, low serum trypsinlike immunoreactivity,[14] and negative results for fecal protease in a soybean stimulation test.[15]

Four feeding periods were conducted during a period of 14 weeks in each dog's home. During the 2-week control period, all dogs were fed the diet they customarily received at home. Thereafter, 3 special diets were fed for 3 weeks each. Dogs were randomly allocated to 1 of 6 possible sequences of the diets, with 3 or 4 dogs in each group. Dogs' owners were unaware of the order in which the special diets were fed. All food cans were similar in appearance and were labeled only with a code number. Dogs were allowed to become accustomed to each new diet for 1 week before the commencement of each recording period, so that data were recorded for the last 2 weeks of each 3-week period. Except for the different diets, dogs lived in their home environments with no changes.

The original diets (ie, fed before the study) differed from dog to dog and usually consisted of commercial dry kibble plus homemade food (eg, beef, chicken, rice, and potato). The special diets were a high-fat diet,[a] a low-fat high-fiber diet,[b] and a low-residue (ie, highly digestible, moderate-fat) diet.[c] The 3 special diets were fed in canned form. Nutrient and energy contents of the diets as reported by the manufacturer were summarized (**Table 1**). Bacterial culture was performed on samples of each special diet. Owners fed all diets twice a day in a quantity necessary to maintain the dogs' body weight. Dogs were weighed by owners every other day during the first week and then once per week for the next 2 weeks of each feeding period. Total daily consumption of the

Table 1—Nutrient (% dry matter) and energy (kJ/g) content of 3 special diets fed to 21 dogs with EPI. Dogs were first fed their home diet for 2 weeks and then received each of the special diets for 3 weeks.

Variable	High-fat diet	Low-residue diet	High-fiber diet
Moisture	70.0	70.1	75.8
Protein	30.3	25.4	25.6
Fat	27.3	14.7	7.0
Fiber	1.0	0.7	25.2
Carbohydrate	34.0	51.2	36.0
Energy	19.6	17.6	9.8

EPI Exocrine pancreatic insufficiency

special diets was recorded by the owners. Mean daily consumption of each diet was calculated from values for the last week of each feeding period. Enzyme supplementation[d] was maintained throughout the study at a dosage of 3 g/25 kg of body weight (3 g/55 lb) administered orally per meal.

Dogs were assessed by owners daily for 21 days and scored for the following clinical signs: appetite, defecation frequency, consistency of feces, flatulence, borborygmus, and coprophagia. Data were recorded such that the lowest score of 0 represented a clinical sign least typical of EPI, and the highest score of 3 represented a sign most typical of EPI (**Appendix**). An EPI index was calculated by adding the daily scores for each sign.

During the last week of each diet, owners collected dogs' feces over a 24-hour period. Feces were stored at –20°C while awaiting processing, and all samples were analyzed at the end of the study. For analyses, feces were thawed, weighed, and homogenized. Fecal fat excretion was determined by a modification of the van de Kamer method.[16] Fecal enzyme activities of protease, amylase, and lipase were determined via radial gel diffusion in a described method.[17]

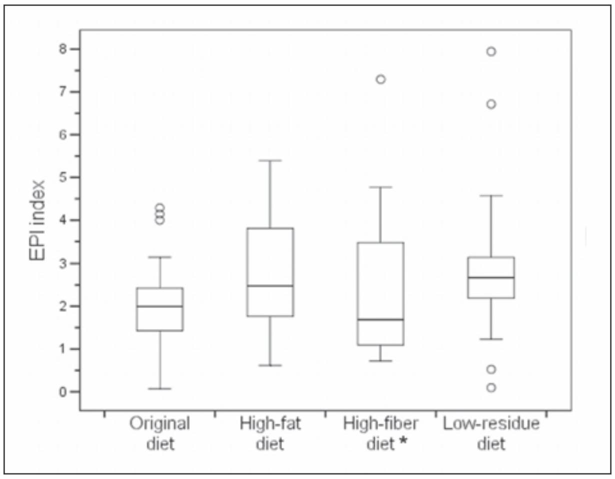

Figure 1—Box plots of EPI indices of 21 dogs with EPI during 2-week-long feeding trials for each of 4 diets with different nutrient content. Box indicates interquartile range, line in box indicates median, whiskers indicate range, and circles indicate outliers. *One dog did not complete the feeding period for the high-fiber diet. *See* Appendix for scoring system used to calculate EPI indices.

