FEEDING GUM ARABIC TO NEW WORLD MONKEYS: SPECIES DIFFERENCES AND PALATABILITY

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Abstract *Animal Welfare 2001, **10:** 249-256*

Members of the New World primate genera Callithrix *and* Cebuella *have specialisations for eating plant exudates. Exudates are also an important component of the diets of many other callitrichid species in the wild, especially at times of nutritional stress. Gum arabic is fed daily to all marmosets and to some tamarins in Jersey Zoo's collection. This study investigated species differences in liking for gum and the effects of the concentration of gum solutions on palatability. As predicted from field data,* Callithrix *species consumed more gum than other species;* Saguinus *also showed quite a strong liking for gum. In parallel with data from the wild, lion tamarins (*Leontopithecus *spp.) consumed the least, and* Callimico *also took relatively little. The two marmoset species tended to like stronger solutions of gum more than weak solutions and, therefore, the provision of smaller amounts of stronger concentrations is likely to be the most cost-effective way of incorporating gum into the diet. Providing gum to callitrichids on a regular basis can have significant welfare benefits.*

Keywords: *animal welfare, exudates, Goeldi's monkey, gum, marmoset, nutrition, tamarin*

Introduction

Exudates are an important component of the wild diets of many members of the Callitrichidae, a family of small New World primates, and particularly of the marmosets (genera *Callithrix* and *Cebuella*), which have specialised dentition enabling them to gnaw into exudate-producing plants, as well as digestive adaptations permitting microbial fermentation of gums (eg Power & Oftedal 1996). Marmosets spend around 14–73 per cent of their feeding and foraging time exploiting exudates (Soini 1988; Rylands 1989; Ferrari & Rylands 1994; Digby & Barreto 1996; Ferrari & Digby 1996; Passamani 1998; Veracini 1998; Martins & Setz 2000).

Other members of the family, the tamarins and lion tamarins (*Saguinus* and *Leontopithecus*), will also eat gum, and although they can only do so on an opportunistic basis, exudates may provide an important source of calcium and energy when other resources are in short supply (eg Peres 1989) or at critical times in the reproductive cycle such as during lactation (eg Garber 1984; but see Smith 2000). On average, *Saguinus* species appear to spend more of their feeding time on exudates than *Leontopithecus*: 1–16 per cent compared with 1–6 per cent for lion tamarins (eg Garber 1984, 1993; Peres 1989, 1993; Rylands 1989; Savage 1990; Egler 1992; de la Torre *et al* 1995; Albernaz 1997; Dietz *et al* 1997). Furthermore, although none of the lion tamarins use exudate a great deal, it may form a higher proportion of the diet of black lion tamarins *L. chrysopygus* than of the other two species for which data are available, particularly at times of low fruit availability such as

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during the dry season (Rylands 1993; Albernaz 1997). As yet, very little information is available on the diet of wild Goeldi's monkeys (*Callimico goeldii*), although exudate-feeding appears to be rare (Heltne *et al* 1981). However, many authorities now believe that this species is a member of the Callitrichidae and particularly closely related to the marmosets (eg Pastorini *et al* 1998), and it was therefore of interest to investigate gum-feeding in this species.

The main nutrients provided by gums are probably energy in the form of complex carbohydrates and some minerals, particularly calcium (eg Garber 1984; Nash 1986; Power 1996; Smith 2000). Jersey Zoo, headquarters of the Durrell Wildlife Conservation Trust, introduced gum arabic into the daily diet of all marmosets in the early 1990s following a study of Geoffroy's marmosets, *Callithrix geoffroyi*, that suggested that some health and breeding problems may have been related to a lack of calcium and energy (Price 1992). Gum is also supplied regularly to pied tamarins *Saguinus b. bicolor*, which have also proved rather difficult to maintain in captivity (Wormell *et al* 1996), in order to provide an additional source of these nutrients. Although commercial primate pellets are fortified with adequate quantities of nutrients, it is difficult to ensure that animals take in sufficient quantities of pellet (Price *et al* 1999), and therefore the diet may be lacking in some essential nutrients. Gum arabic may thus provide a way of increasing nutrient intake, as it is easily available and is known to be non-toxic.

As part of a programme of developing species-specific diets for callitrichids, we believed it was important both to determine the palatability of gum for different species, and to assess how best to maximise the monkeys' intake of gum in the most cost-effective way. Gum is purchased in either 'kibbled' form (small lumps), or powder form, and is diluted with water as required. Previously, the concentration was not standardised, but staff had the impression that all species given gum liked a thicker consistency. A preliminary study (Ordoñez 1997) indicated species differences in consumption, and a liking for stronger solutions of gum. The present study expands on this, focusing on two main issues: first, the liking of two species of marmoset for gum of different concentrations, in order to establish the best way of presenting gum; and second, species differences in liking for gum, in order to discover whether these differences parallel the differences in exudate-use seen in the wild. We predicted that *Callithrix* species would show the strongest liking for gum, and *Leontopithecus* the least.

