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# Evaluation of *Lotus corniculatus* for increasing pre-weaning growth of red and hybrid deer

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## SUMMARY

Lactating red deer (*Cervus elaphus*) hinds and their calves were rotationally grazed on *Lotus corniculatus* or perennial ryegrass/white clover pasture at an allowance of 12 kg DM/hind/day during summer 1996 in Palmerston North, New Zealand. Half the hinds suckled pure red deer calves and half suckled hybrid (0·25 elk:0·75 red deer) calves. Measurements were made of the diet selected, voluntary feed intake of the hinds and liveweight changes of the hinds and calves.

*Lotus corniculatus* and perennial ryegrass constituted *c.* 90% of green material in the diet selected on the respective forages. Total nitrogen (N) content and organic matter digestibility (OMD) were higher for *Lotus corniculatus* than for perennial ryegrass/white clover pasture. *Lotus corniculatus* contained 21 g condensed tannin (CT)/kg dry matter (DM), whilst pasture contained only traces of CT (1·6 g/kg DM).

Hinds grazing *Lotus corniculatus* tended to have higher voluntary feed intake, and calf liveweight gain (485 *v.* 399 g/day) and weaning weight (52·6 *v.* 48·1 kg) were greater than for deer grazing perennial ryegrass/white clover pasture. Hybrid calves grew faster than pure red deer calves ($P < 0.01$), with hybrid calves grazing lotus having very high liveweight gain (*c.* 520 g/day). Liveweight gain of hinds grazing *Lotus corniculatus* also tended to be higher (91 *v.* 20 g/day) than for hinds grazing perennial ryegrass/white clover pasture. CT was bound more strongly during chewing by red deer than had been found in comparable studies with sheep and the nutritional significance of this is discussed. Nutritional reasons for the superior performance of deer grazing *Lotus corniculatus* are discussed.

## INTRODUCTION

Target weaning weight in the New Zealand (NZ) deer industry is 50 kg at 110 days of age (Barry & Wilson 1994). This is against the backdrop that calving in red deer (*Cervus elaphus*) occurs during late spring and early summer (November–December), after the spring peak in pasture production (October). Peak lactation thus occurs during summer (January/February) by which time perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) herbage, the bulwark of NZ pastoral agriculture, is maturing and is of reduced dry matter (DM) yield and digestibility owing to moisture stress (Adam 1988). Consequently calves do not realise their full genetic potential for growth from birth to weaning, the period of maximum growth potential, both in relative and absolute terms (Barry & Wilson 1994).

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With high quality NZ fresh forages, 70% of the dietary protein is ruminally degraded, resulting in insufficient amino acid absorption for maximum productivity in grazing ruminants (Barry 1981; Waghorn & Barry 1987). A method of reducing this degradation is to exploit the ability of forage condensed tannins (CT) to form complexes with dietary protein. Condensed tannins occur in a restricted range of forages; and they bind plant protein in the rumen (pH 5·5–7·0) to form stable CT–protein complexes which then dissociate in environments of pH < 3·5 such as occur in the abomasum (Jones & Mangan 1977). This increases non-ammonia nitrogen (NAN) flux to the intestines (Barry *et al.* 1986; Waghorn *et al.* 1987*a*; 1994).

The ideal CT concentration in plants for ruminant animal nutrition has been suggested to be 20–40 g/kg DM (Barry 1989; Waghorn 1990) and concentrations in *Lotus corniculatus* fulfil this condition. Studies in sheep fed on *Lotus corniculatus* showed that the action of CT increased the absorption of essential

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amino acids (EAA; excluding methionine and cystine) from the small intestine by 62% (Waghorn *et al.* 1987*b*), increased the irreversible loss rate (IRL) of cystine from blood plasma and increased cystine flux to body synthetic reactions (Wang *et al.* 1994). Liveweight gain and wool production of lambs (Wang *et al.* 1996*a*) were also increased by the action of CT, as well as milk secretion in ewes rearing twin lambs (Wang *et al.* 1996*b*). There is, however, no information on the feeding value of *Lotus corniculatus* for deer. The objective of this study was to evaluate *Lotus corniculatus* for increasing pre-weaning growth and subsequent weaning weight of red and hybrid deer calves.