Statistical analysis—The Friedman test for multiple treatments with same subjects and multiple comparison tests were used to evaluate differences among diets in feeding-period mean EPI indices, clinical signs, consumption, fecal variables, and body weight. Pairwise comparisons between mean ranks for all 4 diets were performed. Overall error rate was controlled by setting the error rate for each test to 0.05 divided by the number of comparisons. One dog (dog No. 8) did not complete the high-fiber diet feeding period and was excluded from those analyses. For all dogs, the Kruskal-Wallis 1-way ANOVA was applied, incorporating the daily EPI index values as input, to determine whether there were differences in EPI indices among diets in any given dog. The Spearman correlation coefficient was used to test associations among variables. For all analyses, values of $P < 0.05$ were considered significant.

Results

Twenty-one dogs with EPI were included in the study. Breeds represented were the German Shepherd Dog (11 dogs), Rough-coated Collie (9), and mixed-breed dogs (1). Dogs' ages ranged from 2 to 6 years. Dogs had been given enzyme replacement treatment for at least 6 months prior to the study. All dogs were in good clinical condition despite the illness, and none were receiving medication other than enzyme supplementation. Comparison of mean EPI indices for each feeding period in all 20 dogs that completed the study revealed no significant differences in scores among the 4 feeding periods ($P = 0.195$). In general, the mean EPI index was lowest (best) while dogs were consuming the original diets. Among the special diets, lowest (best) mean values for EPI index were associated with consumption of the high-fiber diet and median values for EPI index for that diet were better than those associated with the original diet (**Figure 1**; **Table 2**).

Table 2—Variables (mean [range]) associated with feeding 4 diets to dogs with EPI.

Variable	Original diet	High-fat diet	High-fiber diet*	Low-residue diet
EPI index†	2.07 (0.0–4.29)	2.82 (0.62–5.38)	2.47 (0.71–7.29)	2.89 (0.10–7.94)
Appetite†	0.56 (0–2.00)	0.44 (0–2.00)	0.66 (0–2.00)	0.36 (0–2.00)
Defecation frequency per day†	0.54[a] (0–2.50)	0.82[ab] (0–2.05)	1.12[b] (0–2.59)	0.93[b] (0–2.78)
Consistency of feces†	0.31[ab] (0–1.00)	0.64[a] (0–1.43)	0.14[b] (0–1.00)	0.69[a] (0–2.00)
Flatulence†	0.33 (0–1.36)	0.43 (0–1.60)	0.26 (0–1.18)	0.43 (0–1.62)
Borborygmus†	0.28 (0–1.36)	0.43 (0–1.60)	0.22 (0–1.24)	0.43 (0–1.72)
Coprophagia†	0.04 (0–0.86)	0.06 (0–0.76)	0.07 (0–0.81)	0.05 (0–0.76)
Consumption‡ (g/kg[BW]/d)	39.8 (15.6–92.0)	53.4[a] (20.0–88.0)	71.8[b] (19.1–121.3)	53.3[a] (28.1–93.6)
Consumed fat (g/kg[BW]/d)	2.22[ab] (0.25–6.41)	4.38[c] (1.60–7.20)	1.23[a] (0.32–2.10)	2.33[b] (1.20–4.20)
Feces (g/kg[BW]/d)	9.8[a] (3.6–22.0)	14.4[ab] (2.2–32.9)	23.0[b] (4. –52.5)	16.7[ab] (4.4–63.3)
Fecal fat (g/kg[BW]/d)	0.31[a] (0.04–0.90)	0.70[b] (0.10–2.10)	0.21[a] (0.02–0.67)	0.31[a] (0.02–1.50)
Fecal protease (U/g)	262[a] (0–878)	265[a] (99–987)	80[b] (0–347)	142[b] (6–596)
Fecal amylase (U/g)	2.36[a] (0.05 7.90)	1.81[a] (0.07–6.49)	0.26[b] (0.04–1.86)	0.36[b] (0–2.06)
Fecal lipase (U/g)	19.3[a] (0–60.0)	13.3[ab] (0–96.8)	8.1[b] (0–37.9)	11.3[ab] (0–47.9)
Body weight (kg)	27.3 (16.0–42.0)	27.4 (16.8–42.0)	26.6 (16.0–41.4)	27.0 (16.0–42.0)

