Feeding preferences of captive brushtail possums for eucalypt and acacia foliage

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Abstract

*Intake by brushtail possums (*Trichosurus vulpecula*) and their preferences for juvenile foliage from four* Eucalyptus *species and foliage from two* Acacia *species were measured with paired–species feeding trials using captive animals in individual cages. By choice, foliage made up 12–23% of the total dry matter intake of possums; the rest was a highly digestible basal diet provided at the same time. Possums showed significant preferences in most comparisons. Plantation-grown* Eucalyptus nitens *was preferred more than* E. delegatensis, E. regnans, Acacia dealbata *and* A. melanoxylon. *Almost no foliage from* A. melanoxylon *was eaten. No preference could be detected between plantation-grown* E. nitens *and plantation-grown* E. globulus, *but nursery-grown* E. globulus *was preferred more than plantation-grown* E. nitens. *These results demonstrate that, at least in captivity, brushtail possums generally have distinct feeding preferences. It appears that juvenile foliage from the subgenus* Symphyomyrtus *is more preferred than* Monocalyptus *foliage, and the* Acacia *species are least preferred. The results suggest that the main plantation species in Tasmania (*E. globulus *and* E. nitens*) are probably the most preferred by possums, even compared with other species which may grow incidentally on site (e.g.* A. dealbata*), although apparently there is enough leaf biomass at the sapling stage to prevent severe defoliation. Damage by breaking branches in* A. melanoxylon *plantations is unlikely to be associated with high foliage intake by possums, but could conceivably result from searching for young growing tips as possums move through the trees.*

Introduction

Brushtail possums (*Trichosurus vulpecula*) are one of the three main native herbivore species implicated in causing damage in plantations and regenerated coupes in Tasmania (Mollison 1960; Cremer 1969; Statham 1983). These herbivores generally cause browsing damage to seedlings, but brushtails can also damage saplings and older trees of some species by breaking branches. This has been observed particularly with *Eucalyptus globulus* and *Acacia melanoxylon* (D. de Little and A. McMasters, pers. comm.). In order to understand the actual or potential damage caused by possums, it is useful to determine whether they simply use the trees as runways, or eat the foliage, and if they do eat the leaves whether they have any species-specific preferences. There are no studies which have rigorously addressed the question of feeding preferences of possums in Tasmania, as distinct from simply a diet description, although it has been noted that brushtail possums are associated with damage to *E. nitens* and *E. globulus* trees (Neilsen 1990).

We report here on the feeding preferences of captive brushtail possums for foliage from trees of four eucalypt and two acacia species which are used or occur naturally in forestry coupes. Our main aims were to determine whether brushtails demonstrated any preferences, measured by differences in intake in paired-species feeding trials, and if so, how they were manifest, in terms of actual intake of each species and total intake. While doing this, we were also able to investigate whether growing conditions (plantation versus nursery) of one species (*E. globulus*) could affect preferences; and finally, whether trials in the short term (five days) reflected or differed from longer term trials (14 days). This is part of a larger study whose main emphasis is interactions between herbivores and seedlings. The trials reported here were an initial investigation into the potential impact of possums in forestry.

Preference is multi-faceted, and can be measured with captive animals as comparisons of intake when food items are fed individually, in pairs, or as part of a 'cafeteria' choice; with or without an alternative or basal food source (Gillingham and Bunnell 1989; McArthur *et al.* 1993; Hjalten *et al.* 1996); or in less controlled field trials (Landsberg 1987). Each experimental design examines a different aspect of the process of diet selection. We chose to examine preferences when captive animals were offered a choice of two plant types (species), and with sufficient basal diet so that they did not have to consume any foliage for energetic or nutritional reasons. Brushtail possums are generalist browsers, with a reasonably broad diet including leaves of trees and shrubs (Freeland and Winter 1975; Statham 1983; Kerle 1984). Eucalypts are not eaten exclusively, although they can be common dietary items. It was therefore more realistic to perform preference trials with a basal diet to mimic the soft forbs which make up an important part of their natural diet than to provide only foliage from trees. We also provided a choice of tree foliage to reflect their dietary breadth (Freeland and Winter 1975), but avoided the complications of cafeteria trials in which plant types may remain uneaten simply because of the overwhelming supply of alternative options.

