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An evaluation of sulla (*Hedysarum coronarium*) with pasture, white clover and lucerne for lambs

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ABSTRACT

Pasture-based diets restrict animal performance, due to limitations in voluntary feed intake and release of nutrients during digestion failing to meet nutrient requirements. Opportunities for improving the efficiency of pasture utilisation include the addition of a soluble carbohydrate source to enable an improved capture of ammonia by rumen bacteria, or the inclusion of condensed tannins (CT) to reduce protein degradation. A feed evaluation trial was conducted at AgResearch Grasslands to investigate the ability of sulla, a forage containing high concentrations of soluble carbohydrate and CT, to complement pasture and legume species. Fifty-six weaned ram lambs were allocated to seven diets: pasture (80% ryegrass and 20% white clover), white clover, lucerne, sulla, and 50:50 mixtures (DM basis) of pasture:sulla, white clover:sulla and lucerne:sulla. Lambs fed sulla, white clover, white clover:sulla and lucerne:sulla had the most rapid daily gains (256-263 g/day) while lambs fed pasture gained 105 g/day, respectively. Wool growth was influenced by diet. Sulla added to pasture, white clover and lucerne diets significantly reduced rumen ammonia concentrations and acetate:propionate ratios in lambs. Lamb performance can be improved by combining sulla with pasture and lucerne, and rumen parameters can be used to explain animal performance differences.

Keywords: sulla; forages; lamb performance; rumen parameters.

INTRODUCTION

New Zealand's livestock industries are reliant on ryegrass/white-clover-dominant pastures. Several studies have shown that significant improvements in animal performance are achievable by feeding forages other than perennial-ryegrass-based pasture. Relative feeding values show white clover to be about twice that of ryegrass for live weight gain (Ulyatt, 1981).

Perennial ryegrass is not the ideal feed to meet ruminant nutrient requirements because of low soluble carbohydrate concentrations, high concentrations of slowly degradable fibre that restrict feed intake, and rapidly degradable crude protein producing surplus ammonia when degraded in the rumen. Sulla (*Hedysarum coronarium*) is a potentially useful supplement for pasture because it has high concentrations of soluble carbohydrates (18-25% DM) and contains condensed tannin (CT), which reduces rumen proteolysis and increases the flow of amino acids to the small intestine (Bermingham *et al*., 2001). This biennial legume promotes high intakes and high live weight gains (Terrill *et al*., 1992; Stienezen *et al*., 1996), but Douglas *et al*. (1999) showed 8.8% CT in sulla suppressed rate of gain in sheep. When dietary CT exceeds 4-6% of dietary DM, intake and performance may be reduced, dependent upon the chemical structure and source of CT (Waghorn *et al*., 1990). Sulla could be fed with fibrous forages (e.g., ryegrass-based pastures) as a means to dilute dietary fibre, supply soluble carbohydrates to rumen bacteria and increase protein supply to the small intestine.

The objective of this study was to determine the effect supplementing pasture and legume species with sulla has on animal performance and rumen parameters.

MATERIALS AND METHODS

Experimental design

An experiment was conducted with lambs fed pasture, white clover, lucerne, sulla and mixtures of pasture:sulla, white clover:sulla and lucerne:sulla. Live weight gain, wool growth, carcass weights, feed intakes and rumen pH, ammonia (NH_3) and volatile fatty acids (VFA) were measured during the experiment according to animal ethics guidelines.

Animals and diets

Fifty-six weaned ram lambs (aged 12 weeks) were fed seven contrasting forage diets *ad-libitum* for eight weeks from 19 October to 18 December 2000. The seven diets were pasture (comprising 80% ryegrass and 20% white clover), white clover, lucerne, sulla and 50:50 mixtures (DM basis) of pasture:sulla, white clover:sulla and lucerne:sulla. All forages were grown and harvested daily at Aorangi Research Farm, Manawatu and transported to the feeding facility at Grasslands Research Centre, Palmerston North. The ryegrass, lucerne and sulla were chopped to 3-6 cm lengths using a JF Forage chopper (Model FC80) to facilitate accurate mixing for feeding.

