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RESEARCH ARTICLE

Digestion in the Common Marmoset (*Callithrix jacchus*), A Gummivore–Frugivore

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Wild common marmosets (*Callithrix jacchus*) feed on fruits, insects, and gums, all of which provide different digestive challenges. Much of the ingested mass of fruits consists of seeds. In general, seeds represent indigestible bulk to marmosets and could inhibit feeding if they are not eliminated rapidly. In contrast, gums are β-linked polysaccharides that require microbial fermentation. Their digestion would benefit from an extended residence time within the gut. Earlier research found that mean retention time (MRT) for a liquid digestive marker (cobalt EDTA) was significantly longer than MRT for a particulate marker (chromium-mordanted fiber), suggesting that common marmosets preferentially retain liquid digesta. We conducted two four-day-long digestion trials on 13 individually housed adult common marmosets fed a single-item, purified diet in order to examine the relations among MRT of cobalt EDTA and chromium-mordanted fiber, food dry matter intake (DMI), and apparent digestibility of dry matter (ADDM). We compared the MRT values with the data from the previous study mentioned above and a study using polystyrene beads. There were no significant correlations among MRT, ADDM, or DMI, although increases in DMI between trials were associated with decreases in MRT. ADDM was consistent within individuals between trials; but the mean values ranged from 75.0 to 83.4% among individuals. We found no difference in MRT between the liquid (17.5 ± 1.6 hr) and particulate (17.9 ± 1.4 hr) markers. Although these values were not significantly different than found previously, the MRT for chromium-mordanted fiber tended to be longer. This probably reflects the relatively small size of the chromium-mordanted fiber particles used in this study. An inverse relationship between particle size and MRT was evident; the mean MRT of polysterene beads, the largest marker, was only 8.3 ± 1.5 hr. Marmosets appear to retain liquids and small particles within the gut longer than large particles. Am. J. Primatol. 71:957–963, 2009.

Key words: mean retention time; apparent digestibility; callitrichids

INTRODUCTION

Common marmosets (*Callithrix jacchus*) are small (about 350 g), New World monkeys that belong to the monophyletic primate family Callitrichidae. The callitrichid family includes marmosets (genera *Callithrix*, *Mico*, and *Cebuella*), tamarins (genus *Saguinus*), lion tamarins (genus *Leontopithecus*), and Goeldi's monkey (*Callimico goeldii*). All callitrichids are omnivorous, and feed on fruit, gum, other plant exudates, nectar, invertebrates, and small vertebrates. As a general rule, marmosets are more likely than the other callitrichids to feed extensively on gums and have dental adaptations that allow them to gouge trees and stimulate the flow of gum [Coimbra-Filha & Mittermeier, 1977]. This appears to have allowed marmosets to colonize drier forests and small forest fragments where there is little fruit [Fonseca & Lacher, 1984].

Gums are β-linked polysaccharides and, as such, should be resistant to mammalian digestive enzymes [Booth & Henderson, 1963; Booth et al., 1949; Hove & Herndon, 1957; Monke, 1941]. Gums need to be fermented by gut microbes in order for their nutrients to be utilized by the primates that eat them; thus, primate gum-feeders would benefit nutritionally from having an area of the digestive tract conducive to fermentation and by retaining ingested gum within that region of the digestive tract for an extended time. The most likely site

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for fermentation in callitrichid digestive tracts is the cecum.

Although exudate feeding has often been emphasized in marmoset dietary adaptations, marmosets do feed extensively on fruit, when available. The fruits marmosets ingest often are small, seed-filled and fleshy. The pulp is presumed to be easily digestible, but the seeds appear to pass through the marmoset gut virtually unchanged [Power, personal observation; P. Garber, personal communication]. Thus, seeds represent indigestible bulk fill to a marmoset, and should be eliminated rapidly in order to maximize food intake. There would appear to be a conflict between the "optimal" digestive strategies for gum (long retention time) and fruit (short retention time).