Methods

Animals and cages

Six male possums weighing between 2.6 kg and 4.8 kg (mean 3.6 kg, SD = 0.8) were used for all feeding trials. They were caught from Hobart and surrounding areas ten days to five weeks before the start of the first trial, and maintained in individual cages situated outside in an animal enclosure (Department of Zoology, University of Tasmania). The cages were 4.3 m long, 1.7 m wide and 2.5 m high, with concrete floors, wire mesh walls and protective roofing against the rain. Each animal was provided with a nest box and logs as above-ground runways. Animals were fed daily and weighed regularly to monitor condition. On average, they gained about 1% of their initial body weight during each trial period, indicating they were in a reasonably steady state.

Maintenance and experimental basal diets

Animals were maintained between trials on a mixed diet of apples, carrots, bread, cabbage, lettuce and some eucalypt and other leaves. They ate a homogeneous basal diet during feeding trials. A daily intake between 20–35 g dry matter (DM). $kg^{-0.75}$ (metabolic body weight MBW) of this basal diet was adequate for maintaining body weight. By fresh weight, the basal diet consisted of 40% grated apple, 30% finely chopped silver beet, 4% lucerne chaff (ground through 2 mm mesh), 15% added water, 8% grated carrot and 3% raw sugar. It was 15–18% dry matter and 1.4% nitrogen (as percentage of dry matter). Fresh drinking water was always available.

Foliage

Foliage from *Eucalyptus nitens* (subgenus *Symphyomyrtus*) was used in all trials because of its increasing importance as a plantation species. The second species in each paired trial was either *E. regnans*, *E. delegatensis* (both subgenus *Monocalyptus*), *E. globulus* (subgenus *Symphyomyrtus*), *Acacia dealbata* or *A. melanoxylon*. Branches of juvenile eucalypt foliage, and acacia foliage (adult for *A. melanoxylon*) were cut from trees twice a week and stored with stems in water in buckets in a cool room.

In Trials 1 and 2, foliage was obtained from Forestry Tasmania plantations around Geeveston in the southern forests of Tasmania for all species apart from *E. globulus* in Trial 2. The latter was obtained from saplings grown in fertile soil with adequate water in tubs at the University (called nursery-grown hereafter). In Trial 3, *E. nitens* and *E. globulus* foliage were collected from plantations.

Feed and feeding trials

In Trials 1 and 2, animals were fed the basal diet in sufficient quantities (400–600 g fresh weight, FW) to maintain body weight (i.e. at or slightly below *ad libitum*). In Trial 3, animals were provided with a more precise amount of basal diet (35 g $DM.kg^{-0.75}.day^{-1}$). The diet was prepared and fed daily. Two subsamples of the diet were dried daily in an oven at 80°C to determine percentage dry matter (%DM) and hence the DM offered. Next morning, the food remaining (orts) was also dried at 80°C and DM intake for each animal was calculated by subtracting DM (orts) from DM (offered).

Animals were offered a choice of foliage from two plant species in addition to the basal diet. Bunches of branches (100–300 g FW) of each species were prepared each afternoon. Bunches were prepared for the six animals, and an additional three bunches for each species were prepared for controls. For each animal, a bunch of *E. nitens* and a bunch of the second species were weighed and then placed with stems in water in containers, with leaves presented at either side of a log runway. Both bunches were readily available to the animal, and were swapped each day to avoid any container bias. Next morning, the remains were weighed and discarded. Control bunches were placed in the same conditions but inaccessible to possums. They were also weighed at the beginning and end of this period, to determine percentage weight loss or gain of branches in the absence of feeding. The mean of the three control weight changes was used to adjust the estimated bunch weight offered to each animal for each species each day. Fresh weight intake was then calculated by subtracting the final bunch weight from the adjusted bunch weight offered.

Two leaf subsamples, mimicking the leaf type eaten by the animals (e.g. just tips, expanded but soft young leaves and/or mature leaves), were taken from the controls each morning and dried at 80°C to determine %DM of leaves eaten. This was used to convert FW intakes of each species to DM intakes. Trials 1 and 2 both consisted of three consecutive five-day periods, and three treatments were tested in each trial. In each period, animals were fed a particular treatment consisting of *E. nitens* plus one other species. Six animals were used in a balanced cross-over design (Table 1), so that we could test for any carry-over effect between periods (Ratkowsky *et al.* 1993). In Trial 1, *E. nitens* was compared with *E. regnans*, *E. delegatensis* and *A. dealbata*. In Trial 2, *E. nitens* was compared with *E. delegatensis* (to act as a standard between trials), *E. globulus* and *A. melanoxylon*. As mentioned, the *E. globulus* in Trial 2 was nursery-grown.