Each group of eight lambs were held on sawdust feed pads (10 m x 3 m), fed *ad libitum* from troughs and provided with shelter and water. Each group was given their daily allowance at about 1100 h and refusals were about 15-25% of feed offered. Refusals were removed and weighed. Intakes of DM and DM constituents were calculated from feed offered less feed refused. Individual intakes were determined during one week of the trial (day 39 to 43) using alkane markers (Dove & Mayes, 1991) but are not reported in this study. Lambs were drenched with selenium and an anthelmentic drench (Leviben) at the start and week four of the trial.

Fresh forage samples and refusals were collected throughout the trial, frozen and freeze-dried to determine chemical composition by Near Infra Red Spectrometry (NIRS). Chemical composition of mixed diets were calculated from the proportion of each forage used in the mixtures.

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All forages were cut daily and maintained in a vegetative state. Changes in composition were monitored throughout the trial and efforts were made to maintain consistent quality by selecting forages of similar maturity whenever possible.

Lamb performance

Lambs were weighed weekly prior to feeding, at about 0900h, and fasted live weights were taken on days 7 and 58 of the trial. Mid-side patches were trimmed on both sides of the lambs at the commencement of the trial and wool growth was determined from 10 cm x 10 cm patches shorn on days 54 or 55. Samples were washed in a four-bowl aqueous mini scour to obtain yield and clean weights (Kenyon *et al*., 1999). At the conclusion of the trial carcass weights of lambs were recorded.

Rumen measurements

Rumen contents were obtained by lavage (stomach tube) on days 9, 14, 21, 29, 35 and 42 of the experiment, 2-4 hours after feeding, to measure pH, NH_3 and VFAs. Rumen digesta pH was measured at the time of sampling and 10 mL was centrifuged (28000g; 10 minutes) for analyses. One aliquot was frozen for VFA analysis by gas-liquid chromatography (Attwood *et al*., 1998) and a further 1 mL of supernatant was acidified (15 μL concentrated HCl), mixed, centrifuged (14000g; 15 minutes) and frozen for ammonia determination by the colourimetric reaction of Chaney & Marbach (1962).

Statistical analysis

Effects of diet on rumen parameters, wool growth and carcass weight were determined using the GLM procedure of SAS (1996). Repeated-measures analysis was used to determine effects of diet on lamb live weights. Statistical analyses were not calculated on DM intake because they are means of treatment groups. Results are expressed as means with standard errors of the mean (SEM).

RESULTS

Feed composition

Table 1 illustrates the contrasting nature of the seven forage diets offered. The dietary DM content ranged from 13.8% (sulla) to 24.0% (pasture) and the crude protein content (% of DM) ranged from 15.5 (pasture) to 27.9 (white clover). Pasture had high neutral detergent fibre (NDF) concentrations, averaging 48% of DM, compared to other diets, whilst sulla contained only 21.5% NDF in the DM. Sulla and diets containing sulla had higher soluble:structural carbohydrate ratios than pasture, white clover or lucerne (Table 1). The mean concentration of soluble carbohydrate for sulla was 21.8% of DM compared to only 12.1% DM in pasture. Concentrations of total CT in sulla averaged 5.6% of the DM and ranged from 4.5 to 6.7% DM throughout the eight-week trial period. Sixty-two percent of sulla CT was unbound (able to interact with other proteins), 34% bound to protein and 4% bound to fibre. Condensed tannin concentrations in pasture:sulla, white clover:sulla and lucerne:sulla ranged from 2.7 to 3.0% DM.

TABLE 1: Average dry matter content (DM) and composition (% of DM) of seven diets offered to lambs over eight weeks.