Methods

Part 1

Two groups of silvery marmosets *Callithrix a. argentata*, initially numbering two and four individuals, and two groups of Geoffroy's marmosets *Callithrix geoffroyi* (one group of two and one of five) were studied. The larger group of silvery marmosets was reduced from four to three during the study. Groups were housed in large indoor/outdoor cages in one of three buildings (see Wormell *et al* 1996 for details). The marmosets were fed three times per day: a commercial primate pellet mixture soaked in sweetened water and mixed with bread was given at approximately 0800h; a mixture of chopped fruit and vegetables with a protein item such as egg or pet food was given at approximately 1230h; and a snack feed, usually of insects, was given at about 1630h.

Gum arabic was obtained from Joseph Flach & Sons Ltd (8 Maxwell Road, Woodston, Peterborough, Cambridgeshire PE2 7HU) as lumps, which were dissolved in water to the required consistency. Four different concentrations were used — 1:1, 1:3, 1:6, and 1:10 of gum:water by volume. Each solution was given for three days. Because the gum was purchased in lump-form, the volume measurement did not necessarily produce exactly the

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same weight of gum daily; however, this was the easiest method of ensuring an approximately equivalent concentration each time and care was taken to use approximately the same size of chunk each day. As every group was studied at each trial, the gum consumption of all the monkeys was investigated under the same set of conditions.

The gum was presented at the lunchtime feed in one or two dishes in each cage, depending on the number of animals in the group. Initially, approximately 65 ml per dish was given, but in the pilot studies this was adjusted to a larger quantity if necessary so as to ensure that the monkeys did not consume the entire quantity. The amount remaining at the end of the day was measured, and a mean intake per individual per day was calculated for each concentration. Species differences were investigated using Mann-Whitney *U* tests, and the effects of concentration were measured using a Friedman test (Siegel & Castellan 1988) with post-hoc Tukey multiple comparisons tests.

Part 2

To investigate species differences in liking for gum, a 1:2 solution was given for 9–10 days to all possible single-species groups of the eight species in the collection. Details of groups are given in Table 1; husbandry and diet were as described in Part 1. Again, sufficient gum was given daily so that not all was consumed. Mean intake per individual per day was calculated as before, excluding dependent infants, which did not consume gum. Differences between genera and species were analysed using Kruskal-Wallis tests (Siegel & Castellan 1988).

Table 1 Details of subject groups for part 2 of the study.

Common name	Scientific name	Number of groups	Group sizes[1]
pied tamarin	*Saguinus bicolor*	3	5, 6, 7
cotton-top tamarin	*Saguinus oedipus*	2	2, 2
Geoffroy's marmoset	*Callithrix geoffroyi*	3	1, 2, 5
silvery marmoset	*Callithrix argentata*	1	4 then 3
Goeldi's monkey	*Callimico goeldii*	1	5
black lion tamarin	*Leontopithecus chrysopygus*	4	2, 2, 5, 9
golden-headed lion tamarin	*Leontopithecus chrysomelas*	3	2, 2, 4
golden lion tamarin	*Leontopithecus rosalia*	1	7

[1] Excluding dependent infants

Results

Part 1

The results are shown in Figure 1. There was no significant difference in intake between the two species for any concentration (for all four comparisons, Mann-Whitney $z = -0.387$, $P = 0.698$). The effect of concentration was, however, statistically significant, both species most liking the second-strongest solution (Friedman's $\chi^2 = 11.1$, $df = 3$, $P = 0.012$). Post-hoc Tukey tests showed that the 1:10 solution was consumed significantly less than the 1:3 solution ($Q = 4.648$, $P < 0.05$).