## MATERIALS AND METHODS

### *Experimental design*

A 2×2×2 factorial experiment involving lactating hinds and their calves grazing two forages (*Lotus corniculatus v.* perennial ryegrass/white clover pasture) over the summer was conducted at the Massey University Deer Research Unit, Palmerston North, New Zealand, from 8 January to 29 February 1996. Calves of both sexes and of either pure red or elk×red hybrid (0·25 elk:0·75 red) genotype were used in the study.

### *Forages*

The perennial ryegrass/white clover pasture (2·68 ha; seven paddocks) was several years old, whilst the *Lotus corniculatus* (birdsfoot trefoil; cv. Grasslands Goldie) was either 1 or 2 years old (1·65 ha; four paddocks). The paddocks sown to *Lotus corniculatus* were ploughed, disk-harrowed, power-harrowed and sown at 15 kg seed/ha. After plant emergence, the lotus paddocks were sprayed with MCPB (Shell Chemicals Ltd) at 4 litres/ha to control weeds, and lightly irrigated to help plant establishment during early summer.

### *Animals*

Thirty-six lactating red deer hinds and their calves were used. Hinds had been mated to either hybrid (0·5 red:0·5 elk) stags to produce the hybrid deer calves, or mated to pure red deer stags. Calving occurred during November and December 1995. Newly born calves were identified with numbered collars until 2 weeks before weaning and then ear-tagged. Hinds were grouped by calving date, sex and genotype of calf and randomly assigned to graze either perennial ryegrass/white clover pasture or *Lotus corniculatus* from 8 January to 29 February 1996. All calves were weaned on 29 February 1996. Twenty hinds and their calves were assigned to graze perennial ryegrass/white clover pasture, and 16 hinds and their calves were assigned to graze *Lotus corniculatus*. At the start of the trial, mean liveweights (±S.E.) of the deer grazing perennial ryegrass/white clover pasture were 110·4±2·26 kg (hinds) and 28·2±0·98 kg (calves); and 109·0±2·65 kg (hinds) and 28·3±1·15 kg (calves) on *Lotus corniculatus*. Both hinds and calves on each treatment were treated orally with moxidectin anthelmintic ('Cydectin'; Cyanamid of NZ Ltd) twice (30.1.96 and 24.2.96) during the trial to control internal parasites, at 0·59 and 0·88 mg per kg liveweight.

### *Grazing management*

Animals were rotationally grazed on both forages at a pasture allowance of 12 kg DM/hind/day. Time spent in each paddock was calculated as:

$$\text{Length of grazing period (days)} = \frac{\text{Herbage mass (kg DM/ha)} \times \text{Total area of paddock}}{\text{Total no. animals/group} \times \text{Pasture allowance/hind/day}} \quad (1)$$

The rotational length was 2·0–3·0 weeks on perennial ryegrass/white clover pasture and 2·5–4·0 weeks on *Lotus corniculatus*. A follow-up grazing with sheep was used to maximize leaf production of *Lotus corniculatus*.

### *Pasture measurements*

Pre-grazing and post-grazing herbage mass (kg DM/ha) was measured for each paddock. Measurements were done by the quadrat method (eight quadrats of 0·1 m² each per sampling period). Plants in each quadrat were cut to soil level using a hand-clipper, and were then washed, oven-dried at 100 °C for 18–24 h and weighed to estimate the available DM in each paddock. Areas surrounding each quadrat were also cut to soil level, bulked per paddock, mixed and divided into two halves. These were referred to as feed on offer. One part was used to estimate botanical composition, and the other half stored at −20 °C to determine nutritive value.

Hand-plucked samples of each forage were taken daily from each paddock by simulating the grazing activity. These were referred to as diet selected (hand-plucked). Samples were stored at −20 °C. At the end of each grazing period, these were bulked per paddock, thoroughly mixed and divided into two halves. One part was used to estimate botanical composition, with the other part used to determine the nutritive value. Samples were also taken with two oesophageal-fistulated (OF) deer grazed on each forage on six occasions. On each occasion they were fasted for 3 h and then grazed for 20 min to collect extrusa. The extrusa were also used to determine the nutritive value of the diet selected. The OF deer were changed over between forages after the third sampling to eliminate animal differences.