	DM%	Sulla fed (%)	Soluble Carbohydrate	Crude Protein	NDF[1]	Lipid	Condensed Tannin	ME[2] (MJ/kgDM)
Pasture	24.0		12.1	15.5	48.0	2.8	0	10.1
White Clover	14.6		14.5	27.9	26.4	3.1	0	11.8
Lucerne	21.2		12.3	24.4	32.3	2.8	0	10.0
Sulla	13.8	100	21.8	19.2	21.5	2.2	5.6	12.2
Pasture/Sulla	19.2	48	16.7	17.3	35.3	2.5	2.7	11.1
White Clover/Sulla	14.2	53	18.5	23.0	23.9	2.6	3.0	12.0
Lucerne/Sulla	17.6	50	17.0	21.8	26.9	2.5	2.8	11.1

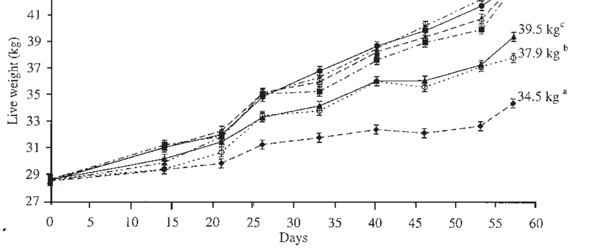
[1] NDF, Neutral detergent fibre; [2] ME, Metabolisable energy

NIRS analysis of the refused feed confirmed the selection of leafy components of the forages. This was particularly noticeable in the sulla, lucerne and mixed diets where sulla and lucerne stems were left behind, and lambs fed pasture selected all the leafy white clover.

Lamb performance

Initial live weights were 28.5 ± 0.13 kg and differences between treatments for daily gains were evident after 2 weeks of feeding (Figure 1). Pasture-fed lambs grew at 105 g/day over the duration of the trial and achieved a final live weight of 34.5 ± 0.34 kg which was significantly lower than all other treatments (Figure 1). Lambs fed white clover, sulla, white clover:sulla and lucerne:sulla had the most rapid daily gain (256-263 g/day) achieving final live weights of 43.1-43.5 kg, whilst those fed lucerne and pasture:sulla had daily gains of 191 and 162 g/day, respectively (Table 2). Live weights of pasture- and

FIGURE 1. Liveweight profile of lambs fed seven forage diets over eight weeks. (Means ± SEM; n = 8. Means with different subscripts are significant (P<0.05)).



lucerne-fed lambs were significantly lower than pasture:sulla- and lucerne:sulla-fed lambs, respectively, indicating the advantage of incorporating sulla with these

TABLE 2: Live weight gain (LWG), daily dry matter intake (DMI), efficiency of live weight gain, carcass weight (WT) and clean wool yield of lambs fed seven forage diets over eight weeks. (Means ± SEM. Means with different subscripts are significant (P<0.05)).

Diet	LWG (g/day)[1]	Mean DMI[3] /lamb (kgDM/day)	Mean Efficiency (g/kgDM)	Carcass WT(kg)[1]	Wool yield (g/100 cm²)[2]
Pasture	105 ± 18[a]	1.10	96	13.0 ± 0.60[a]	4.7 ± 0.30[a]
White Clover	256 ± 6[b]	1.48	173	19.0 ± 0.50[b]	7.1 ± 0.52[b]
Lucerne	191 ± 14[c]	1.37	139	16.1 ± 0.38[c]	5.9 ± 0.18[cd]
Sulla	257 ± 10[b]	1.47	175	18.3 ± 0.47[bd]	6.8 ± 0.26[b]
Pasture/Sulla	162 ± 16[d]	1.21	134	15.2 ± 0.42[c]	4.7 ± 0.25[a]
White Clover/Sulla	263 ± 11[b]	1.49	177	18.5 ± 0.33[bd]	5.5 ± 0.21[ad]
Lucerne/Sulla	259 ± 18[b]	1.54	175	17.7 ± 0.35[d]	6.6 ± 0.37[bc]

[1] n = 8; [2] n = 16 [3] DM intake on a group basis and no statistical analysis has been made.

TABLE 3: Rumen pH, ammonia and volatile fatty acid (VFA) concentrations, and acetate:propionate (A:P) ratios of lambs fed seven forage diets over eight weeks. (Means ± SEM. Means with different subscripts are significant (P<0.05)).

