Gastric Emptying Rate Is Inversely Related to Body Weight in Dog Breeds of Different Sizes


* National Veterinary School of Nantes, Laboratory of Nutrition and Endocrinology, Nantes, France, † Human Nutrition Research Centre, Nantes, France, and ** Royal Canin Research Centre, Aimargues, France

KEY WORDS: • gastric emptying • body weight • dog • feces

Introduction

When fed an identical diet, large and giant breeds of dog tend to defecate more frequently and produce feces that have higher water content and are of a poorer quality (softer) than smaller breeds (1–4). However, the reason for the effect of body size on fecal variables in otherwise healthy dogs remains unknown.

With such a huge range of body sizes (1–100 kg), different breeds of dog might be expected to differ in many aspects of gastrointestinal physiology. Larger breeds have a proportionately smaller gastrointestinal tract, comprising 3–4% body weight (BW) compared to 6–7% BW in smaller breeds (5). Previous studies showed little effect of canine BW on orocecal transit time (6,7), fecal microflora profile (7), or small intestinal absorption studies showed little effect of canine BW on orocecal transit time (C211 0022-3166/04 $8.00

Gastric Emptying Rate (GER) is the speed with which substances leave the stomach after ingestion. Liquids are retained for the shortest period, followed by small then large solid particles. GER is also affected by food-specific factors including fat content. It could be hypothesized that size-related differences in GER might contribute to the poorer feces quality of larger dogs.

Nuclear scintigraphy was considered to be the “gold standard” method for the measurement of GER, and was validated in humans and dogs; when compared with other methods in these species the technique provides the best evaluation of GER (8,9). However, the cost of equipment and use of radioactivity limit its use, and alternative methods was therefore developed so as not to expose patients to high doses of radiation. These methods include the use of the radio-opaque markers and the 13C-octanoic acid breath test (OABT). Both have been compared to scintigraphy and validated in humans and animals (10,11).

A previous study of gastric emptying time (GET), measured by tracking the progress of radio-opaque markers from the stomach into the small intestine, in four breeds of dog, aged 12–60 wk, found no effect of BW (3). However, the behavior of such markers may not reflect that of food, because they cannot be broken down by the mechanical action of the stomach. Large markers are therefore retained for a disproportionately long time, whereas small markers empty very quickly, probably during liquid phase emptying. Intermediate-sized markers more accurately reflect food, but the GET measured by this method shows considerable intra- and inter-individual variation (11,12).

The OABT was used for measuring GER in many species including humans, rat (13), cat (14), and dog (15). The test involves monitoring the concentration of 13CO2 in expired air after ingestion of a meal labeled with 13C-octanoate. This medium-chain fatty acid is rapidly absorbed from the duodenum after gastric emptying of the test meal and carried to the liver where it is quickly and completely oxidized to carbon dioxide that is then exhaled in the breath. The rate of appearance of 13CO2 in breath air would reflect the rate and pattern of gastric emptying because gastric emptying would be the limiting step in the digestion and metabolism of octanoic acid (16). The method has advantages over the radio-opaque...
The aim of this study was to measure the GET of a conventional dog food, in 24 healthy adult dogs ranging in BW from 3.5 to 59 kg, using the 13C-octanoic acid breath test.

**MATERIALS AND METHODS**

Twenty-four healthy adult dogs (2 males and 22 females, aged 4.0 ± 0.3 yr, BW 25.96 ± 3.75 kg (range 3.5–59.1 kg) were recruited, representing six breeds: Miniature Poodle (n = 3), Beagle (n = 1), Schnauzer (n = 6), Giant Schnauzer (n = 5), Great Dane (n = 5), Labrador Retriever (n = 3), Argentine Dane (n = 1). Labrador Retrievers and the Argentine Dane were loaned to the school by private owners. Other dogs were owned by the National Veterinary School of Nantes, where all dogs were housed for the duration of the study. All experimental protocols were approved by the Animal Use and Care Advisory Committee of the Nantes Veterinary School, and adhered to European Union guidelines.

GET was assessed on a single occasion in each dog using a test meal consisting of a commercially available extruded (dry) food (Maxi Adult Young, Royal Canin, Aimargues, France; 25.7% crude protein, 15.2% ether extract, 7.5% total dietary fiber, 1.71 MJ ME/kg). After a 12-h fast, each dog was given half its daily estimated energy requirement (i.e., 276 kJ ME/kg BW0.75), labeled with sodium 13C-octanoate (7.5 mg/kg BW0.75; sodium octanoate 13C, 99% atom 13C, Eurltopo, Gif-sur-Yvette, France). To increase retention of the isotope in the solid phase, the octanoate was added to egg yolk (2.64 g/kg BW0.75), which was mixed with the test meal and then baked in a microwave, before immediately feeding to the dog. All dogs had constant access to water throughout the study, but were not allowed to eat anything other than the test meal and were confined to their kennel.

GET was assessed using the sodium 13C-octanoate breath test. Dogs were maintained in a quiet environment, to maintain a constant carbon dioxide production rate. After appropriate habituation training of the dogs to the apparatus, duplicate samples were obtained at baseline (T0; immediately before ingestion of the test meal). Duplicate samples were then taken for the 6-h period after ingestion of the test meal: every 15 min for 4 h, and every 30 min for the final 2 h of the test.