Table 1. *Mean* (± S.E.) *pre- and post-grazing herbage mass (kg DM/ha) of perennial ryegrass/white clover pasture and* Lotus corniculatus *grazed by red deer hinds and their calves during lactation*

| | Perennial ryegrass/ white clover ($n = 14$) | *Lotus corniculatus* ($n = 7$) |
|---|---|---|
| Pre-grazing | 2910±103·6 | 3796±522·8 |
| Post-grazing | 2503±77·5 | 2305±371·9 |

*Animal measurements*

Hinds and their calves were weighed at 2-weekly intervals and at weaning (29 February 1996). Hinds were dosed with an intra-ruminal slow release chromium (Cr) capsule (CRD, $Cr_2O_3$ matrix, Captec Ltd, NZ) on 30 January 1996 to estimate faecal output. Eight days thereafter, rectal faecal samples were taken from each hind every other day for 16 days. Each succeeding sampling was done 2 h later than the preceding sampling time to account for any differences in Cr excretion rates. Five and three rumen-fistulated deer were grazed alongside animals on perennial ryegrass/white clover pasture and *Lotus corniculatus*, respectively, to measure Cr release rate from the capsules. Cr capsules were suspended in the rumen on 31 January 1996, and plunger travel monitored by measurement with vernier callipers at 3-day intervals from 5 February to 29 February 1996.

*Laboratory analysis*

The frozen hand-plucked herbage and OF extrusa samples were freeze-dried and ground to pass through a 1 mm mesh diameter sieve (Wiley mill, USA) prior to laboratory analysis. Total nitrogen (N) content of each forage was determined using the Kjeldahl method, with selenium catalyst and $H_2SO_4$ digestion. Organic matter (OM) content was determined by ashing samples at 550 °C for 16 h. *In vitro* digestibility was determined by the enzymatic method (Roughan & Holland 1977), in which neutral detergent-extracted plant residue was incubated with fungal cellulase enzymes at 50 °C for 24 h and then filtered. Extractable and bound condensed tannins were determined using the method of Terrill *et al.* (1992*a*). Faecal Cr concentrations were determined by atomic adsorption spectrometry (Costigan & Ellis 1987). Botanical composition of both feed on offer and diet selected (hand-plucked samples only) was determined by dissecting each sample into grass, lotus, clover, dead matter and weed. Samples were separately oven-dried at 100 °C for 18–24 h and weighed.

*Data calculations and statistical analysis*

Factorial analysis of variance was used to examine treatment effects in all liveweight data, with the factors being forage (*Lotus corniculatus v.* perennial ryegrass/white clover pasture), genotype (pure red *v.* hybrid deer) and sex (male *v.* female) using the General Linear Model (GLM) procedure (SAS 1996). Age was used as a covariate for calf liveweight data. Mean values and standard errors of the mean (±S.E.) are presented.

Voluntary feed intake (VFI) was calculated as:

$$\mathrm{VFI} = \frac{\mathrm{F\ (g\ OM/day)}}{1-\mathrm{D}} \qquad (2)$$

where F is faecal OM output and D is the *in vitro* OM digestibility (OMD) of the diet selected. F was calculated from Eqn 3.

$$\mathrm{F\ (g\ OM/day)} = \frac{\mathrm{Cr\ release\ rate\ (RR)\ (mg/day)}}{\mathrm{Faecal\ Cr\ concentration\ (mg/g\ OM)}} \qquad (3)$$

## RESULTS

*Herbage mass and botanical composition*

Pre-grazing herbage mass was higher for *Lotus corniculatus* than for perennial ryegrass/white clover pasture (3796±522·8 *v.* 2910±103·6 kg DM/ha), but post-grazing herbage mass was similar for both forages (Table 1) and was not likely to be limiting animal production. Perennial ryegrass and *Lotus corniculatus* formed the major components in both forage on offer and diet selected in their respective treatments, being just over 90% of green material in the diet selected (Table 2). For both forages, diet selected was higher in the major constituents and in clover contents but lower in weed and dead material than in the forage on offer. There was a very high dead matter content (46·9±4·68 *v.* 30·5±3·86%) for the forage on offer and diet selected in the perennial ryegrass/white clover pasture, reflecting hot dry summer growing conditions; whilst *Lotus corniculatus* contained only 6·2±5·24 *v.* 1·4±1·05% dead matter for forage on offer and diet selected, respectively, indicating that it was almost a pure sward. Generally there was a very low clover content in both swards (Table 2).