Trial 3 lasted 14 days, and used only one treatment, *E. nitens* compared with *E. globulus*, both from plantations. This trial was undertaken mainly to test whether preferences changed over a longer timeframe compared with that tested in Trials 1 and 2, but also to test whether the nursery growing conditions of *E. globulus* in Trial 2 could have affected the preference results. Because *E. globulus* in Trial 2 was grown in excellent conditions (fertile soil, sufficient water), it was hypothesised that it would be relatively more palatable than *E. globulus* growing in plantations, although it was not compared directly.

Table 1. Balanced cross-over design used in Trials 1 and 2. Each period lasted five days, with no interval between periods. Eucalyptus nitens *was used in all periods of both trials. In Trial 1, Treatment A* = E. nitens *cf.* E. delegatensis, *Treatment B* = E. nitens *cf.* E. regnans, *Treatment C* = E. nitens *cf.* A. dealbata. *In Trial 2, Treatment A* = E. nitens *cf.* E. globulus, *Treatment B* = E. nitens *cf.* E. delegatensis, *Treatment C* = E. nitens *cf.* A. melanoxylon.

Possum	Period 1	Period 2	Period 3
1	A	B	C
2	B	C	A
3	C	A	B
4	A	C	B
5	B	A	C
6	C	B	A

Table 2. Summary of the (least squares mean) intake results ($g.day^{-1}$) for each treatment in Trial 1, showing the total leaf dry matter intake (total DMI), the dry matter intake (DMI) of E. nitens, *the dry matter intake of the particular 'other' species as indicated by the treatment, the difference in the intake of* E. nitens *compared with the other species, and the relative amount of* E. nitens *eaten (as percentage of the total leaf DMI). (Values bearing different superscripts in the same column are significantly different from each other ($P < 0.05$). * indicates that the difference in intake within a treatment is significant ($P < 0.05$); i.e. that there is a significant preference for* E. nitens.*)*

Treatment	Total DMI	DMI *E. nitens*	DMI 'other'	Difference in DMI	% *E. nitens*
E. nitens versus					
E. regnans (B)	24.1[a]	17.9[a]	6.2[a]	11.7[a] *	74
A. dealbata (C)	20.9[a]	15.2[a]	5.7[a]	9.5[ab] *	73
E. delegatensis (A)	19.9[a]	12.0[a]	7.9[a]	4.1[b] *	60

Table 3. Summary of the (least squares mean) intake results ($g.day^{-1}$) for each treatment in Trial 2, showing the total leaf dry matter intake (total DMI), the dry matter intake (DMI) of E. nitens, *the dry matter intake of the particular 'other' species as indicated by the treatment, the difference in the intake of* E. nitens *compared with the other species, and the relative amount of* E. nitens *eaten (as percentage of the total leaf DMI). (Values bearing different superscripts in the same column are significantly different from each other ($P \leq 0.05$). * indicates that the difference in intake within a treatment is significant ($P < 0.05$); i.e. that there is a significant preference for* E. nitens *(positive result) or the other species (negative result).)*

Treatment	total DMI	DMI *E. nitens*	DMI 'other'	difference in DMI	% *E. nitens*
E. nitens versus					
E. globulus (A)	18.1[a]	5.9[a]	12.3[a]	-6.3[a] *	33
E. delegatensis (B)	16.7[a]	11.8[a]	4.9[b]	+6.8[b] *	71
A. melanoxylon (C)	11.7[a]	11.1[a]	1.5[b]	+10.4[b] *	95

Statistical analysis

In Trials 1 and 2, results for statistical analyses were expressed as the mean dry matter intake ($g.day^{-1}$) of each plant species eaten by each possum over each five-day period. Intake of *E. nitens*, intake of the other plant species offered in each treatment, the difference in intake of *E. nitens* compared with the other species, and the total intake of the foliage from both species were the dependent variables analysed using the General Linear Models Procedure (PROC GLM, SAS Institute 1989). The models tested for effects of possum, period and treatment. Initial models tested for a carryover effect but, as this was never significant, it was not included in the final models. Repeated measures analyses were not used because we were interested in the overall response of possums over five days, rather than intake fluctuations on a daily basis. Final intake results are presented as least squares means (lsm), and an alpha level of 0.05 was used to test for significance of the Type II sums of squares. A significant preference for *E. nitens* or the other plant species, when offered as a pair, was indicated if the 95% confidence intervals of the (lsm) difference in dry matter intake between the two species did not include zero.