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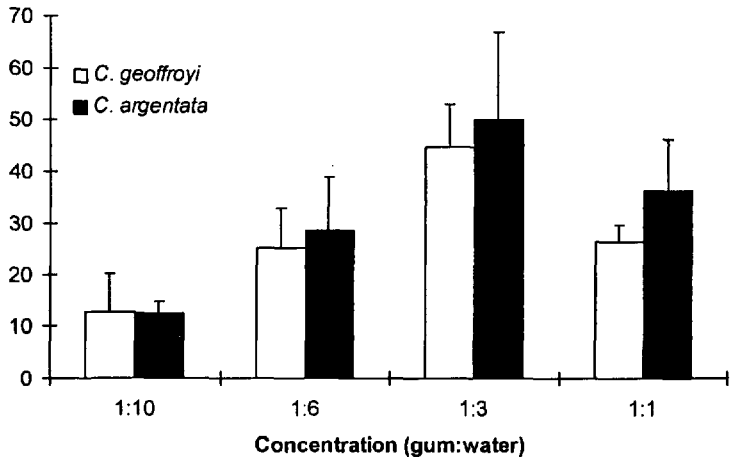

Figure 1 **Mean daily intake per individual of four different solutions of gum arabic in two marmoset species. Bars indicate standard errors.**

Part 2

Species comparisons are shown in Figure 2. Overall, there was a significant difference between species in gum consumption (Kruskal-Wallis test $H = 14.6$, $df = 7$, $P = 0.044$). There was little difference between species within each genus, and thus there was also a significant overall difference between genera ($H = 14.42$, $df = 3$, $P = 0.003$). As predicted, the two marmoset species liked the gum the most. All the others also ate gum, but the two *Saguinus* species showed a stronger liking for it than the Goeldi's monkeys and the three lion tamarins.

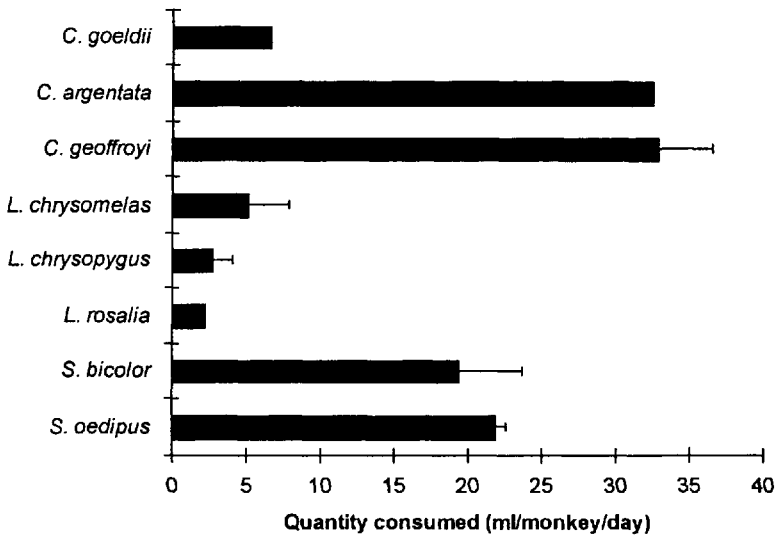

Figure 2 **Mean daily intake per individual of a 1:2 dilution of gum arabic in eight species of New World monkey. Bars indicate standard errors.**

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Discussion

There is considerable variation between species and genera of callitrichid in dependence on exudates in the wild (eg Soini 1988; Stevenson & Rylands 1988; Rylands 1989, 1993; Garber 1993). Marmosets are often heavily dependent on gum, and at least some *Saguinus* species moderately so, while lion tamarins consume least. The present study has shown that levels of gum arabic consumption by callitrichids in captivity closely parallel these field results. As expected, marmoset species showed the strongest liking for gum, followed by *Saguinus* species, with *Leontopithecus* and *Callimico* eating relatively little.

Some monkeys in this study had not previously been fed gum. It is therefore possible that in the case of those species that consumed relatively little, unfamiliarity was a factor. However, although cotton-top tamarins at Jersey had not previously been given gum, pied tamarins were provided with it regularly. The fact that both species showed a similar liking for gum suggests that familiarity may not have been an important factor in determining consumption levels.

The characteristics of the plant gums utilised by marmosets in the wild vary. Some are liquid when first exuded, others sticky and viscous (eg Fonseca & Lacher 1984). Furthermore, marmosets do not necessarily gnaw new gum holes each time they feed. Instead, they frequently harvest gum that has been exuded from previously gnawed holes — if not harvested immediately, liquid gums tend to form viscous masses or solid lumps upon exposure to air (Fonseca & Lacher 1984; Stevenson & Rylands 1988; E Price, personal observations). It is therefore interesting that the marmosets in this study liked more concentrated, gelatinous solutions, and hence the provision of more dilute gum is unlikely to result in significant cost-saving: a smaller quantity at a higher concentration would be more beneficial. The concentration most liked by the marmosets (1:3) was one which produced a thick jelly-like consistency but which the monkeys could still lick from the dish or from their hands. The most concentrated solution proved too difficult for the animals to manage: informal observations suggested that they were unable to separate manageable amounts from the mass in the dish with either their mouth or their hands. Finding the ideal compromise between concentration, palatability and ease of consumption is likely to be a matter of trial and error and may depend on the characteristics of the gum used. In the initial pilot study (Ordoñez 1997), powdered gum from the same suppliers as mentioned previously was used. However, we found that although powder was easier for the keepers to manage, it appeared to be less palatable to the monkeys than the kibbled form. The powder and the lumps were obtained from different sources in Africa (S Flach, personal communication 1998) and may therefore have tasted slightly different to the animals.