Earlier work on digestive function in five callitrichid species [Power, 1991] indicated that in general the ability to digest a common diet and the amount of time it took for digesta to pass through the digestive tract were associated with body size. Mean transit time of particulate digesta (defined as the time to first appearance of an indigestible particulate marker) and the apparent digestibility of both dry matter and energy declined with mean body mass for four of the species: golden lion tamarins (*Leontopithecus rosalia*, ca. 700 g), cotton-top tamarins (*Saguinus oedipus*, ca. 500 g), common marmosets (ca. 350 g), and saddle-back tamarins (*Saguinus fuscicollis*, ca. 300 g). Thus, any differences in digestive function between common marmosets and other callitrichids appeared to be explained by allometry. In contrast, the mean value for transit time for the smallest callitrichid species, the pygmy marmoset (*Cebuella pygmaea*, ca. 150 g), was greater than in any of the other species, and the mean values for apparent digestibility of dry matter (ADDM) and energy were equal to those of the golden lion tamarin. In addition to being the smallest callitrichid, the *C. pygmaea* is also the marmoset most dependent on gum as a dietary staple in the wild and the least likely to feed on fruit. This species' divergence from the pattern of digestive function exhibited by other callitrichids may be related to the digestive advantage of retaining gum within the digestive tract for fermentation to occur, as well as to a relaxation of the adaptive constraint from the need to eliminate seeds from the gut [Power, 1991; Power & Oftedal, 1996].

Although digestive function of the common marmoset did not appear different from that of tamarins and lion tamarins and did differ from its relative the pygmy marmoset, earlier research has shown that both common and pygmy marmosets were similar in being better able to digest gum when it was added to the diet than were the other species [Power, 1991; Power & Oftedal, 1996]. This implies that there is indeed some difference in digestive function between common marmosets and tamarins and lion tamarins. Marmoset gut morphology does differ from that of other callitrichids; marmosets have a larger proportion of the intestinal tract represented by the cecum and colon than do tamarins and lion tamarins [Ferrari & Martins, 1992; Ferrari et al., 1993; Power, 1991] and a more complex cecum [Coimbra-Filha et al., 1980]. An earlier study of passage rate of digesta in three common marmosets using both a particulate (chromium-mordanted fiber) and a liquid marker (cobalt EDTA) indicated that the liquid marker passed through the marmoset digestive tract more slowly than did the particulate marker [Caton et al., 1996]. Caton and colleagues hypothesized the common marmoset has a cecal–colonic separation mechanism, in which particulate matter is largely excluded from the cecum, and liquid digesta (e.g. gum) is preferentially retained within the cecum, facilitating its fermentation.

This study was to characterize the digestive function in the common marmoset in terms of the passage rate of liquid and particulate material, and to examine the relationships among passage rate, body mass, food intake, and apparent digestibility of food. The results for passage rate were compared with the results from Caton et al. [1996] for liquid and particulate markers, and from Power [1991] for polystyrene beads, a seed-like particulate marker.

METHODS

Subjects

The animals in this study were 13 singly housed adult common marmosets (five female and eight male) housed at the Southwest National Primate Research Center (SNPRC) in San Antonio TX; the study was approved by the SNPRC Animal Care and Use Committee. Animals ranged from 1 year and 10 months to 5 years and 2 months. A common marmoset is sexually mature at 18 months and reaches its full adult size between two and three years [Abbott et al., 2003]. Body weights were available on nine of the individuals in this study (Table I). The mean body mass for these nine individuals was 383.7 ± 11.5 g.

Diet

A single-item, purified agar-gelled diet was given to all the subjects. This diet is the base colony diet as described by Tardif et al. [1998], and all the animals had been fed it from birth. The diet has an estimated metabolizable energy (ME) content of 3.8 kcal/g. The diet contains 5% cellulose and 4% agar on a dry matter basis; agar is a fermentable substance. A small batch of the base diet (marker diet) was made with the solid and liquid phase indigestible markers (chromium-mordanted fiber and cobalt EDTA) added at approximately 0.3% of the dry matter of the diet.