*One dog did not complete the feeding period for the high-fiber diet. †*See* Appendix for scoring system. ‡Original diet was excluded when testing for differences in consumption.

BW = Body weight.

[a-c]Diets with the same superscript letter were not significantly ($P < 0.05$) different.

To convert kilograms to pounds, multiply by 2.2.

Interindividual variation in EPI index scores associated with the different diets was high. The effect of the different diets on the EPI index of each dog was assessed by comparing daily indices during the feeding periods. In 20 of the 21 dogs, significant differences among feeding periods were observed. The original diet resulted in the lowest or best EPI index score in 8 of 20 (40%) dogs (dog No. 8 excluded), the high-fat diet was best in 5 of 20 (25%) dogs, the high-fiber diet was best in 4 of 20 (20%) dogs, and the low-residue diet was best in 2 of 20 (10%) dogs. In 1 dog, the lowest EPI index scores during feeding of the original and high-fat diets were equal. In some dogs, EPI index scores for 2 diets differed only slightly. Results indicated that the effect of the study diets on dogs' well-being was unpredictable.

The diets appeared to influence certain clinical signs associated with EPI (Table 2). During the high-fiber and low-residue diet feeding periods, frequency of defecation was significantly higher than during feeding of the original diet. Fecal consistency was significantly firmer with the high-fiber diet than with the other 2 special diets. Flatulence and borborygmus were decreased with the high-fiber diet, compared with the other diets. Coprophagia was seldom observed in any feeding period.

Dogs' mean daily consumption of the less energy-dense high-fiber diet was significantly higher than consumption of the other special diets. Mean consumption of fat varied significantly among the special diets and was lowest with the high-fiber diet and highest with the high-fat diet. Mean fluctuation in body weight of the dogs was ± 800 g during all feeding periods. Pathogenic bacteria were not detected via bacterial culture of any samples from the special diets.

Volume of feces and fecal fat excretion were affected by diet. Fecal volume was significantly increased during the high-fiber diet feeding period, compared with volume observed with the original diets. Fecal fat excretion was significantly higher during the high-fat diet feeding period than with the other diets (**Figure 2**); mean daily fecal fat excretion was 0.7 g/kg of body weight, a value that is consistent with mild steatorrhea,

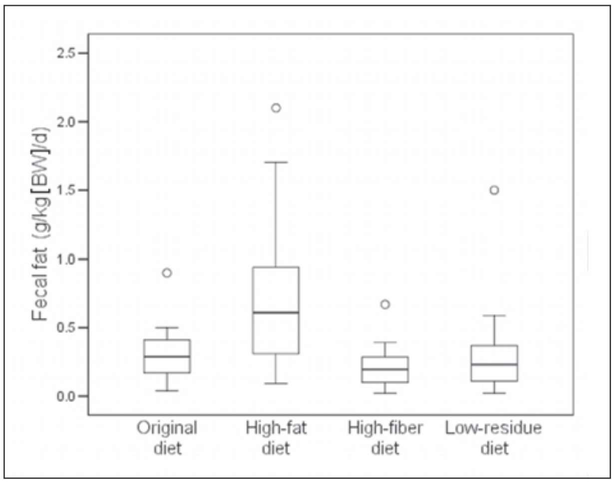

Figure 2—Box plots of fecal fat content in the same dogs as in Figure 1. BW = Body weight. *See* Figure 1 for remainder of key.

