Relationship between faecal character and intestinal transit time in normal dogs and diet-sensitive dogs

The relationship between stool character and whole gut transit time (WGTT), which is the average time for the passage of material through the lumen of the alimentary tract from ingestion to defecation, was studied in eight control dogs and 12 dogs with non-specific dietary sensitivity. Dogs were fed four diets in a cross-over design, and faecal quality was assessed daily and WGTT determined using plastic pellets. Faecal quality was unaffected by diet in the control dogs. Dogs with dietary sensitivity produced looser faeces compared with the control dogs, and this was significant for two of the diets. There was no significant effect of diet on mean WGTT within or between groups. Minimum WGTT, which was the interval to the first appearance of markers in faeces, was shorter in sensitive dogs compared with controls, and this was significant for two of the four diets. There were significant, inverse relationships between minimum WGTT and both mean faeces score and percentage unacceptable defecations. These data suggest that rapid transit of certain dietary components may impact negatively on stool quality and contribute to loose faeces in dogs with non-specific dietary sensitivity.

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INTRODUCTION

The primary function of the colon is to absorb water and electrolytes from the luminal contents, thereby dehydrating the residue, which is stored prior to elimination as faeces. The efficiency of the process is determined by close alignment of motility patterns with absorptive capacity, such that the latter is influenced by the rate of passage of luminal contents (Rolfe 1999). In normal dogs, food typically reaches the ileocolic junction within five hours of ingestion and then remains in the colon for up to 48 hours prior to excretion (Murdoch 1996). The delayed passage of ingesta along the colon is a function of segmental peristaltic activity that mixes the luminal contents, encourages water and electrolyte absorption and slows transit. An increased rate of transit reduces the capacity for water absorption, and results in the passing of loose faeces. This is most marked in colitis where there is loss of segmental peristalsis, along with stimulation of giant migratory contractions that sweep down the colon, forcing the patient to frequently pass small amounts of liquid faeces (Sethi and Sarna 1991).

While dogs have been widely used in experimental studies of colonic motility and transit, there has been little research on the relationship between diet and colonic transit in this species. Sources of insoluble dietary fibre, such as bran or cellulose, are suggested for dogs with large bowel diarrhoea with the aim of promoting faecal bulk and enhancing segmental contractility (Batt and Burrows 1994). Research has shown that feeding healthy dogs dietary fibres with low fermentability is associated with decreased frequency of defecation and lower faecal moisture content, whereas highly fermentable fibre sources are associated with diarrhoea (Sunvold and others 1995).

The purpose of this study was to examine the relationship between transit times and stool character, and quantify the impact of dietary sensitivity on gut transit. These investigations were carried out in normal dogs and dogs with non-specific dietary sensitivity. The latter are representative of a proportion of the canine population that produces loose faeces, which respond to dietary change and which the authors have shown to be associated with changes in colonic absorptive function (Rolfe and others 2002). The present study was designed to investigate whether altered colonic motility was also a factor in the genesis of poor stool quality in these dogs. Colonic transit was measured indirectly by recording the whole gut transit of small plastic beads, on the basis that colonic transit accounts for 80 to 90 per cent of whole gut transit time (WGTT) (Iwanaga and others 1998, Bruce and others 1999). It was first established that the incorporation of the beads into the dogs' meals did not affect intestinal transit of the food.

All aspects of animal husbandry and procedures used in this study were in accordance with the United Kingdom Home Office regulations.

MATERIALS AND METHODS

Comparison of measures of WGTT using plastic beads and chromium oxide

The first part of the study was designed to test whether plastic beads incorporated in the daily ration influenced the rate of passage of ingesta, and involved comparing transit times of these markers with that of an inert dye – chromium oxide – widely used as a faecal marker. Six dogs were fed their daily ration of a canned food at 11.00 hours, which contained one capsule of chromium oxide (0·05 g, BDH, Derby) and 30 small plastic beads. The beads each weighed 10 mg and were cylindrical in shape, 4 mm long with an external diameter of 4 mm. All stools were collected for five days and were sieved, washed and the number of beads noted. The dogs were monitored by video camera, when housed, to record the timing of each defecation. Faeces passed during exercise and socialisation periods were collected by the dogs' handlers and the time of defecation noted. Chromium oxide concentrations were measured in faeces that were freeze dried, ground and ashed at 550°C for three hours. The chromium content was determined by atomic absorption spectrophotometry (Spectra AA20, Varian, Surrey) against potassium dichromate standards. The mean WGTT, which is the average time that a marker takes to pass through the gut, was calculated according to the equation:

$$\text{Mean WGTT} = \sum_{i=1}^{i=n} x_i t_i \div \sum_{i=1}^{i=n} x_i$$

where x_i is the number of beads present in faeces (or the faecal concentration of chromium oxide) passed after time interval t_i (Cummings and others 1976).