TABLE I. Mean±SEM Dry Matter Intake (DMI), Apparent Digestibility of Dry Matter (ADDM), and the Dry Matter Content of Feces (Fecal DM)

Animal ID	Body mass (g)	DMI (g/day)	ADDM (%)	Fecal DM (%)
181	423	15.1±1.0	75.0±1.6	30.0±0.0
298	382	13.3±1.3	79.0±0.2	31.5±3.9
302	n/a	9.5±1.1	77.3±0.8	32.6±0.6
303	330	10.9±1.0	83.4±0.1	33.1±2.8
312	430	14.5±0.5	80.4±0.3	23.3±0.3
315	355	14.6±0.8	77.6±0.1	24.5±2.5
317	n/a	11.3±0.3	80.2±0.7	27.9±3.7
318	n/a	15.5±0.3	77.7±1.1	29.0±2.1
324	344	6.4±2.4	77.1±0.6	28.3±4.1
325	390	14.3±0.8	76.8±1.4	20.0±0.1
326	363	16.3±2.2	75.1±0.2	29.6±0.8
336	434	15.6±0.6	81.0±0.7	20.8±0.9
342	n/a	15.3±0.3	75.6±1.0	30.0±0.3
Mean	383±13	13.3±0.6	78.1±0.5	27.7±0.9

The chromium-mordanted fiber was made from neutral detergent fiber extract of canned marmoset diet (Premium Nutritional Products Inc, Mission, KS) according to the procedure described by Wrick [1979]. The animals in this colony were fed this product routinely in addition to the base diet. The mordanted fiber was sieved through a 2 mm screen, and only the larger particles that did not pass through the sieve were used in the study.

Digestion Trial Protocol

Two digestion trials were conducted on consecutive weeks, each was four days long. To begin a trial, animals were offered a small, weighed piece of the marker diet within 15 min of the lights coming on in the room. The time an animal ingested the marker diet was recorded. If the piece of food was not completely consumed the uneaten portion was recovered and weighed. From these data, the amount of both markers ingested by each animal was calculated. The animals were then given a normal ration of the base diet. During all days of the trial, all amounts of food offered to the animals each day were weighed, and a fresh sample of the same food that was offered was frozen for later analyses. For the first two days of the trial, the cages were checked hourly, and any feces present were collected into preweighed aluminum weigh boats, weighed, placed into small, closable plastic bags, and frozen for latter analyses. Captive marmosets (and other callitrichids) retire to their nest boxes once the lights go off and they do not feed or defecate through their night sleep [Power, 1991]. Thus, overnight checks were not required. Based on earlier research [Power, 1991], it was estimated that 100% of the marker would be excreted within 30 hr of ingestion. During days three and four of the trial, fecal collections were made in the morning and late afternoon only. During all days, all uneaten food was collected and stored in the same manner as the collected feces. The trial ended on the fifth day in the same manner it started, with a weighed amount of marker food offered to the animals, and hourly cage checks to collect and weigh feces for the rest of that day. The first feces excreted that contained marker indicated the end of the digestion trial, and that feces and all subsequently collected feces were not included in the calculations of apparent digestibility.

Laboratory Analyses

All the nutritional assays were completed at the Nutrition Laboratory of the Smithsonian National Zoological Park, Washington DC. All the food samples, uneaten food, and feces were freeze-dried for seven days, and then oven-dried at 100°C for 24 hr. The samples were then weighed and ground for sub-sampling. Concentrations of chromium and cobalt were determined by first digesting subsamples of the materials in perchloric and nitric acids and then assaying the digests using an atomic absorption spectrophotometer.

Calculation of Digestive Parameters

Dry matter intake (DMI)

The amount of food ingested calculated on a dry matter basis (dry amount of diet offered minus dry amount of uneaten ration collected); expressed as grams/day.