*Nutritive value of forages*

*Lotus corniculatus* on offer was of higher OMD than perennial ryegrass/white clover pasture ($P < 0·05$). For both forages the diet selected was higher in both total N and OMD than forage on offer, as determined

Table 2. *Botanical composition (% DM ± S.E.) of perennial ryegrass/white clover pasture and* Lotus corniculatus *grazed by red deer hinds and their calves during summer 1996*

| | Forage | | | |
|---|---|---|---|---|
| | Perennial ryegrass/white clover ($n$ = 14) | | *Lotus corniculatus* ($n$ = 7) | |
| Species | Forage on offer | Diet selected* | Forage on offer | Diet selected* |
| Grass | 45·7 ± 4·31 | 61·2 ± 3·20 | 0·7 ± 0·53 | 0·4 ± 0·19 |
| Clover | 4·6 ± 1·27 | 5·1 ± 1·18 | 0·3 ± 0·22 | 1·6 ± 1·09 |
| Lotus | — | — | 76·6 ± 6·87 | 91·2 ± 2·35 |
| Weeds | 2·9 ± 0·59 | 1·3 ± 0·55 | 15·9 ± 7·07 | 5·4 ± 2·87 |
| Dead matter | 46·9 ± 4·68 | 30·5 ± 5·24 | 6·2 ± 5·24 | 1·4 ± 1·05 |

* Hand-plucked samples.

Table 3. *Organic matter (OM; % DM), organic matter digestibility (OMD; % OM), total nitrogen (N; % OM) and condensed tannin (g/kg DM) of forage on offer and diet selected by red deer hinds grazing either perennial ryegrass/white clover pasture or* Lotus corniculatus *during lactation in summer 1996. Mean values ± S.E.*

| | Perennial ryegrass/white clover | | *Lotus corniculatus* | |
|---|---|---|---|---|
| | Forage on offer | | | |
| $n$ | 7 | | 7 | |
| OM | 83·9 ± 2·24 | | 89·4 ± 2·24 | |
| OMD | 49·1 ± 1·97 | | 57·8 ± 2·32 | |
| Total N | 2·10 ± 0·21 | | 2·68 ± 0·21 | |
| | Diet selected | | | |
| | Hand-plucked | OF extrusa | Hand-plucked | OF extrusa |
| $n$ | 7 | 6 | 7 | 6 |
| OM | 87·7 ± 2·24 | 75·6 ± 2·41 | 91·2 ± 2·24 | 77·0 ± 4·30 |
| OMD | 57·2 ± 2·32 | 60·5 ± 2·32 | 68·5 ± 2·32 | 60·8 ± 3·34 |
| Total N | 2·69 ± 0·21 | 2·63 ± 0·21 | 3·51 ± 0·20 | 3·10 ± 0·31 |
| Condensed tannins ($n$ = 3) | | | | |
| Extractable* | 1·8 ± 0·84 | 0·03 ± 0·03 | 8·0 ± 0·82 | 1·0 ± 0·08 |
| Extractable† | ND | ND | 10·0 ± 0·26 | 0·2 ± 0·14 |
| Protein-bound† | 0·8 ± 0·03 | 0·2 ± 0·12 | 10·3 ± 0·75 | 3·8 ± 0·53 |
| Fibre-bound† | 0·7 ± 0·07 | 0·8 ± 0·06 | 0·8 ± 0·03 | 1·3 ± 0·20 |
| Total† | 1·6 ± 0·07 | 1·1 ± 0·06 | 21·2 ± 0·51 | 5·2 ± 0·63 |

* Vanillin-HCl method, † Butanol-HCl method, ND = not detected.