Effects of diet on faeces quality and WGTT in control and diet-sensitive dogs

For the second part of the study, dogs with non-specific dietary sensitivity were identified by the criterion that they produced faeces of consistently poorer quality (looser) than other dogs in the population during a diet rotation screening procedure. The panel of 12 sensitive dogs consisted of seven Labrador retrievers, two English springer spaniels, two large Munsterlanders and one beagle. Their ages and bodyweights ranged from 2·6 to 10 (mean 5·0) years and 14·4 to 36·6 (mean 26·8) kg, respectively.

A group of eight control dogs was selected on the basis that they produced faeces of average quality (close to median values for mean faeces score and percentage unacceptable defecations) during the screening procedure, and were thus representative of the general population. This group consisted of one Labrador retriever, one golden retriever and six beagles, with ages and bodyweights ranging from 1·8 to 6·2 (mean 5·0) years and 10·0 to 30·1 (mean 19·3) kg, respectively. There were no significant differences in age or bodyweight between the sensitive and control dogs.

The dogs were split into four groups and fed four test diets (A, B, C and D) for four weeks each in a cross-over design. Each group was fed the diets in sequences known to avoid any potential for diet-induced diarrhoea if diets associated with looser stool quality were fed consecutively. The dogs were fed to maintain stable bodyweight. Diets A, C and D were canned foods with a moisture content of 78 to 79 per cent. The major protein sources were poultry, beef, pork, fish, wheat, maize and rice. Levels of insoluble and soluble dietary fibre were 0·0 and 0·1 g/100 g in A, 1·0 and 0·5 g/100 g in C, and 0·3 and 0·3 g/100 g in D, respectively. Diet B was a dry food with a moisture content of 6·4 per cent; it contained poultry, rice and maize as sources of protein and had levels of insoluble and soluble dietary fibre of 4·2 and 1·8 g/100 g, respectively.

Faecal quality was assessed daily using a grade 1 to 5 scale, and mean faeces scores were calculated for each trial period. Trained assessors graded all defecations. Grade 1 represented dry crumbly faeces and grade 5 represented diarrhoea. Grade 2 was the ideal grade and represented faeces that were well formed, easy to pick up and left no marks. Grade 3 represented faeces of good quality that were slightly moist and less well formed than grade 2 faeces. As such, grade 3 faeces left a mark when removed from a dry surface, were tacky to the touch, and were soft centred. Grade 4 faeces were of poor quality; they were moist and poorly formed, with a consistency of putty or porridge. The linear scale was thus divided into four major sectors (ie, 1 to 2, 2 to 3, 3 to 4, and 4 to 5), and each of the four major sectors was subdivided into four subsectors, giving a total of 17 points, to allow more accurate scoring of faecal quality. The percentage of defecations that would be unacceptable to owners was calculated as the number of defecations that resulted in faeces with a grade of above 3·5 divided by the total number of defecations, multiplied by 100.

Minimum and mean WGTT were measured during weeks 3 and 4 of the trial period using plastic beads, as described earlier. Three different colours of beads were fed for three consecutive days and the mean of the three results used for each animal. The interval to the appearance of the first bead of each colour was taken as the minimum transit time. Any beads that took 80 hours or more to appear were not used in the calculation of mean WGTT.

Statistical methods

The values for WGTT derived from the plastic bead and chromium oxide markers were compared using the Wilcoxon signed rank test. Results for faeces quality and WGTT were compared within sensitive and control groups for diet effect and between sensitive and control groups using

Table 1. Mean faeces score in eight control dogs and 12 dogs with non-specific dietary sensitivity ('sensitive') fed four test diets

Diet	Control	Sensitive
A	2·5^{a,b} (0·3)	3·0^{c} (0·6)
B	2·4^{a,b} (0·3)	2·7^{b} (0·4)
C	2·5^{a,b} (0·2)	3·2^{c} (0·5)
D	2·3^{a} (0·3)	2·6^{a,b} (0·4)

Data are shown as the mean with one standard deviation of the mean in parentheses
Data sharing the same superscript letter, within columns or rows, are not significantly different

Table 2. Minimum WGTT (hours) in eight control dogs and 12 dogs with non-specific dietary sensitivity ('sensitive') fed four test diets

Diet	Control	Sensitive
A	29·8^{c} (4·4)	17·0^{a,b} (1·8)
B	20·6^{b} (5·0)	17·7^{a,b} (1·1)
C	19·4^{a,b} (3·0)	12·1^{a} (1·8)
D	33·8^{c} (5·2)	17·4^{a,b} (1·4)

Data are shown as the mean with one standard error of the mean in parentheses
Data sharing the same superscript letter, within columns or rows, are not significantly different

ANOVA. The level of significance was taken as P<0·05 unless otherwise stated. Data are presented as mean ± standard deviation (SD).