Coefficient of ADDM

The amount of dry matter ingested minus the amount of dry matter excreted in the feces, all divided by the amount of dry matter ingested.

Mean retention time (MRT)

The sum for all feces collected of the amount of marker in feces times the amount of time since

ingestion that sum is divided by the total amount of marker excreted ($\sum m_i t_i / \sum m_i$ where m_i is the amount of marker in feces collected at t_i).

Statistical analyses

DMI, ADDM, fecal DM, and MRT for both Co and Cr were compared between trials using paired-sample *t*-tests. The relationships among these parameters were examined using correlation. The difference between MRT for Co and for Cr was examined using paired-sample *t*-tests. The differences in MRT values among the three data sets (this study, Caton et al. [1996], and Power [1991]) were examined using ANOVA.

RESULTS

Mean DMI was 13.3±0.6 g/day and mean ADDM was 78.1±0.5%. Neither parameter varied significantly between the two trials, though the values for both tended to be higher in trial 2 ($P = 0.083$ and $P = 0.060$, respectively). The mean dry matter of fresh-collected feces (fecal DM) was 27.7±0.9%. Within animals, both DMI and ADDM were highly correlated between trials ($r = 0.827$ and $r = 0.884$, respectively, $P < 0.001$; see Fig. 1). One animal (ID 324) had an exceptionally low DMI in the second trial; otherwise DMI was consistent with past results with this diet (Power, unpublished data). Estimated ME intake based on the ME of the diet was approximately twice the estimated metabolic rate for callitrichids of this size [Power, 1991; Power et al., 2003]. There was considerable variation among individuals in all measured parameters (Table I). There were no significant correlations among DMI, ADDM, or fecal DM. None of these parameters were associated with body mass.

Only ten animals ate sufficient amounts of the marker diet during both trials to warrant assaying feces for the markers (Table II). For these animals, MRT for cobalt (17.5±1.6 hr) and chromium (17.9±1.4 hr) were not statistically different ($P = 0.662$). The concentrations of cobalt and chromium were virtually identical for most fecal samples. Traces of marker could be detected up to 56 hr after ingestion, but in all the cases over 90% of marker had been excreted by 30 hr, and generally more than 60% of both markers were excreted by 11 hr, before the animals retired for sleep. There was considerable variation among individuals in MRT values (Table II); but in all the individuals the values for MRT of cobalt and chromium were similar. Surprisingly, there were no significant correlations among either marker's MRT and DMI, ADDM, fecal DM, or body mass.

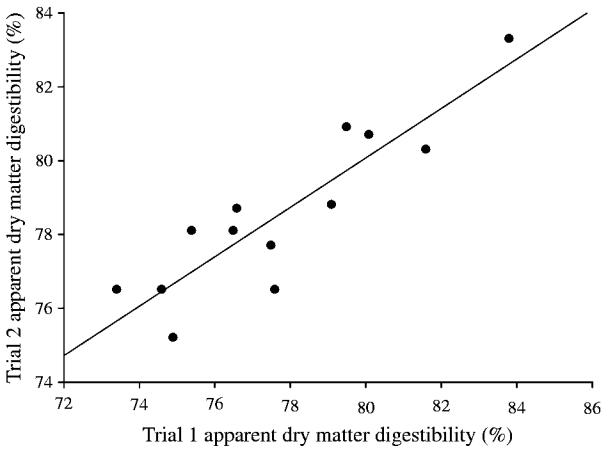

Fig. 1. Although the apparent dry matter digestibility (ADDM) of the diet varied among animals, ADDM values for each animal were consistent between the two trials.