In Trial 3, the difference in dry matter intake of *E. nitens* versus *E. globulus* was compared with a paired t-test (PROC MEANS, SAS Institute 1990) using the average intakes over days 1–5 of the 14-day trial, for comparison with Trials 1 and 2. Then, in an attempt to determine whether results differed if tested in the short term (first five days) or after previous exposure and over a longer time frame (last nine days), intakes over days 1–5 were compared to those over days 6–14 with paired t-tests.

Results

Trial 1

Possums ate an average of 76 g $DM.day^{-1}$ of the basal diet, or 29 g $DM.kg^{-0.75}.day^{-1}$ in Trial 1. Table 2 summarises the intake results for each treatment. Animals ate a total of 20–24 g $DM.day^{-1}$ of foliage, irrespective of the combination provided, which represented 20–23% of their total daily DM intake (i.e. including the basal diet). *Eucalyptus nitens* made up between 60% and 74% of the total foliage intake (i.e. excluding the basal diet).

Intake of *E. nitens* did not differ significantly between possum, period or treatment (lsm = 15.0 g $DM.day^{-1}$; $F_{9,8} = 2.36$, $P = 0.12$). Intake of the other species varied (lsm = 6.6 g $DM.day^{-1}$; $F_{9,8} = 3.27$, $P = 0.05$); there was no significant possum or treatment effect overall (d.f. = 5, $F = 2.15$, $P = 0.16$; d.f. = 2, $F = 1.35$, $P = 0.31$ respectively), but there was a significant period effect (d.f. = 2, $F = 8.00$, $P = 0.01$), although no consistent trend in increase or decrease in intake from the first to last period (data not shown). The total intake of *E. nitens* plus the other species was not significantly affected by possum, period or treatment (lsm = 21.6 g $DM.day^{-1}$; $F_{9,8} = 2.15$, $P = 0.15$).

There was a significant effect of treatment, but not possum or period on the difference in intake between *E. nitens* and the other species ($F_{9,8} = 3.32$, $P = 0.05$; treatment effect d.f. = 2, $F = 5.27$, $P = 0.03$; possum effect d.f. = 5, $F = 2.94$, $P = 0.08$; period effect d.f. = 2, $F = 2.33$, $P = 0.16$).

In summary, there was a significant preference for *E. nitens* foliage compared with *E. regnans*, *E. delegatensis* and *A. dealbata*. Intake of *E. nitens* tended to be lowest when offered with *E. delegatensis* and highest when offered with *E. regnans*.

Trial 2

Possums ate an average of 80 g $DM.day^{-1}$ of the basal diet, or 30 g $DM.kg^{-0.75}.day^{-1}$ in Trial 2. Table 3 summarises the intake results for each treatment. Animals ate a total of 11–18 g $DM.day^{-1}$ of foliage, which represented 12–18% of their total daily DM intake (i.e. including the basal diet). *Eucalyptus nitens* made up between 33% and 95% of the total foliage intake (i.e. excluding the basal diet).

Intake of *E. nitens* did not differ significantly between possum, period or treatment (lsm = 10.2 g $DM.day^{-1}$; $F_{9,7} = 2.04$, $P = 0.18$). Intake of the other species differed significantly ($F_{9,7} = 3.27$, $P = 0.01$); there was a significant treatment effect (d.f. = 2, $F = 17.29$, $P = 0.002$), but no significant possum or period effect (d.f. = 5, $F = 1.61$, $P = 0.27$; d.f. = 2, $F = 2.87$, $P = 0.12$ respectively). Total intake of *E. nitens* plus the other species was not significantly affected by possum, period or treatment (lsm = 15.9 g $DM.day^{-1}$; $F_{9,7} = 2.26$, $P = 0.15$).

There was a significant effect of treatment, but not possum or period on the difference in intake between *E. nitens* and the other species ($F_{9,7} = 4.60$, $P = 0.03$; treatment effect d.f. = 2, $F = 15.50$, $P = 0.003$; possum effect d.f. = 5, $F = 1.54$, $P = 0.29$; period effect d.f. = 2, $F = 1.32$, $P = 0.33$).