whereas during feeding with the original high-fiber and low-residue diets, results of tests for fecal fat were within reference range.[6]

A significant decrease in fecal protease and amylase activities was observed during the high-fiber and low-residue diet feeding periods, compared with the other diets. Values for fecal lipase activity associated with the high-fiber diet were significantly lower than with the original diet (Table 2). There was a significant negative correlation ($r_s = -0.36$; $P < 0.001$) between fecal lipase activity and fecal fat excretion. No relationship between fecal protease activities and EPI index was detected.

During the study, 9 dogs had sporadic gastrointestinal disturbances and a short course of orally administered tylosin[e] (dose, 20 mg/kg [9 mg/lb]) was given every 12 hours for 1 to 3 days. These problems were most apparent with the low-residue diet, affecting 7 dogs. In 1 dog, the high-fat diet was discontinued 2 days earlier than planned because of excessive flatulence, and 1 dog refused to eat the high-fiber diet.

Discussion

Clinical feeding studies have yielded contrasting results on the benefits of special diets as treatment for dogs with EPI. We previously investigated[11,12] the use of 2 special diets, and our findings indicated that a highly digestible low-fiber diet alleviated certain clinical signs of EPI, but that the low-fat diet resulted in no significant changes in clinical signs. Advantages of feeding special diets were minimal in our recent study[10] of long-term treatment of EPI in dogs. The chief aim of the present study was to elucidate how owners of dogs with EPI should feed affected pets. Therefore, dogs were fed 4 diets of substantially different composition, and an EPI index score was calculated. Because the composition of dogs' original diets was not analyzed, it is possible that the original diets in some dogs did not differ substantially in content from certain special diets. The EPI index has been validated as a reliable means of comparing effects of various feeding regimens,[11,12] with values increasing when enzyme supplementation is decreased in dogs with EPI.[12] Use of the index does, however, pose certain practical difficulties. When owners act as observers, interobserver variation is high because evaluation of some signs is subjective. Moreover, certain factors, including stress and the stealing of food, cannot be controlled in studies such as this. In our study, the effects of single erroneous evaluations were minimized by calculation of mean scores over a protracted period. The time required for adaptation when diets are changed is not known; it is possible that the adaptive intervals in our trial should have been longer. The feeding of the special diets was carried out with owners unaware of diets' compositions with the intention of diminishing subjective effects during owner scoring.

In individual dogs, values of the daily EPI indices varied significantly among the different diets. This result indicates that diet plays an important role in the treatment of dogs with EPI. However, results also indicated that there was marked interindividual variation among dogs. This observation is problematic with regard to using the information to formulate instructions for feeding affected dogs and was the primary reason why no significant differences were detected in the mean EPI index values among the 4 diets. The original diet fed at home resulted in the lowest EPI index score for 8 of 20 (40%) dogs and for 1 dog in which the original and high-fat diets yielded equal EPI scores.

An unexpected finding was that 5 of 20 dogs fed the high-fat diet and 4 fed the high-fiber diet had low (good) EPI index scores because those diets have been proposed to adversely affect dogs with EPI.[18] For purposes of comparing the influence of different diets by use of the EPI index, it should be remembered that the index incorporates 6 clinical signs. One diet might increase the severity of 1 clinical sign while simultaneously decreasing the severity of another sign, thus having a net effect of zero on the EPI index. This was observed particularly in dogs fed the high-fiber diet, which increased the severity of certain clinical signs and decreased the severity of others.