The MRT results were compared with the results from Caton et al. [1996] and Power [1991] (Fig. 2). MRT for the liquid marker was not different between this study and Caton et al. [1996] (17.5±1.6 vs. 14.8±1.7 hr; $P = 0.405$). The results for the particulate markers were variable; MRT for chromium-mordanted fiber from this study tended (17.9±1.4 vs. 12.4±1.4 hr; $P = 0.063$) to be longer than the results from Caton et al. [1996]. The value for MRT of polystyrene beads (8.3±1.5 hr) from Power [1991] was the shortest of all the studies. The mean difference between liquid and particulate markers found by Caton et al. [1996] was 2.47 hr with a standard deviation of 0.833 hr. Based on these data a sample of ten animals was sufficient to detect a mean difference of 0.66 hr between liquid and particulate markers at $P = 0.05$ with an power of 80%. The value found in this study (−0.44 hr; standard deviation of 1.51 hr) was significantly different from that of Caton et al. [1996] ($P = 0.01$), and in the opposite direction. Based on the standard deviation found in this study the sample size was sufficient to detect a 1.2 hr difference at $P = 0.05$ and with a power of 80%.

DISCUSSION

The mean value for ADDM and the range of variation among individuals is similar to the values from Power [1991], as is the lack of an association of digestive parameters with body mass. Power [1991] found significant effects of body mass on digestive parameters among species but no associations within species.

The lack of any association between MRT and ADDM is somewhat surprising. Longer retention of digesta within the gut would be predicted to be associated with higher digestive efficiency. It is possible that the extent of variation in MRT is simply not great enough to result in significant variation in the digestion of this diet. This may be especially true because much of the variation in MRT can be explained by how much marker was excreted before the animals retired for the nighttime sleep.

TABLE II. The Mean Retention Times (MRT) of Cobalt and Chromium Calculated from the Concentrations of the Elements in the Excreted Feces

Animal ID	Co MRT (hr) trial 1	Cr MRT (hr) trial 1	Co MRT (hr) trial 2	Cr MRT (hr) trial 2
181	11.4	11.4	10.2	10.6
298	23.3	22.7	21.3	19.5
303	24.0	24.0	19.9	22.7
312	21.7	22.4	19.1	18.8
315	13.2	14.5	9.2	14.9
318	16.2	15.9	12.7	12.1
325	12.7	14.5	10.9	13.4
326	27.2	26.9	16.2	17.4
336	21.4	19.9	13.8	13.3
342	23.1	21.3	22.4	22.5
Mean	19.4±1.8	19.4±1.6	15.6±1.5	16.5±1.4

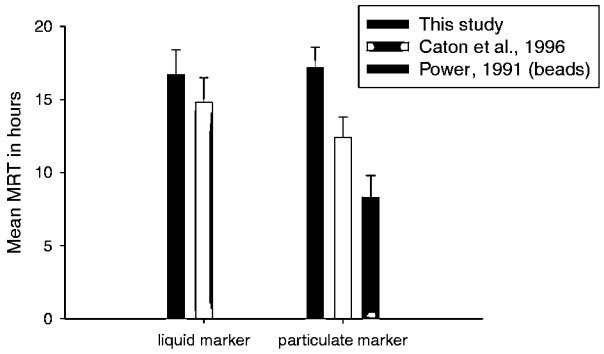

Fig. 2. Mean retention time (MRT) for cobalt EDTA in this study was not different from the results in Caton et al. [1996]. MRT for particulate markers were variable, with the mean values being different among all the three studies, indicating an effect of particle size on the results. The particulate markers in this study were the smallest, and those in Power [1991] were the largest.

This ranged from 60% to over 80% of marker. Because the common marmoset, like other callitrichids, significantly reduces its body temperature and metabolic rate at night [Power et al., 2003], it remains in a semi-torpid state through the night. In this study, as in others [Caton et al., 1996; Power, 1991], there was no defecation for this 12 hr period. Digesta, however, was certainly still moving through the digestive tract, though possibly at a reduced rate. Much of the digesta probably reached the rectum long before the animals awoke at lights-on and produced their first, and usually most copious, defecation of the day. Nutrients are unlikely to be absorbed from digesta in the rectum. Thus, MRT may overestimate the mean amount of time digesta is retained within the parts of the digestive tract where digestion and absorption of nutrients occur [Power & Oftedal, 1996].