Diet	pH[1]	Ammonia[1](mM/L)	VFA[2](mM/L)	A:P ratio[2]
Pasture	6.44 ± 0.036[a]	17.0 ± 0.54[a]	79 ± 8.6[a]	4.1 ± 0.15[a]
White Clover	6.35 ± 0.052[ad]	28.5 ± 0.79[b]	96 ± 6.3[c]	3.3 ± 0.19[b]
Lucerne	6.37 ± 0.042[ad]	27.5 ± 0.84[b]	97 ± 14.3[c]	3.4 ± 0.27[b]
Sulla	6.09 ± 0.045[b]	13.6 ± 0.69[c]	82 ± 5.7[a]	2.6 ± 0.16[d]
Pasture/Sulla	6.23 ± 0.040[c]	12.6 ± 0.43[c]	83 ± 6.9[ab]	3.3 ± 0.39[b]
White Clover/Sulla	6.33 ± 0.032[d]	21.6 ± 0.57[d]	91 ± 6.8[bc]	3.3 ± 0.22[b]
Lucerne/Sulla	6.21 ± 0.042[c]	16.0 ± 0.71[a]	90 ± 2.7[bc]	3.0 ± 0.14[c]

[1] n=48; [2] n=8

forages. However, there was no difference in live weight between white clover-, sulla- or white clover:sulla-fed lambs.

Differences in live weight gain are reflected in carcass weights (Table 2). Carcasses of lambs fed white clover, sulla and white clover:sulla were heavier (18.3-19.0 kg) than other treatments.

Intakes of lambs fed white clover, white clover:sulla, sulla and lucerne:sulla ranged from 1.47 to 1.54 kg DM/lamb/day, compared to 1.10 to 1.37 kgDM/lamb/day from lambs fed pasture, pasture:sulla or lucerne. These differences were associated with a range of 96-177g live weight gain/kgDM (Table 2).

Pasture- and pasture:sulla-fed lambs had significantly lower clean wool yields (4.7 g/100cm^2) than lambs fed white clover:sulla, sulla and lucerne:sulla (7.1, 6.8 and 6.6 g/100cm^2, respectively). Effects of supplementing lambs with sulla were mixed (Table 2) with a reduction in wool growth in lambs fed white clover:sulla, no change when pasture:sulla was fed and improved growth when lucerne:sulla was fed.

Rumen ammonia, volatile fatty acids and pH

Rumen pH of sulla-fed lambs was lower at 6.09 than all other diets (Table 3). Adding sulla to pasture and lucerne also reduced rumen pH (pasture vs pasture:sulla = 6.44 vs 6.23; lucerne vs lucerne:sulla = 6.37 vs 6.21). Rumen NH_3 concentrations (mM/L; Table 3) were highest in lambs fed diets containing high concentrations of crude protein (% of DM; white clover, 28.5 and lucerne, 27.5) relative to lambs fed pasture (17.0) and sulla (13.6). Adding sulla to pasture, lucerne and white clover significantly reduced rumen NH_3 concentrations compared to the sole diets (Table 3).

Lambs fed white clover, lucerne, white clover:sulla and lucerne:sulla produced the highest concentration of rumen VFAs relative to pasture, sulla and pasture:sulla (Table 3). Sulla resulted in a higher percentage of propionate (23.7%) and butyrate (12.0%), with less acetate (62.1%) compared to lambs fed other diets, particularly when compared to pasture (propionate = 16.9%, butyrate = 9.1% and acetate = 69.6%). Ratios of acetate:propionate (A:P) indicate relative glucogenic values for VFAs and were lower for sulla than other diets. Addition of sulla to pasture decreased the A:P ratios of pasture from 4.1 to 3.3, and to lucerne from 3.4 to 3.0 suggesting a shift away from lipogenesis with the addition of sulla.

DISCUSSION

This is the first evaluation of sulla with pasture or legumes for lambs. Pasture quality was medium-poor (10.1 MJME/kg DM), typical of summer pasture and the 1.5 fold increase in live weight gain when legumes were fed is similar to field observations (Brown, 1990). High quality pasture would result in better performance but the field trials summarised by Ulyatt (1981) showed the feeding value of white clover to be about twice that of good quality perennial ryegrass pasture.