In summary, there was a significant preference for *E. nitens* foliage compared with that of *E. delegatensis* and *A. melanoxylon*, but nursery-grown *E. globulus* was preferred over plantation grown *E. nitens*. Intake of *E. nitens* tended to be lowest when offered with the more preferred *E. globulus*. Intake of *A. melanoxylon* leaves was extremely low, and consisted mainly of the young growing tips.

Trial 3

Possums ate an average of 70 g $DM.day^{-1}$ of the basal diet, or 27 g $DM.kg^{-0.75}.day^{-1}$ in Trial 3. The mean daily intake of foliage during the first five days was 6.6 g $DM.day^{-1}$ for *E. nitens* and 7.3 g $DM.day^{-1}$ for *E. globulus*, a total of 14.0 g $DM.day^{-1}$ (Table 4) which represented

Table 4. Summary of the mean intake results (g.day⁻¹) (±SD) for Trial 3, showing the total leaf dry matter intake (total DMI), the dry matter intake (DMI) of E. nitens *and* E. globulus, *the difference in the intake of* E. nitens *compared with* E. globulus, *and the relative amount of* E. nitens *eaten (as percentage of the total leaf DMI). (Values bearing the same superscripts in a column are not significantly different from each other (P > 0.05). NS indicates that the difference in intake within the time period specified is not significantly different from zero (P > 0.05), i.e. that there is no significant preference for either* E. nitens *or* E. globulus.*)*

Days in trial	Total DMI	DMI *E. nitens*	DMI *E. globulus*	Difference in DMI	% *E. nitens*
1–5	14.0^{a} (± 2.7)	6.6^{a} (± 1.8)	7.3^{a} (± 3.1)	$-0.7^{a\,NS}$ (± 4.3)	47
6–14	14.9^{a} (± 3.5)	7.2^{a} (± 2.3)	7.7^{a} (± 2.8)	$-0.5^{a\,NS}$ (± 3.7)	48

17% of their total daily DM intake (i.e. including the basal diet). *Eucalyptus nitens* made up 47% of the total foliage intake (i.e. excluding the basal diet). The difference in intake between *E. nitens* and *E. globulus* was not significant (d.f. = 5, t = -0.42, $P = 0.69$), indicating that neither species was preferred. When results from days 1–5 were compared with those of days 6–14, there were no significant differences in any intake variables ($P > 0.05$) (Table 4).

Figure 1 shows the mean dry matter intake of each species and the total intake each day for the complete 14-day trial. For the first ten days, there is no discernable preference for either *E. nitens* or *E. globulus*. On days 11–14, the mean intake of *E. globulus* was higher than that of *E. nitens*, but it is not possible to say whether a longer term preference was becoming established.

Discussion

This study is the first to deal specifically with dietary preferences of one of the main herbivores implicated in browsing damage in Tasmania, and using plant species relevant to the forestry industry. The results demonstrate that, at least in captivity, brushtail possums generally have distinct feeding preferences. Juvenile foliage from the two *Symphyomyrtus* species was more preferred than *Monocalyptus* foliage, and the acacias were least preferred. This is consistent with anecdotal evidence (Neilsen 1990), and encouraging because it suggests that captive animal trials can reflect aspects of feeding in the field. The preference for *Symphyomyrtus* may seem surprising given the higher oil yields in juvenile foliage of this group compared with *Monocalyptus* (Li *et al.* 1995, 1996). However, as generalist folivores, brushtail possums have a reasonable capacity to detoxify oils and other plant secondary metabolites (Hinks and Bolliger 1957; Freeland and Winter 1975; R. Boyle, pers. comm.). Furthermore, the eucalypt foliage comprised less than 25% of the overall diet in these trials, and the rest was highly digestible and nutritious. Presumably this provided sufficient nutritional and energetic resources to tolerate the toxic load (Illius and Jessop 1995). The preferences must be due to other factors, such as phenolics and primary constituents, and/or qualitative differences in the oils between the two groups, rather than simply quantitative differences.

The results suggest that the main plantation species in Tasmania (*E. globulus* and *E. nitens*) are preferred by possums, even compared with other species which may grow incidentally on site (e.g. *A. dealbata*). Despite this, there is apparently enough leaf biomass at the sapling stage to prevent significant damage to foliage in the field. Damage by breaking branches in *A. melanoxylon* plantations is unlikely to be associated with high foliage intake by possums, but could conceivably result from searching for young growing tips as possums move through the trees.