by both hand-plucked and OF ($P < 0·01$) sampling (Table 3). Organic matter (OM) content was consistently lower for OF extrusa than for hand-plucked samples of diet selected ($P < 0·001$), because of salivary contamination. Consequently total N values were expressed as a percentage of OM. When expressed in this manner, there was no difference in total N content in the two methods used to measure diet selected. There was, however, a significant interaction between forage and sampling method for the diet selected ($P < 0·05$). OMD of perennial ryegrass/white clover selected was similar for hand-plucked and OF extrusa samples, but OF extrusa samples for *Lotus corniculatus* gave lower values than hand-plucked samples ($P = 0·057$). Only trace amounts of CT were detected in perennial ryegrass/white clover pasture using both the vanillin-HCl and butanol-HCl methods. Similar values were found for hand-plucked samples and OF extrusa (Table 3). Total CT concentration in *Lotus corniculatus* selected was much lower for OF extrusa than for hand-plucked samples ($P < 0·01$), because of an almost total disappearance of CT from the extractable fraction and a major reduction in protein-bound CT.

Table 4. *Voluntary organic matter intake (OMI, g/day) as determined by two methods of estimating diet selection by grazing red deer hinds on either perennial ryegrass/white clover pasture or* Lotus corniculatus *during lactation in summer 1996*

| | Perennial ryegrass/ white clover | *Lotus corniculatus* | S.E. (D.F. = 28) |
|---|---|---|---|
| Hand-plucked | 1921 | 2757 | 115·4 |
| OF extrusa* | 2081 | 2216 | 99·9 |

* Obtained by using oesophageal fistulated (OF) deer.

### *Voluntary intake and liveweight gains*

Voluntary organic matter intake (OMI) was higher for hinds grazing *Lotus corniculatus* than for those on perennial ryegrass/white clover pasture, the difference attaining significance when OMI was estimated using OMD of hand-plucked samples ($P < 0.001$; Table 4).

Initial liveweight was significantly higher ($30.1 \pm 0.61$ *v.* $26.3 \pm 0.61$ kg; $P < 0.001$) for hybrid deer than pure red deer calves, but there was no significant sex effect on calf initial liveweight (Table 5). Liveweight gain was significantly higher for hybrid than for red calves ($468 \pm 12.8$ *v.* $416 \pm 12.8$ g/day; $P < 0.01$) and for calves grazing *Lotus corniculatus* than for calves grazing perennial ryegrass/white clover pasture ($485 \pm 13.2$ *v.* $399 \pm 11.8$ g/day; $P < 0.001$). Male calves also gained weight at a faster rate than female calves ($P = 0.10$). There were no significant interactions between sex, genotype and forage for liveweight gain.

Genotype, sex, forage and their interactions had no significant effect on weaning age of calves. Average weaning ages were 92 days on both forages, 90 and 94 days for pure red and hybrid calves, and 91 and 93 days for female and male calves respectively (Table 5). However, weaning weight was significantly higher for hybrid deer than for pure red deer calves ($P < 0.01$). Significantly higher weaning weights were also achieved on *Lotus corniculatus* (52·6 kg) than with perennial ryegrass/white clover pasture (48·1 kg; $P < 0.01$) (Table 5). There were no significant interactions between sex, genotype and forage on calf weaning weight.

Hinds (i.e. dams) grazing *Lotus corniculatus* tended to gain more weight than the hinds grazing perennial ryegrass/white clover (90 *v.* 20 g/day; $P = 0.12$).

## DISCUSSION

The most important findings from this study were the significant increases in daily liveweight gain ($P < 0.001$) and weaning weight ($P < 0.01$) of calves raised by hinds grazing *Lotus corniculatus* compared to those grazing perennial ryegrass/white clover pasture and the greater liveweight gains obtained in hybrid calves than in pure red deer calves. Liveweight gains in hybrid calves grazing lotus in this study exceeded 500 g/day, this being the first time we have attained this in a grazing study with suckling calves. This is a major improvement on earlier studies, which established the growth of red deer calves suckled by hinds grazing summer pasture at 331 g/day (Niezen *et al.* 1993). Kusmartono *et al.* (1996) similarly reported greater liveweight gains in hybrid deer than in red deer calves when their dams were grazed on chicory (*Cichorium intybus*), indicating the importance of improved nutrition for the realisation of the greater genetic potential for growth of elk × red hybrid deer.