We have also in the past presented gum in solid lumps. However, this was less successful than the dissolved form for several reasons. Firstly, if the chunks were given in open dishes, much of it was simply dropped on the floor, which was very wasteful. We tried placing it in closed mesh hoppers so that the monkeys could lick it through the bars. It was necessary to moisten the gum daily with water, because if it was allowed to dry the monkeys did not take as much. This presented hygiene problems, however, as the gum remained in the hoppers for some time and other pieces of food and debris tended to stick to the surface. It was also more difficult to quantify how much was eaten.

Gum is now regularly given to captive marmosets in many collections as a form of enrichment (McGrew *et al* 1986; Kelly 1993). Very little time is involved in its preparation, and liquid gum can also be presented in artificial gum-trees or holes drilled in natural branches. However, although it is not often used as an integral part of the daily diet,

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providing gum to captive callitrichids is a relatively simple way of supplementing diets with essential nutrients. Some callitrichid species, notably *Saguinus bicolor* and *Callithrix geoffroyi*, have exhibited health problems in captivity that may result in part from nutritional factors (eg Price 1992; Wormell *et al* 1996). Gums may therefore be a way of supplementing captive diets to ensure that nutritional requirements, particularly for energy and calcium, are met. Gums contain relatively high proportions of calcium (Garber 1984; Nash 1986; Smith 2000), and recent studies have suggested that common marmosets *Callithrix jacchus*, particularly lactating females, have a preference for calcium solutions over water (Power *et al* 1999). This may indicate a particular need for this mineral in the diet. Furthermore, an analysis of the effects on the health of Geoffroy's marmosets at Jersey Zoo of changes to diet and husbandry, the most prominent of which was the daily provision of gum arabic, has shown that they have led to a dramatic reduction in illness and non-infant mortality (Wormell & Price, in preparation), and 'wasting syndrome' and bone demineralisation in females are now very rare. For example, occurrences of diarrhoea and weight loss have decreased in frequency per animal per year by factors of five and 18, respectively, while non-infant mortality has been reduced to less than 30 per cent of the level at which it stood before dietary changes were made.

Although provision of gum for captive marmosets reflects the importance of this food source in wild diets and appears to have positive health benefits, Power and Oftedal (1996) suggested that including gum arabic in the diet of tamarin species (*Saguinus* and *Leontopithecus*) may result in lowered digestibility of dry matter and energy. This could be interpreted as an argument against providing gum for tamarins. However, the monkeys in Power and Oftedal's study were given gum only for 13–16 days, and the authors noted that the reduction in digestive efficiency decreased over time — in other words, given sufficient time, it is likely that individuals would adapt to the inclusion of gum in the diet and that any detrimental effects on digestibility would disappear. Our own informal observations also suggest that although a monkey given gum for the first time initially produces looser faeces, this effect disappears after several days. Consequently, we feel that there are unlikely to be any adverse effects of giving gum to most callitrichid species, and that there may be strong welfare benefits even for tamarins.

Timing of gum-feeding may also affect digestibility. The gut passage time of captive callitrichids that are not regularly given gum is typically 4–5 hours (Price 1993). However, a recent field study of two sympatric *Saguinus* species (Heymann & Smith 1999) showed that wild tamarins tend to feed on gum in the afternoon rather than earlier in the day. This may allow them to retain gum in the gastrointestinal tract overnight, allowing much more time for the microbial fermentation that is required to digest the gum. However, we have found that if gum is presented late in the afternoon, the monkeys tend to eat much less.

Animal welfare implications

Provision of gum can stimulate naturalistic behaviour in marmosets and tamarins and consequently can be a beneficial form of environmental enrichment for captive monkeys. However, it also has other welfare implications. First, health benefits may accrue by helping to ensure an adequate intake of essential nutrients. Second, providing opportunities for animals to practise necessary skills and to encounter natural foods is vital in maintaining behavioural diversity in captivity, particularly in preparation for possible reintroduction. Even for those genera without specific dental or anatomical adaptations for gum-feeding, an ability to use this resource when other food supplies are limited may be crucial to survival. Attempting to provide a diet that corresponds as closely as possible with the one to which a

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species is adapted in the wild is therefore likely to result in significant improvements to health, welfare and the success of captive-breeding and reintroduction programmes.

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