Some investigators[2,19] have concluded that a high-fiber diet should be avoided in dogs with EPI because fiber may further diminish the absorption of other nutrients. Moreover, certain fibers inhibit the activity of pancreatic enzymes, especially lipase.[19] The high-fiber diet is restricted in fat and energy content and thus is recommended for use when weight reduction is desired. Although there were no marked changes in body weights of dogs during the 3-week feeding periods, some dogs had mild weight loss, likely a result of the difficulty in consuming sufficient food to meet daily energy requirements. Increased food consumption and poor digestion caused significant increases in fecal mass. The frequency of defecation was also increased, likely as a result of the influence of fiber on intestinal transit time. In addition to the negative effects of fiber, positive effects were also noticed; fecal consistency was better (ie, firmer) than that observed with the other diets, and flatulence and borborygmus were reduced.

Because enzyme supplementation alone cannot restore normal fat absorption in dogs with EPI, a low-fat diet has been considered necessary to achieve a favorable response. However, results of 1 study[20] indicate that a diet with a high proportion of fat corrects steatorrhea in dogs with EPI. Orally administered lipase is destroyed by the acidic conditions in the stomach, and up to 90% of lipase activity is lost before lipase reaches the duodenum.[7] In dogs with small intestinal disease, fat absorption may also be negatively influenced by bacterial deconjugation of bile salts, an action that produces metabolites that in turn may result in diarrhea.[5,9,21] Simpson et al[9] reported that during the initial period of enzyme treatment, a low-fat diet is important for achievement of a satisfactory treatment response. Results of an earlier study[12] with low-fat diets in affected dogs, however, did not reveal an association between a decrease in fat intake and alleviation of clinical signs. In the present trial, we studied the response of dogs with EPI to excessive dietary fat. The EPI index scores of dogs fed the high-fat diet were not significantly different from those of dogs fed the original diets, although the content of the original diet was unknown. However, we only measured the quantitative fecal fat excretion over a 24-hour period because the methodology for conducting the measurements is time consuming and unpleasant. Single-day collection of feces has been reported[16,22] to provide reliable results, although a 72-hour collection period is preferable. The effect of the dietary fat content was obvious during the high-fat feeding period in that fecal fat output was significantly increased, compared with output during the other feeding periods. During the feeding periods for the original, low-residue, and high-fiber diets, mean fecal fat excretion was within reference range, indicating that fat absorption returns to normal with enzyme supplementation in most dogs. The fecal consistency in dogs fed a high-fat diet was much poorer than when fed their original diet.

Findings from an earlier study[11] indicated that clinical signs of EPI may be alleviated when a dog's original diet is changed to a low-residue diet. However, in the present study, the low-residue diet was not superior to the other diets but, rather, yielded results that were contradictory in certain respects. That diet was only the best diet (as per the calculated EPI index) for 2 dogs. An unexpected finding associated with feeding the low-residue diet was that fecal mass was greater with that diet than with the original and high-fat diets. In another study,[2] consistent reductions in fecal mass were detected in dogs fed a low-fiber diet. In the present study, the low-residue diet induced unexpected gastrointestinal tract disturbances in some dogs and such disturbances were likely responsible for the high EPI scores. The etiology of the gastrointestinal tract disturbances associated with the low-residue diet remains undetermined. An explanation for the divergent results in the previous[11] and present studies with low-residue diets may lie in the different form of the feeds used. In the first study,[11] a dry diet was used, which was in contrast to the canned form used in the present study. Nevertheless, feeding dry versus canned food has not been reported to significantly change fecal moisture.[23] The possibility of bacterial contamination of the diets in this study was ruled out by bacterial culture of each diet.