Table 5. *Growth of red and elk × red hybrid deer calves raised by hinds grazing either perennial ryegrass/white clover pasture or* Lotus corniculatus *during lactation in summer 1996*

| Forage... | Perennial ryegrass/white clover | | | | *Lotus corniculatus* | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sex... | Stag | | Hind | | Stag | | Hind | | |
| Genotype... | R | H | R | H | R | H | R | H | S.E. (D.F. = 28) |
| Calves | | | | | | | | | |
| Number of animals | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | |
| Initial weight (kg)* | 26·1 | 31·5 | 25·9 | 28·8 | 25·7 | 30·0 | 28·2 | 29·9 | 0·73 |
| Weight change (g/day)* | 239 | 450 | 371 | 386 | 456 | 534 | 450 | 502 | 12·13 |
| Weaning weight (kg)* | 45·6 | 54·1 | 44·5 | 48·1 | 48·5 | 56·7 | 50·3 | 55·0 | 1·13 |
| Age at weaning (days) | 91 | 91 | 89 | 97 | 92 | 97 | 88 | 91 | 1·00 |
| Hinds | | | | | | | | | |
| Weight change (g/day) | 2 | 68 | 3 | 7 | 103 | 60 | 123 | 78 | 11·9 |

R = red deer, H = hybrid deer (0·25 elk:0·75 red).
DM allowance = 12 kg DM/hind/day.
* Corrected for age of calf.

Table 6. *Liveweight changes (g/day) of deer calves during lactation grazing either perennial ryegrass/white clover pasture or one of three special purpose forages developed for deer production in New Zealand. Values in parentheses are percentages relative to perennial ryegrass/white clover pasture fed in the same experiment as 100, and may be used as indices of relative feeding value (FV). Feed allowances were 12 kg DM/hind + calf for all forages in each experiment*

| Author | Perennial ryegrass/ white clover pasture | Red clover | Chicory | *Lotus corniculatus* |
|---|---|---|---|---|
| | 333 (100) | 433 (130) | | |
| Niezen *et al.* (1993)* | 331 (100) | 410 (124) | 385 (116) | — |
| Kusmartono *et al.* (1996)† | 351 (100) | — | 404 (116) | — |
| Present study† | 399 (100) | — | — | 485 (122) |
| Mean values | 100 | 127 | 116 | 122 |

* Calves all red deer.
† Half calves were red deer and half were 0·25 elk:0·75 red deer hybrids.

Ulyatt (1973) defined feeding value as the animal production response to grazing a forage under conditions where intake was not restricted by plant availability. He further proposed feeding value as a function of voluntary feed intake, digestive efficiency and the efficiency of utilization of digested nutrients. As a summer feed during deer lactation, it is therefore evident that the feeding value of *Lotus corniculatus* was higher than that of perennial ryegrass/white clover pasture but similar to that of chicory and red clover (Table 6), despite the presence of considerable CT in lotus. One of the reasons for the higher feeding value is the higher VFI of hinds grazing lotus; this may have increased milk production, and this needs to be measured in future studies. Organic matter digestibility was also higher for deer grazing lotus, when based upon hand-plucked samples of the diet selected, but not when based upon samples of OF extrusa. The extractability of CT was greatly reduced in the latter, and this may have lowered the OMD value; for this reason OMD and VFI calculated from hand-plucked samples are considered to give more realistic values than when calculated from OF extrusa.

Adu (1997) found lower methane, urine and heat energy losses in young deer fed on fresh *Lotus corniculatus* than on perennial ryegrass, with the efficiency of utilization of ME for growth ($k_g$) during autumn being higher for deer fed on *Lotus corniculatus* than on perennial ryegrass (0·45 *v.* 0·32). Similarly, Rattray & Joyce (1974) found higher $k_g$ values for young sheep fed on fresh white clover than on fresh perennial ryegrass (0·51 *v.* 0·33). Improved efficiency of energy utilization in young deer fed on lotus rather than on perennial ryegrass is a further reason for the increased growth rates obtained with lotus in the present experiment.