Breath samples were collected using an anesthetic mask (Canine Ventilation/Anesthesia Mask, Harvard Apparatus, Les Ulis, France) connected to a 2-L Douglas rubber bag (Fisher Scientific Labos, Elancourt, France) by a two-way valve (Two-Way Non-Ref-breathing Valve, Harvard Apparatus, Les Ulis, France). This system allowed the dogs to breathe normally, while expired air only was collected in the bag. The mask was fitted snugly around the muzzle, and the dog was allowed to breathe normally until the reservoir bag was filled. Duplicate samples of the expired air were withdrawn from the bag using 20-ml syringes and a three-way tap. The syringes were sealed using a second three-way tap, and the samples were immediately transferred to sealed vials (Hexatainer®, Labco, Buckinghamshire, UK); these were stored at room temperature for up to 4 wk before analysis.

The ratio of 13CO2:14CO2 in the breath samples (ppm) was determined by gas chromatography-isotope ratio-mass spectrometry (Breathmat®, Finnigan, Bremen, Germany) and then converted to APE (atom percent excess). The net effect of the test meal was obtained by subtracting the baseline (T0) values for each dog.

The 13CO2 excretion curve (APE against time) was fitted as described previously (15), and the area under the curve used to determine gastric emptying characteristics. The time at which 25% (T0.25), 50% (T0.50), and 75% (T0.75) of the area under the curve was reached and the time corresponding to peak excretion (Tmax) were calculated. These coefficients were each plotted against BW and assessed by regression to determine if any relationship was present.

The data are presented as mean ± SEM, and P < 0.05 was considered significant.

**RESULTS**

Overall, excretion of 25% of the octanoate dose (T0.25) took 85 ± 4 min. Fifty percent of the dose was excreted in 154 ± 5 min (T0.50) and 75% of the dose in 240 ± 6 min (T0.75). Peak excretion occurred at 91 ± 9 min (Tmax).

T0.25 was significantly longer in the larger dogs. Hence, there was a significant positive linear correlation between BW and T0.25 (r = 0.76, P < 0.0001 (Fig. 1), and between BW and T0.50 (r = 0.67, P = 0.0004).

T0.75 was also significantly longer in larger dogs. Hence, there was a significant positive linear correlation between BW and T0.75 (r = 0.46, P = 0.02), and a significant positive polynomial correlation (GET = 78.80–1.38*BW + 0.05*BW²) between BW and Tmax (r = 0.78, P < 0.0001) (Fig. 2).

**DISCUSSION**

We used the OABT to compare the gastric emptying pattern in dogs differing in body size. It has been shown that postgastric processing of 13C-octanoic acid and subsequent 13CO2 exhalation occurs very rapidly, and with minimal inter-subject variability (17). Octanoic acid is rapidly absorbed from the intestine and carried via the portal vein to the liver where it undergoes β-oxidation. A peak excretion of 13CO2 has been observed ~12 min after intraduodenal administration of 13C-octanoic acid in human volunteers (16). In a dog 2H2O appeared 15 min earlier in saliva than 13CO2 in breath air after oral administration of [1H13C] octanoic acid, due to incorporation of 13CO2 into the bicarbonate pool (18). Gastric emptying measured using OABT is then delayed compared to scintigraphy. A 69-min difference in the half-emptying times between these two methods was reported (19). It was nevertheless shown that the gastric emptying pattern was similar when determined simultaneously by both these methods (16).

Large dogs had a longer GET at every sample point, compared to small dogs, when fed a commercial extruded dog food. This means that in large breeds of dog, food is retained in the stomach for a longer period; they have a lower rate of gastric emptying. These findings are in contrast with those of a previous study in dogs that failed to find any correlation between BW and GET (3). However, a strong inverse relationship was identified in a study in humans weighing 59–93 kg (20). A weak correlation was reported in dogs weighing 13.5–37 kg (21), and also in another dog study (n = 60), although the weight range was not indicated (10).

Compared with a previous study using the OABT (15), GET in the current study was much shorter. This could be explained...
by differences between the test meals used; although the energy allowance was similar, the composition was different. Thus, the test meal used in the Wyse et al. study consisted of whole-meal bread, skimmed milk, and sunflower margarine (15), compared to a conventional dog food in this study. The bread, milk, and margarine test meal would contain more fat, which is known to slow gastric emptying and could lead to longer emptying time. All of these factors could explain the differences between the previous results and ours.

The stomach is a muscular bag with several roles in digestion. It stores food temporarily and participates in the initial stages of digestion including denaturation and predigestion of proteins. Contractions of the muscular walls facilitate the mixing and maceration of ingesta then the formation of the chyme. The stomach also controls the rate of entry of the chyme into the small intestine. Relatively premature gastric emptying may discharge inadequately predigested particles. A high emptying rate may overload the small intestine. Either of these circumstances would be likely to occur in small breed dogs. Premature discharged and/or overloading particles would be less susceptible to intestinal enzymatic hydrolysis, and so they may pass relatively undigested into the large bowel. The microflora residing there utilize nitrogen and carbohydrate sources to produce metabolites, which can affect colonic absorption and physiology, a major determinant of feces quality (22). It would therefore be possible that gastric emptying time might alter the physiology of the large intestine. Some digestive troubles would then be expected in small dogs, in which GER was higher. The fact is that small breed dogs did not generally experience any fecal consistency problem, whereas large dogs did. Our results therefore be possible that gastric emptying time might alter the physiology of the large intestine. Some digestive troubles would then be expected in small dogs, in which GER was higher. The fact is that small breed dogs did not generally experience any fecal consistency problem, whereas large dogs did. Our results show that in smaller dogs, and this would not be likely to contribute to the poor feces quality associated with higher body weight.

ACKNOWLEDGMENT

The authors are grateful to Samuel Ninet and Gérard Pondevie for technical assistance.

LITERATURE CITED