No protease activity can be detected in the feces of untreated dogs with EPI. Detected amounts of amylase and lipase are minimal, and these enzymes are probably not of pancreatic origin.[2,15] In fecal samples in our study, amylase and protease activities were variable, but in many samples, no lipase activity was detected. This is probably a result of destruction of lipase during passage through the intestinal tract. Storage of fecal samples before analyses may have affected results because lipase may be inactivated during storage.[15] The detection of high fecal protease activity in feces of dogs with EPI during enzyme supplementation may be considered an indication that the treatment is adequate and that consumption or destruction of enzymes during intestinal passage is

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not excessive. However, in the present study, there was no correlation between fecal protease activity and EPI indices. Conversely, a significant negative correlation between fecal lipase activity and fecal fat excretion was observed, a finding that might indicate that orally administered enzyme supplementation should be increased if a high-fat diet is being consumed. A dietary influence on fecal enzyme excretion was also observed in that the lowest values for fecal activities of protease, amylase, and lipase were detected in dogs fed the high-fiber diet. Dietary fiber is known to bind to pancreatic enzymes, and certain types of fiber may also have decreased duodenal pH, thus enhancing enzyme inactivation.[24-26]

Our findings indicate that by changing the composition of the diet, the severity of some clinical signs of EPI can be decreased. However, responses to diets varied among individual dogs. Large interindividual variation may explain why none of the 4 diets was superior to the others with regard to mean EPI index scores. The most suitable diet for a given dog with EPI is likely best discerned by trial and error; thus, an individually planned feeding regimen is recommended for affected dogs.

a. Hill's Prescription Diet p/d, Hill's Pet Nutrition Inc, Topeka, Kan.
b. Hill's Prescription Diet r/d, Hill's Pet Nutrition Inc, Topeka, Kan.
c. Hill's Prescription Diet i/d, Hill's Pet Nutrition Inc, Topeka, Kan.
d. Viokase V, Fort Dodge Laboratories, Fort Dodge, Iowa.
e. Tylan 200-mg tablets, Elanco Animal Health, Eli Lilly Co, Indianapolis, Ind.

Appendix

Scores assigned to 6 clinical signs of EPI and used by owners of 21 dogs with EPI to assess changes associated with feeding 3 special diets.

Variable	Score
Appetite	0 = Normal or poor 1 = Very good 2 = Excessive
Defecation frequency per day	0 = 1 to 2 times 1 = 3 to 4 times 2 = 5 to 6 times 3 = $\geq$ 7 times
Consistency of feces	0 = Ideal 1 = Moist and poorly formed 2 = Poorly digested and pulpy 3 = Watery diarrhea
Flatulence	0 = None 1 = Occasionally 2 = Often
Borborygmus	0 = None 1 = Occasionally 2 = Often
Coprophagia	0 = No 1 = Yes

