



Feeding *Acacia saligna* to Sheep and Goats with or without the Addition of Urea or Polyethylene Glycol

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ABSTRACT : The objective of the research was to investigate the effect of polyethylene glycol (PEG) or urea supplementation in sheep and goats fed a basal diet of *Acacia saligna* and wheat straw. The 3 dietary treatments were: (1) Control: *ad libitum* *A. saligna*+400 g/d wheat straw (95% DM) (basal diet); (2) Basal diet+50 g/d PEG 4000; and (3) Basal diet+1% (on a DM basis) urea sprayed onto the straw and *A. saligna* 30 min prior to feeding. All animals maintained live weight, regardless of the dietary treatment. All sheep readily consumed the *A. saligna* in preference to straw. In sheep both DMD and OMD were higher ($p<0.05$) where PEG was included in the diet compared to the other two treatments. Contrary to findings by other researchers there was no significant difference in DML, DMD or OMD between sheep and goats in corresponding treatment groups. All animals were in positive N balance. For both sheep and goats, rumen ammonia concentrations were increased with the use of either urea or PEG. In these groups the maximum ammonia concentrations exceeded 50 mg/L, considered the minimum required to maximise microbial growth. This threshold, however, was exceeded only for a period of 8-11 h. Of those measured, rumen ammonia levels were generally the highest at 4 h post feeding. None of the measurements of rumen ammonia for the control group approached 50 mg/L. It is unclear how and why feed intake and live weight were maintained when rumen ammonia levels were often sub-optimal. (**Key Words :** *Acacia saligna*, Sheep, Goats, Urea, PEG)

INTRODUCTION

As part of the battle against land degradation/desertification there is an urgent need to develop sustainable grazing systems. *Acacia saligna*, a native to Western Australia has been widely acknowledged as a useful species for land conservation. More recently, there has been a focus on *A. saligna* as a potential source of fodder for ruminants, particularly in semi-arid/arid regions. It is during the traditional summer/autumn feed deficit that occurs in Western Australia that *A. saligna* grows best, thus providing a source of green feed to grazing animals.

The common conclusion drawn by researchers, however, is that *A. saligna* is inadequate as the ruminant's sole source of nutrients. This is largely attributed to its condensed tannin (CT) content that has been shown to have an inverse relationship with voluntary intake, digestibility and nitrogen (N) retention in ruminants. Previous studies undertaken by the researchers have shown that feeding *A. saligna* without

supplementation has detrimental effects on rumen metabolism in sheep. The aim of this study was to determine whether the addition of either PEG or supplemental N in the form of urea could improve the nutritive value of *A. saligna* to maintain a minimum of animal maintenance. Goats were also included in this trial for the purpose of comparing their responses with those of sheep. Some researchers (Degen et al., 1995; Silanikove et al., 1997) have indicated that goats are better able than sheep to tolerate high tannin feeds.

MATERIALS AND METHODS

Experimental design

The experiment was based on a Latin square design, involving 3 dietary treatments and 2 animal species (sheep and goats). Six merino wethers and 6 mature Boer cross wether goats, each fitted with a permanent rumen cannula, were used. Within each species the animals were randomly allocated to 1 of 3 dietary treatments. Each experimental period was of 28 d duration, made up of 20 d for diet adaptation followed by 1 d of sampling of ruminal fluid and then 7 d of recording of feed intake and faecal and urinary output. Live weight of the animals was recorded at the start

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Table 1. Nutritive value of the basal diet

	Wheat straw	<i>A. saligna</i>
DM (%)	92	35
OM (%DM)	97.5	94.3
CP (%DM)	2.6	13.8
Total extractable phenolics ¹ (%DM)		7.38
Condensed tannins ² (% DM)		2.46
PPC ¹ (% DM)		0.022

¹ As tannic acid equivalent.² As leucoocyanidin equivalent.

and end of each experimental period. On day 1 of each sampling period, approximately 1 kg (fresh weight) of leaves was randomly collected from each 20 kg batch for chemical analyses.