In addition, common marmosets are susceptible to chronic enteritis [Ludlage & Mansfield, 2003; Sainsbury et al., 1987], which can affect nutrient absorption. The animals in this study were all apparently healthy. Fecal material was judged to be firm and well-formed, and fecal DM was similar to that found in Power [1991] for this species (27.7 vs. 29.6%). However, intestinal inflammation in common marmosets often persists in a sub-clinical state and is only diagnosed at necropsy. It is possible that the variation in digestive efficiency among the subjects in this study was at least partly due to variation in the extent of sub-clinical intestinal inflammation. Follow-up studies on marmosets in this colony have found associations between low digestive efficiency and low vitamin D status (Power, unpublished data) and bone mineral density (Jarcho, unpublished data).

In contrast to the findings of Caton et al. [1996], we found no difference in the MRT of particulate and liquid markers. Caton and colleagues measured passage rate in three animals over a single trial for each animal. The values from that study for MRT of CoEDTA (mean = 14.8±2.0 hr, range 11.5–16.7 hr) and chromium-mordanted fiber (mean = 12.4±1.5 hr, range 9.7–14.5 hr) are similar to the values found in this study (Table II). The excretion curves published in Caton et al. [1996] are similar to our excretion curves in that the concentrations of both markers were very similar over time and, for both markers, a majority of marker was excreted before the animals retired for the night.

The liquid marker used in this study and the study of Caton et al. [1996] was identical, and the MRT results from the two studies did not differ; however, the particulate markers differed between the studies. The mordanted fiber particles used by Caton et al. [1996] were longer (3 mm) than the mean size of particles in this study. In addition, the mordanted particles in this study were likely more fragile and thus, more susceptible to mechanical size-reduction when passing through the gut. The tendency for a longer MRT of the mordanted particles in this study possibly reflects the expected relationship between passage rate and particle size. In general, larger fiber particles will pass through the gut of a hind-gut-fermenting animal (such as a marmoset) more quickly than the smaller particles.

The MRT for 3 mm diameter polystyrene beads (and thus, with greater volume than either mordanted fiber marker) fed to common marmosets was significantly shorter than the MRTs found either in this study or in Caton et al. [1996].

Chromium-mordanted fiber was chosen as the solid marker because it is a well-accepted and validated solid marker in passage rate studies. We used fiber from canned marmoset diet because the animals routinely were fed this product and, thus, the fiber particles represented ones the animals ingested on a regular basis. However, most of the bulk fill that marmosets in the wild would be excluding from the cecum via any hypothesized cecal–colonic separation mechanism would be seeds. Hence, a marker such as plastic pellets may have been a more appropriate choice for determining solid marker rate of passage.

Transit time (time to first appearance of marker) did not differ between cobalt (liquid marker) and chromium (particle marker) in either this study or in Caton et al. [1996]. Earlier research found that transit time measured via plastic pellets did not differ from that measured by chromic oxide, an indigestible marker that is presumed to move with the liquid fraction of digesta, in either the common marmoset or golden lion tamarin (*L. rosalia*) [Power, 1991]. However, the MRT calculated for common marmosets from plastic pellet data was 8.3 hr, a time shorter than any individual value found in this study or Caton et al. [1996]. We cannot exclude the possibility that any existing cecal–colonic separation mechanism is geared to excluding solid particles significantly larger in volume than the mordanted fiber particles used in either study.