The growth of lambs fed sulla with pasture and lucerne, relative to diets fed alone, were associated with small increases (10-12%) in DM and ME (20-25%) intakes. Daily gains increased by 54 and 35% relative to pasture and lucerne diets with commensurate increases in carcass weights. In contrast, supplementation of white clover with sulla did not affect live weight gain and wool growth was reduced. The ME content of both sulla and white clover were similar, and in contrast to supplementation of pasture and lucerne, the CT in sulla did not suppress white clover protein degradation. This is indicated by comparing the mean rumen ammonia concentration of lambs fed diets alone or in combination (Table 3). Sulla complemented pasture and lucerne by lowering rumen ammonia concentrations relative to values for each feed given as a sole diet, but there was no synergy with white clover. The significant reduction in wool growth of lambs fed sulla with white clover, relative to either forage fed alone, emphasises the importance of examining nutrient supply to the tissues and the efficiency with which absorbed nutrients are used.

Previous *in vitro* and *in sacco* incubations of ryegrass, white clover, sulla and lucerne (Burke *et al*., 2000) showed rapid degradation of white clover relative to the three other forages. Rapid degradation (often associated with low fibre concentrations) enables rapid clearance of feed from the rumen and high intakes, which were evident when lucerne was fed with sulla. However, rapid degradation may leave a small proportion of tough slowly degraded fibre, which will limit intakes after a rapid release of nutrients. This may have accounted for the lower than expected intakes of lambs fed sulla with ryegrass and mediocre performance relative to sulla fed alone. Indoor and field trials with lambs fed sulla (Stienezen *et al*., 1996; Douglas *et al*., 1999; Terrill et al., 1990; Bermingham et al., 2001) have shown sulla to be highly palatable for lambs, which selected both leaf and young stem fractions. High voluntary feed intakes obtained in lambs fed sulla suggest rapid feed clearance from the rumen, and the presence of the CT in sulla was not detrimental in this trial.

It was expected that the high concentration of soluble carbohydrate in sulla would improve the capture of ammonia arising from proteolysis, increasing microbial growth and flow from the rumen (Dellow *et al*., 1988), especially in diets yielding high rumen ammonia concentrations (e.g. white clover). The impact of high soluble carbohydrate concentrations should complement the effects of CT with diets containing high protein concentrations because the CT will limit proteolysis, and both microbial and plant protein fluxes to the intestine will increase relative to most CT-free forages (Waghorn *et al*., 1994; McNabb *et al*., 1996). Sulla did provide a protective response when fed with lucerne, but the absence of synergy with ryegrass suggests insufficient nutrients were available to benefit from either the soluble carbohydrates or the CT. Most surprising was the absence of a response when white clover was supplemented with sulla, and this warrants further study to determine the limitations to production from our "best" forage.

CT from one plant species is able to bind with and precipitate protein from another species both *in vitro* and *in vivo* (Min *et al*., 2000). The CT in sulla reduced rumen proteolysis of pasture:sulla- and lucerne:sulla-fed lambs and the protective effect of CT may have contributed to lamb performance. Condensed tannins in the white clover:sulla diet did not reduce proteolysis. The expected improvements in protein nutrition when sulla was incorporated in the diet needs to be accompanied by appropriate energy sources. In ruminants, over 70% of energy arises from VFAs, with propionate being the VFA that is glucogenic. A reduction in proportions of acetate relative to propionate will enable muscle growth rather than accretion of fat. Daily gain and carcass yield of lambs fed sulla, white clover, white clover:sulla and lucerne:sulla relative to pasture and lucerne support the benefits of propionate relative to other VFAs.

CONCLUSION

Lamb performance can be improved by feeding forage diets other than pasture alone. Sulla has the potential to supplement pasture, but greatest benefits were achieved when fed with lucerne. Compared to pasture performance improvement could be due to provision of readily available energy, reductions in protein degradation and the relatively low fibre concentrations encourage high DM and ME intakes. Rumen parameters can be used to help explain animal performance and provide an understanding of the interactions between nutrient supply and animal requirements when fed forage diets.

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REFERENCES

Attwood, G.T.; Klieve, A.V.; Ouwerkerk, D.; Patel, B.K.C. 1998: Ammonia-hyperproducing bacteria from New Zealand ruminants. *Applied and environmental microbiology 64*: 5, 1796–1804.