RESULTS

Comparison of measures of WGTT

There was no significant difference between the values for WGTT derived from the two marker systems, indicating that the beads did not affect the transit of ingesta. The mean WGTT for the plastic beads was 22·9 (±3·9) hours, compared with 24·3 (±3·4) hours for chromium oxide.

Faeces quality in control and diet-sensitive dogs

In control dogs, there was no significant difference in faeces quality for the four diets, whereas, in the sensitive dogs, the mean faeces score was significantly higher on diets A and C compared with diets B and D (Table 1). Faeces quality was consistently poorer in the sensitive dogs compared with the control dogs, with higher mean faeces scores (Table 1) and mean percentage of unacceptable defecations ranging from 7·3 to 28·3 per cent in the sensitive dogs compared with 2·6 to 6·8 per cent in the controls (Fig 1). Mean faeces score was significantly higher in the sensitive dogs compared with the controls when diets A and C were fed, but the differences between the two groups for diets B and D were not statistically significant.

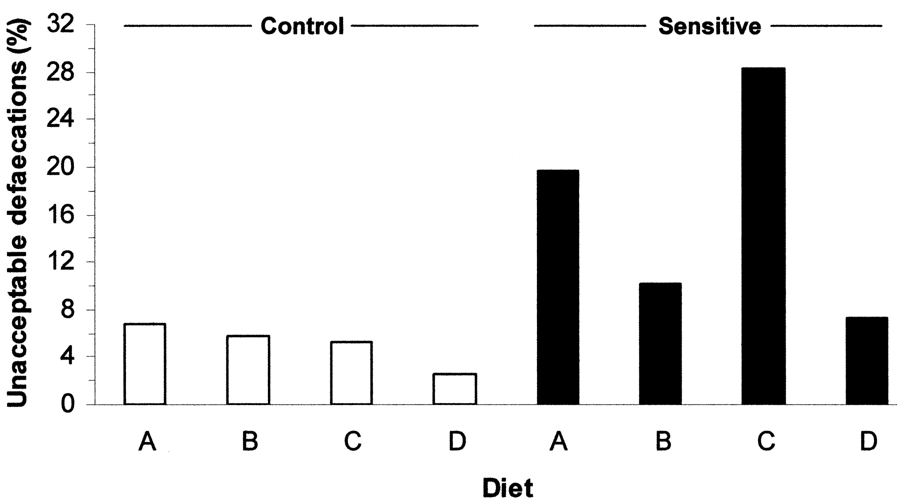

FIG 1. Impact of diet on mean percentage of unacceptable defecations in control dogs (open bars) and sensitive dogs (closed bars)

WGTT in control and diet-sensitive dogs

Mean minimum WGTT ranged from 12 to 18 hours in the sensitive dogs compared with 19 to 34 hours in the control dogs (Table 2). In the controls, the minimum WGTT for diets B and C was significantly shorter than for diets A and D. There were no significant differences between diets in the sensitive dogs. When the data from the two groups of dogs were compared, the minimum WGTT for diets A and D was significantly shorter in the sensitive compared with the control dogs, whereas diets B and C were not significantly different.

Mean WGTT ranged from 29 to 34 hours in the sensitive dogs, compared with 24 to 34 hours in the control dogs (Table 3). Although there was no significant difference in mean WGTT between the four diets in either the control or sensitive dogs, diet D, which was associated with the best faeces quality, had the longest mean WGTT in both groups. There were no significant differences in mean WGTT between the two groups for any of the four diets fed. (It should be noted that, since beads which took over 80 hours to pass were omitted from the calculations, the mean WGTT in control dogs fed diets A and D appears shorter than the minimum WGTT.)