In general, common marmosets and other callitrichids, except for the gum-specialist pygmy marmoset, have relatively rapid passage rates of digesta. Time to first appearance of marker, whether liquid or solid, is measured in hours, and 60–80% of marker is excreted within the first 12 hr [Power, 1991; Caton et al., 1996; this study]. In contrast, for White-faced sakis (*Pithecia pithecia*), a seed predator, the first appearance of marker was generally after 10 hr, and excretion of 60% of marker was not until after 24 hr post ingestion [Norconk et al., 2002]. Admittedly, sakis are approximately five times the mass of common marmosets; however, we hypothesize that the longer retention times between a seed predator, such as a saki monkey, and most callitrichids also reflects the different costs vs. benefits of retaining seeds within the digestive tract for these taxa. For wild common marmosets, seeds represent indigestible bulk, provide essentially no nutrients, but may inhibit feeding by filling the digestive tract. There is a potential opportunity cost in retaining seeds within the gut and little benefit. We hypothesize that the adaptive advantage to eliminating seeds rapidly has driven the evolution of a rapid passage rate in most callitrichids. In contrast, pygmy marmosets feed extensively on gums and rarely feed on fruit; therefore, a slower passage rate has adaptive advantages and fewer costs.

A cecal–colonic separation mechanism is not the only potential strategy to increase gut residence time for gum. Passage rate may vary as a function of diet. Both pygmy and common marmosets fed a diet containing 9% gum arabic on a dry matter basis had longer transit times than when fed the diet without gum [Power, 1991; Power & Oftedal, 1996]. Wild callitrichids feeding extensively on fruit, and hence swallowing many seeds, often have estimated transit times under 1 hr (Power, personal observation; P. Garber, personal communication). Humans fed plastic pellets have shorter transit times [Tomlin & Read, 1988]. The mechanical stimulation of the gut from such particles (seeds or plastic pellets) may increase the rate of passage of digesta.

Heymann and Smith [1999] suggest that the temporal pattern of gum feeding can be a behavioral mechanism to increase the gut residence time of gum. They found that *Saguinus mystax* and *S. fuscicollis* concentrated their gum feeding in the late afternoon, shortly before retiring. Gum would thus be within the intestinal tract at night, when passage rate may have slowed due to the decreased metabolic rate. Peak gum feeding and bark gouging bouts in common marmosets are reported to be early in the morning (when guts are likely empty) and at the end of the day [Alonso & Langguth, 1989]. Both of these patterns would be likely to result in longer gut residence time for gum than if it was ingested during the middle of the day. An examination of the temporal pattern of gum feeding in *Callithrix* spp. is warranted.

The cecum may be performing another function in addition to acting as a fermentation chamber in marmosets. Marmosets likely are cecal–colon fermenters, with gum fermentation taking place in the upper colon as well as within the cecum. Common marmoset ceca are more complex in internal structure than are ceca of lion tamarins [Coimbra-Filha et al., 1980]. The strictures within marmoset ceca produce multiple small pockets, where bacterial populations may be protected from washout. The smoother walls of tamarin and lion tamarin ceca may result in greater bacterial loss due to the passage of digesta. The marmoset ceca may serve as a reservoir of bacteria to recolonize the upper colon after the resident bacterial populations have been reduced, perhaps due to the passage of large, hard seeds. The human appendix has been recently suggested to perform such a function, harboring a reservoir of gut microbes that can recolonize the lower gut [Bollinger et al., 2007]. The greater ability of marmosets to ferment gums may, in part, derive from an enhanced ability to maintain large microbial populations within the upper colon.

In this study we confirmed the results of Caton et al. [1996] for the MRT of liquid digesta in the common marmoset (approximately 16 hr); however, we were not able to replicate their finding of a shorter retention time for particulate markers. A comparison of particulate marker data from this study, Caton et al. [1996] and Power [1991] indicates that, as to be expected, mean retention of particulate markers is negatively associated with particle size. Thus, marmosets retain liquid digesta and small particles within the gut longer than larger particles. This implies that seeds from fruit likely pass through wild marmoset guts much quicker than would gum or well masticated insect parts.

The existence of a cecal–colonic separation mechanism in marmosets, whereby gum is preferentially retained in the cecum and seeds excluded, cannot be ascertained from the current published studies, though the data are consistent with such a mechanism. It is especially important to note that similar studies on tamarins and lion tamarins have not been published; so it is not known whether common marmosets differ from their less gum-reliant sister taxa in retention times of liquid vs. particulate matter.

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