Bermingham, E.M.; Hutchinson, K.J.; Revell, D.K.; Brookes, I.M.; McNabb, W.C. 2001: The effect of condensed tannins in sainfoin (*Onobrychis viciifolia*) and sulla (*Hedysarum coromarium*) on the digestion of amino acids in sheep. *Proceedings of the New Zealand Society of Animal Production 61*: 116-119.

Brown, C. 1990: An integrated herbage system for Southland and South Otago. *Proceedings of the New Zealand Grassland Association 52*: 119-122.

Burke, J.L.; Waghorn, G.C.; Brookes, I.M.; Attwood, G.T.; Kolver, E.S. 2000: Formulating total mixed rations from forages – defining the digestion kinetics of contrasting species. *Proceedings of the New Zealand Society of Animal Production 60*: 5-8.

Chaney, A.L; Marbach, E.P. 1962: Modified reagents for determination of urea and ammonia. *Clinical chemistry 8*: 130-132.

Dellow, D.W.; Obara, Y.; Kelly, K.E.; Sinclair, B.R. 1988: Improving the efficiency of utilisation of pasture protein by sheep. *Proceedings of the New Zealand Society of Animal Production 48*: 253-255.

Douglas, G.B.; Stienezen, M.; Waghorn, G.C.; Foote, A.G. 1999: Effect of condensed tannins in birdsfoot trefoil (*Lotus corniculatus*) and sulla (*Hedysarum coronarium*) on body weight, carcass fat depth, and wool growth of lambs in New Zealand. *New Zealand journal of agricultural research 42*: 55-64.

Dove, H.; Mayes, R.W. 1991: The use of plant wax alkanes as marker substances in studies of the nutrition of herbivores: A review. *Australian journal of agricultural research 42*: 913-952.

Kenyon, P.R.; Sherlock, R.G.; Lee, J.; Blair, H.T. 1999: Relationship between wool sulphur concentration and wool characteristics. *Proceedings of the New Zealand Society of Animal Production 59*: 44-45.

McNabb, W.C.; Waghorn, G.C.; Peters, J.S.; Barry, T.N. 1996: The effect of condensed tannins in *Lotus pedunculatus* on the solubilization and degradation of ribulose-1,5-bisphosphate carboxylase (EC4.1.1.39; Rubisco) protein in the rumen and the sites of Rubisco digestion. *British journal of nutrition 76*: 535-549.

Min, B.R.; McNabb, W.C.; Barry, T.N.; Peters, J.S. 2000: Solubilization and degradation of ribulose-1,5-bisphosphate carboxylase/ oxygenase (EC 4.1.1.39; Rubisco) protein from white clover (*Trifolium repens*) and *Lotus corniculatus* by rumen microorganisms and the effect of condensed tannins on these processes. *Journal of agricultural science, Cambridge 134*: 305-317.

SAS. 1996: The SAS System for Windows. Version 6.12 Edition. SAS Institute Inc., Cary, North Carolina, USA.

Stienezen, M.J.; Waghorn, G.C.; Douglas, G.B. 1996: Digestibility and effects of condensed tannins on digestion of sulla (*Hedysarum coronarium*) when fed to sheep. *New Zealand journal of agricultural research 39-2*: 215-221.

Terrill,T.H.; Douglas, G.B.; Foote, A.G.; Purchas, R.W.; Wilson, G.F.; Barry, T.N. 1992: Effect of condensed tannins upon body growth, wool growth and rumen metabolism in sheep grazing sulla (*Hedysarum coronarium*) and perennial pasture. *Journal of agriculture science, Cambridge 119*: 265-273.

Ulyatt, M. J. 1981: The feeding value of herbage: can it be improved? *New Zealand agricultural science 15: 4*, 200-205.

Waghorn, B.C.; Jones, W.T.; Shelton, I.D.; McNabb, W.C. 1990: Condensed tannins and the nutritive value of herbage. *Proceedings of the New Zealand Grassland Association 51*: 171-176.

Waghorn, G.C.; Shelton, I.D.; McNabb, W.C.; McCutcheon, S.N. 1994: Effects of condensed tannins in *Lotus pedunculatus* on its nutritive value for sheep 2. Nitrogenous aspects. *Journal of agricultural science, Cambridge 123:* 109-119.