Taking the data from the control and sensitive dogs, there were significant inverse relationships between minimum WGTT and both mean faeces score and percentage unacceptable defecations (Fig

Table 3. Mean WGTT (hours) in eight control dogs and 12 dogs with non-specific dietary sensitivity ('sensitive') fed four test diets

Diet	Control	Sensitive
A	29·3[a,b] (5·6)	28·6[a,b] (2·0)
B	28·9[a,b] (5·3)	30·1[a,b] (1·0)
C	24·4[a] (3·6)	28·6[a,b] (1·4)
D	33·7[a,b] (5·3)	34·4[a,b] (2·6)

Data are shown as the mean with one standard error of the mean in parentheses
Data sharing the same superscript letter, within columns or rows, are not significantly different

2). These relationships are best described by power functions, where mean faeces score = $6{\cdot}12 \times$ minimum WGTT $(h)^{-0{\cdot}18}$ ($r=-0{\cdot}81$; $P<0{\cdot}05$) and percentage unacceptable defecations = $2531 \times$ minimum WGTT $(h)^{-1{\cdot}91}$ ($r^2=-0{\cdot}81$; $P<0{\cdot}05$). There was no significant correlation between mean WGTT and either mean faeces score ($r=-0{\cdot}20$) or percentage unacceptable defecations ($r=-0{\cdot}24$).

DISCUSSION

Inert markers have long been used to assess the rate of passage of diets through the gut, to quantify faecal output, and in the calculation of faecal apparent digestibilities in studies of nutrient absorption (Bacon 1980, Morgan 1986). While chromium oxide has been widely employed for this purpose in humans and numerous animal species, the analysis of chromium in faecal samples usually involves storage and batch analysis of samples, with an inherent delay in the acquisition of data. Other techniques used to measure transit times in dogs include radiopaque markers (Burrows and others 1982, Bruce and others 1999) and scintigraphy (Iwanaga and others 1998), but these are associated with exposure to ionising radiation and require significant commitment of time, equipment, expense and technical expertise. The current authors therefore chose to evaluate small plastic beads as markers of gut transit as these were cheap to purchase, non-toxic, easy and safe to analyse, and would allow rapid acquisition of data.

The reliability of transit markers is dependent upon how closely they mimic the natural dietary residue, which in turn is affected by the dimensions of the marker. The markers used in the present study appeared valid, as the values of WGTT derived were commensurate with those obtained using a dispersible marker. Furthermore, the beads used were of similar dimensions to pellets (4 mm long, external diameter 2·5 mm, formed from polyvinyl chloride tubing) that have been successfully used to measure intestinal transit times in dogs previously (Burrows and others 1982). Work in humans has shown that transit time can be accurately measured using polyethylene pellets weighing 7·8 mg or lengths of tubing with external diameter 4·5 mm that weigh 8 mg (Cummings and others 1976), the dimensions of which were also similar to the markers used in the present study.

The technique employed in the present study relied on the assumption that the majority of WGTT is attributable to colonic transit, and that variations in WGTT are largely determined by colonic, rather than gastric and small intestinal, transit. This assumption does appear to hold true when time variability in gastric emptying and small intestinal transit are compared with that of colonic transit. A recent scintigraphic study (Iwanaga and others 1998) showed that 50 per cent of gastric emptying occurred within 240 to 378 minutes of a meal, with small bowel transit taking between 41 and 120 minutes. If the extremes of these values are considered, the time taken for 50 per cent of gastric emptying and transit along the small intestine could have been as short as 281 minutes or as long as 498 minutes, the difference being equivalent to 3·6 hours. Although colonic transit times were not quantified in that study, the mean residence time of polyethylene spheres of 5 mm diameter in the colon of dogs fed a high fibre diet has been reported to range between five and 27 hours, with some spheres still present in the colon at 46 hours (Bruce and others 1999). This latter study demonstrated large, normal, variability in colonic transit and highlighted the fact that this variation is substantially greater than that of transit through the upper bowel, supporting the validity of WGTT as an indirect measure of colonic transit. It should be borne in mind, how-