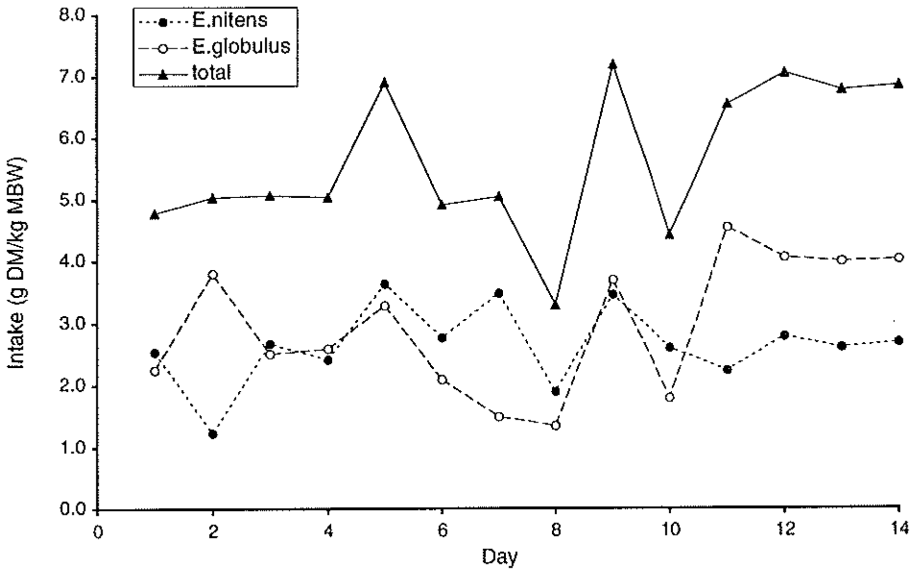

Figure 1. Mean dry matter intake (gDM) of E. nitens, E. globulus *and the total foliage intake each day during the 14-day Trial 3, expressed in relation to metabolic body weight (MBW) ($kg^{-0.75}$) of the possums.*

The preference ranking for foliage from saplings in these trials is the same as that using seedlings of the same species (only *E. delegatensis* seedlings not tested) (McArthur and Turner 1996). Seedlings are thought to be less well defended than leaves from older plants due to the trade-off between requirements for growth versus defense, particularly in species with small seeds (Bryant *et al.* 1991). But the preference results suggest that differences in leaf chemistry between species may be similar for both seedlings and saplings, at least in a relative sense.

Preferences can be made manifest by different combinations of relative and absolute intakes, possibly reflecting physiological constraints in relation to the chemistry of the individual dietary items and the overall chemistry of a mixed diet (e.g. Freeland and Saladin 1989). Intake of *E. nitens* within each trial tended to vary depending on the other species offered. In Trial 1, *E. nitens* intake was highest if presented with *E. regnans*, and lowest if presented with *E. delegatensis*. In Trial 2, *E. nitens* intake was effectively halved when offered with the more preferred *E. globulus* compared with its intake when offered with the less preferred *E. delegatensis* or *A. melanoxylon*. The implication in forestry is that availability of other plant species in a coupe could have significant effects on the consumption of foliage of economically important species by brushtail possums.

Indirect comparison indicates that the high quality growing conditions of the nursery-grown *E. globulus* resulted in foliage which was more preferred by brushtail possums. Landsberg (1987) also found that possums preferred nutrient-irrigated to tapwater-irrigated *E. blakelyi* seedlings. This suggests that, in forestry, trees growing on high quality sites may be preferred to those on low quality sites, although the complicated set of interactions in terms of browsing and compensatory growth makes it difficult to predict the outcome in terms of net growth rate.

In Trial 3, short-term intakes and (lack of) preference were indistinguishable from longer term results. Scott (1997) found that where short- and long-term preferences differed, short-term results seem to reflect field results better. This suggests that it is the more rapid feedback from plant secondary compounds which influences preferences in brushtail possums in the field rather than more long-term effects. The lack of difference in our trial suggests that long-term effects such as digestibility and nutritional status were not constraints affecting preference, which is not surprising given the highly digestible basal diet, and the relatively low proportion of eucalypt and acacia foliage in the overall diet.

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