References

1. Räihä M, Westermarck E. The signs of pancreatic degenerative atrophy in dogs and the role of external factors in the etiology of the disease. *Acta Vet Scand* 1989;30:447–452.
2. Williams DA. The pancreas. In: Guilford WG, Center SA, Strombeck DR, et al, eds. *Strombeck's small animal gastroenterology*. 3rd ed. Philadelphia: WB Saunders Co, 1996;381–410.
3. Wiberg M. Pancreatic acinar atrophy in German Shepherd Dogs and Rough-coated Collies. Etiopathogenesis, diagnosis and treatment. A review. *Vet Q* 2004;26:61–75.
4. Westermarck E, Wiberg M. Exocrine pancreatic insufficiency. In: Ettinger S, Feldman EC, eds. *Textbook of veterinary internal medicine*. 6th ed. Philadelphia: Elsevier Science, 2005;1492–1495.
5. Hall EJ, Bond PM, McLean C, et al. A survey of the diagnosis and treatment of canine exocrine pancreatic insufficiency. *J Small Anim Pract* 1991;32:613–619.
6. Pidgeon G. Effect of diet on exocrine pancreatic insufficiency in dogs. *J Am Vet Med Assoc* 1982;181:232–235.
7. Pidgeon G, Strombeck DR. Evaluation of treatment for pancreatic exocrine insufficiency in dogs with ligated pancreatic ducts. *Am J Vet Res* 1982;43:461–464.
8. Meyer H. Diätik von Hunden mit exokriner Pankreasinsuffizienz. [Feeding dogs with pancreatic insufficiency]. *Wien Tierärztl Monatsschr* 1985;72:91–95.
9. Simpson JW, Maskell IE, Quigg J, et al. The long-term management of canine exocrine pancreatic insufficiency. *J Small Anim Pract* 1994;35:133–138.
10. Wiberg M, Lautala HM, Westermarck E. Response to long-term enzyme replacement therapy of dogs with exocrine pancreatic insufficiency. *J Am Vet Med Assoc* 1998;213:86–90.
11. Westermarck E, Wiberg M, Junttila J. Role of feeding in the treatment of dogs with pancreatic degenerative atrophy. *Acta Vet Scand* 1990;31:325–331.
12. Westermarck E, Junttila JT, Wiberg M. Role of low dietary fat in the treatment of dogs with exocrine pancreatic insufficiency. *Am J Vet Res* 1995;56:600–605.
13. Westermarck E, Wiberg M. Exocrine pancreatic insufficiency in dogs. *Vet Clin North Am Small Anim Pract* 2003;33:1165–1179.
14. Williams DA, Batt RM. Sensitivity and specificity of radioimmunoassay of serum trypsin-like immunoreactivity for the diagnosis of canine exocrine pancreatic insufficiency. *J Am Vet Med Assoc* 1988;192:195–200.
15. Westermarck E, Sandholm M. Faecal hydrolase activity as determined by radial enzyme diffusion: a new method for detecting pancreatic dysfunction in the dog. *Res Vet Sci* 1980;28:341–346.
16. van de Kamer JH, ten Bokkel Huinink H, Weyers HA. Rapid method for the determination of fat in feces. *J Biol Chem* 1949;177:347–355.
17. Sandholm M, Scott ML. Binding of lipase, amylase and protease to intestinal epithelium as affected by carbohydrates and lectins in vitro. *Acta Vet Scand* 1979;20:329–342.
18. Pidgeon G. Exocrine pancreatic disease in the dog and cat. Part 2. Exocrine pancreatic insufficiency. *Canine Pract* 1987;14(2):31–35.
19. Dutta SK, Hlasko J. Dietary fiber in pancreatic disease: effects of high fiber diets on fat malabsorption in pancreatic insufficiency and in vitro study of the interaction of dietary fibers with pancreatic enzymes. *Am J Clin Nutr* 1985;41:517–525.
20. Suzuki A, Mizumoto A, Rerknimitr R, et al. Effect of bacterial or porcine lipase with low- or high-fat diets on nutrient absorption in pancreatic-insufficient dogs. *Gastroenterology* 1999;116:431–437.
21. Batt RM. Relationships between diet and malabsorption in dogs. *J Small Anim Pract* 1990;31:489–493.
22. Merritt AM, Burrows CF, Cowgill L, et al. Fecal fat and trypsin in dogs fed a meat-base or cereal-base diet. *J Am Vet Med Assoc* 1979;174:59–61.
23. Martineau B, Laflamme DP. Effect of diet on markers of intestinal health in dogs. *Res Vet Sci* 2002;72:223–227.
24. Stock-Damge C, Bouchet P. Effect of dietary fiber supplementation on the secretory function of the exocrine pancreas in the dog. *Am J Clin Nutr* 1983;38:843–848.
25. Isaksson G, Lundquist I, Ihse I. Effect of dietary fiber on pancreatic enzyme activity in vitro. *Gastroenterology* 1982;82:918–924.
26. Isaksson G, Lundquist I, Åkesson B, et al. Effects of pectin and wheat bran on intraluminal pancreatic enzyme activities and on fat absorption as examined with the triolein breath test in patients with pancreatic insufficiency. *Scand J Gastroenterol* 1984;19:467–472.