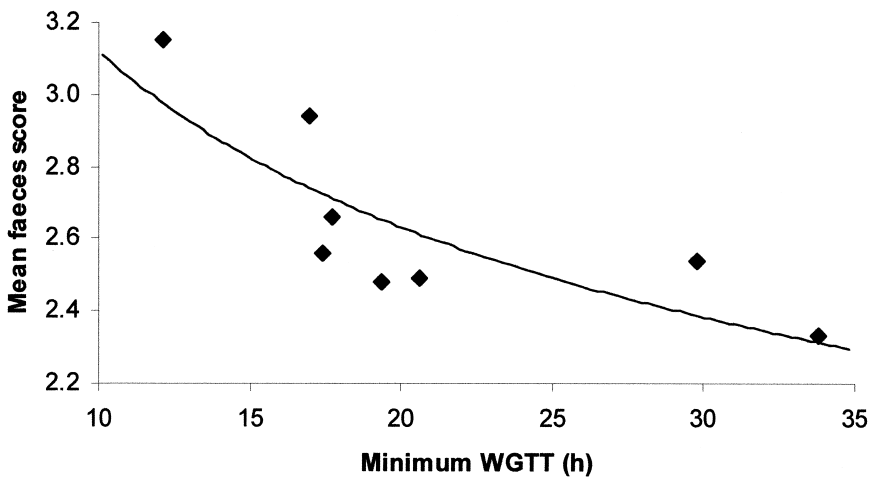

FIG 2. Relationship between minimum WGTT and faecal quality as measured by mean faeces score (upper panel) and mean percentage unacceptable defecations (lower panel) in control and sensitive dogs. Each point represents the mean results for one diet in one of the two groups of dogs

ever, that this assumption is based on data from healthy dogs and it is possible that altered gastric emptying or small intestinal transit could contribute to variation in WGTT in dogs with gastrointestinal disease.

Using this technique, the present authors were able to demonstrate that WGTT is influenced by diet in dogs. A general pattern, in both the control and sensitive dogs, was that minimum and mean WGTT were shortest on diet C and increased gradually through diets A and B to D. While the differences between diets were not statistically significant for minimum WGTT in the sensitive dogs and mean WGTT in both the control and sensitive dogs, there was a significant dietary effect on minimum WGTT in the control dogs.

Given the potential for dietary fibre to modify colonic motility, it is possible that the effects of diet observed here were due to variation in fibre intakes. There were significant differences in levels of insoluble fibre between the four diets, with diets C and B having 3·6 and 4·2 g insoluble fibre per 400 kcal metabolisable energy, respectively, compared with 0·0 and 1·1 g/400 kcal in diets A and D. Soluble fibre contents were 0·4, 0·8, 1·8 and 1·1 g/400 kcal for diets A, B, C and D, respectively. Thus, the diets with higher insoluble fibre contents were associated with shorter transit times. While this is counter to the general idea that insoluble fibres slow colonic transit, previous work in dogs showed that adding α-cellulose to a canned food decreased gastrointestinal transit times (Burrows and others 1982). It is possible that insoluble fibre has a significantly greater effect on faecal weight in the dog, compared with other species, and that this results in earlier elimination of faeces and hence shorter transit times.

There was some relationship between stool character and both minimum and mean WGTT in that diet D, which was associated with the best faeces quality in both groups of dogs, also had the longest minimum and mean WGTT in both groups. This suggests that WGTT and colonic transit might be an important determinant of faecal character, with diets that delay colonic transit allowing greater dehydration of luminal contents. However, analysis of the correlation between WGTT and mean faeces score and percentage unacceptable defecations indicated that minimum, and not mean, WGTT was related to stool character.

Minimum WGTT is representative of the transit of dietary components that move most rapidly through the bowel following a meal. The correlation between minimum WGTT and stool character suggests an association between the rate of passage of such components and the absorptive function of the colon. This may reflect a direct effect of these factors on colonic motility, or an indirect effect on colonic absorptive function. The present authors have previously shown that colonic water absorption is a primary determinant of faecal consistency. Thus, it is possible that the early arrival of certain dietary components in the colon may alter absorptive function. In instances where the minimum and mean WGTT were similar, as was generally the case in the control dogs, it is likely that all dietary components travel in a more homogeneous manner and that the potentially adverse effects of some components are negated by the rest of the dietary mass. While the identity of such rapidly transferred dietary components is unclear, limiting their consumption may provide a means of increasing minimum WGTT and improving stool quality in diet-sensitive dogs.

Conclusions

Stool character was consistently poorer in the sensitive compared with the control dogs, as has been shown in a recent study (Rolfe and others 2002). That study showed that these dogs are particularly sensitive to diet-associated changes in colonic absorptive function, which are associated with damage to colonic microstructure, disrupted electrolyte transport function and failure to dehydrate luminal contents. The purpose of the present study was to determine whether these dogs also experienced altered colonic motility and whether that was a factor in their poor stool character. Although minimum WGTT was generally shorter in the sensitive dogs, there was no difference in mean WGTT between the two groups. This suggests that altered colonic motility is not a significant contributor to the poorer faeces quality, but that these dogs are more sensitive to the effects of diet on minimum WGTT. Dietary modifications that lengthen the minimum WGTT might therefore help to reduce the symptoms of dietary sensitivity.

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