A moderate concentration of CT (20–35 g/kg DM) in forages given to sheep has been reported to increase non-ammonia nitrogen (NAN) flux to the small intestine, to increase the absorption of essential amino acids (EAA) (Barry *et al.* 1986; Waghorn *et al.* 1987*a*, *b*, 1994) and to increase cystine irreversible loss rate (IRL) (McNabb *et al.* 1993; Wang *et al.* 1994). However, binding of CT during eating differs between sheep and deer. A comparison of the action of chewing during eating in the sheep and red deer eating *Lotus corniculatus* and sulla (*Hedysarum coronarium*) on the extractability and recovery of forage CT is shown in Table 7. The extractable CT fraction was greatly reduced during chewing by both sheep and red deer, but this was almost completely recovered in the protein-bound and fibre-bound fractions in the sheep, with the overall recovery of the total CT being close to 90%. However, recovery of total CT in the OF extrusa of red deer was < 30%, illustrating stronger binding of CT. Mule deer saliva contains a proline-rich protein fraction not found in the saliva of sheep (Austin *et al.* 1989), which has a high affinity for forage tannins (Austin *et al.* 1989, Robbins *et al.* 1991). Initial studies suggest that red deer saliva can also bind CT (A. E. Hagerman, personal communication) and this may be binding a large component of the CT in the current studies. The nutritional significance of this tighter CT binding with red deer saliva when eating lotus remains to be established. However, it could be significant as in a related study Adu (1997) found that N retention was similar in weaner deer fed on fresh *Lotus corniculatus* or perennial ryegrass, whereas in sheep the CT-containing forage species promote greater N retention (Reid *et al.* 1974; Egan & Ulyatt 1980; Nuñez-Hernandez *et al.* 1991; Wiegand *et al.* 1995).

The results presented in this paper have clearly established *Lotus corniculatus* as a superior feed for lactating deer hinds and their calves. Further studies are required to evaluate the potential of *Lotus*

Table 7. *Extractability of forage condensed tannins (CT) from oesophageal (OF) extrusa samples of sheep and red deer fed* Lotus corniculatus *and sulla* (Hedysarum coronarium), *compared with the original plant material. CT contents were estimated by the butanol-HCl method*

| | CT concentration (g/kg DM) | | |
|---|---|---|---|
| | Hand-plucked plant material | OF extrusa | Authors and plants fed |
| | Sheep | | |
| Extractable CT | 31·3 | 10·0 | Terrill *et al.* (1992*b*) Sulla |
| Protein-bound CT | 13·1 | 25·5 | |
| Fibre-bound CT | 1·7 | 5·0 | |
| Total CT | 46·1 | 40·3 (87%)* | |
| Extractable CT | 17·0 | 2·8 | Min *et al.* (1998) *Lotus corniculatus* |
| Protein-bound CT | 12·3 | 22·8 | |
| Fibre-bound CT | 0·5 | 1·2 | |
| Total CT | 29·8 | 26·8 (90%)* | |
| | Red deer | | |
| Extractable CT | 36·1 | ND | Min *et al.* (1997) *Lotus corniculatus* |
| Protein-bound CT | 10·9 | 10·6 | |
| Fibre-bound CT | 1·2 | 2·5 | |
| Total CT | 48·2 | 13·1 (27%)* | |
| Extractable CT | 10·0 | 0·2 | Present study *Lotus corniculatus* |
| Protein-bound CT | 10·3 | 3·8 | |
| Fibre-bound CT | 0·3 | 1·3 | |
| Total CT | 21·2 | 5·2 (25%)* | |

* Percentage of total CT in corresponding hand-plucked sample.
ND = not detected.

*corniculatus* for venison production from weaning to slaughter at 1 year of age, and to study the effect of forage CT on EAA absorption in farmed red deer.

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young sheep fed on fresh white clover than on fresh perennial ryegrass (0·51 *v.* 0·33). Improved efficiency of energy utilization in young deer fed on lotus rather than on perennial ryegrass is a further reason for the increased growth rates obtained with lotus in the present experiment.

A moderate concentration of CT (20–35 g/kg DM) in forages given to sheep has been reported to increase or perennial ryegrass, whereas in sheep the CT-containing forage species promote greater N retention (Reid *et al.* 1974; Egan & Ulyatt 1980; Nuñez-Hernandez *et al.* 1991; Wiegand *et al.* 1995).

The results presented in this paper have clearly established *Lotus corniculatus* as a superior feed for lactating deer hinds and their calves. Further studies are required to evaluate the potential of *Lotus*



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