Diets

The *A. saligna* was sourced north east of Perth, Western Australia. The climate of the area is described as Mediterranean with an average annual rainfall of 622 mm. The soil in which the *A. saligna* was growing may be described as sandy gravel (Moore, 2001). Branches were cut from mature trees (5-6 year old) and then fed through a mechanical leaf stripper (McMeniman, 1975). The *A. saligna* offered to the sheep and goats consisted of leaves (mostly whole) and small twigs. After harvesting, material was stored at -18°C pending feeding.

The 3 dietary treatments were: (1) Control: *ad libitum* *A. saligna*+400 g/d wheat straw (95% DM) (basal diet); (2) Basal diet+50 g/d PEG 4000; and (3) Basal diet+1% (on a DM basis) urea sprayed onto the straw and *A. saligna* 30 min prior to feeding. Wheat straw was included in the basal diet to reflect a paddock situation in which plantations of *A. saligna* are interspersed with dry pasture during the summer/autumn period of Western Australia.

The quantity of *A. saligna* to be treated with urea was weighed and then spread out on a clean tarpaulin on the floor. The urea was dissolved in water (1:20 w/v) and then sprayed over the *A. saligna* which was turned several times during the spraying to encourage even coverage. The straw was similarly treated where applicable.

There was no prior knowledge of the content or biological activity of the CT in the *A. saligna*, therefore, the dose rate of PEG (50 g/head/d) was based on those used by Silanikove et al. (1994).

Data collection

To enable the measurement of wool growth, dye-bands were applied on the midside of each sheep at the start and end of each treatment period (28 d). Three weeks after the conclusion of the trial the wool containing the dye bands was removed at skin level with wool growth during each of the 3 trial periods evident from the appearance of the 4 dye-bands. The average fibre diameter within each treatment period was measured using a Sirolan laser scan and linear wool growth was measured using a steel rule.

Samples of ruminal content were obtained via the rumen cannula, just prior to feeding and thereafter, at regular intervals for 24 h using a sampling suction probe. Fluid was strained through a 100 µm sieve and then pH was measured. Samples (16 ml) of strained ruminal fluid were placed in specimen bottles containing 0.2 ml of 18M H₂SO₄. The samples were then stored at -18°C.

Samples of *A. saligna* foliage and faeces were dried in a forced-air oven (Contherm Digital Series 5) at 35°C (to minimise the loss of tannins through excessive heat) until constant weight to determine DM contents. Where applicable, the weight of PEG was subtracted from the faecal weight in determining DM digestibility (DMD). Proximate analysis was used to determine the ash, OM and

Table 2. Intake and digestibility of *A. saligna* and straw offered to sheep and goats, with or without a supplement of PEG 4000 or 1% urea

Parameter	Sheep				Goats				Between species LSD
	Control	+ PEG	+ Urea	Sign.	Control	+ PEG	+ Urea	Sign.	
Av live weight (kg)	66.6±10.7	66.4±9.9	67.5±10.6	NS	47.5±3.6	47.8±3.3	47.5±4.6	NS	
Dry matter intake									
<i>A. saligna</i>									
(g/d)	1,287±200 ^a	1,389±126 ^b	1,295±238 ^a	*	1,091±119	1,173±100	1,134±255	NS	
(g/kg ^{0.75} /d)	55±8.6	60±5.4	55±10.1	NS	60±6.6	64±5.5	63±14.1	NS	10.67
Straw									
(g/d)	75±44	72±28	82±52	NS	34±7	33±18	38±25	NS	
(g/kg ^{0.75} /d)	3.2±0.4	3.1±1.0	3.5±1.4	NS	1.8±0.4	1.8±1.0	2.1±1.4	NS	1.65
Total DM intake									
(g/d)	1,362±175 ^a	1,461±107 ^b	1,377±205 ^a	*	1,125±116	1,206±100	1,172±261	NS	
(g/kg ^{0.75} /d)	58.4±7.5	62.8±4.6	58.4±8.7	NS	62.2±6.4	66.4±5.5	64.8±14.4	NS	10.23
DMD (%)	48.2±2.6 ^a	55.2±4.7 ^b	49.0±2.8 ^a	*	51.2±3.3	54.2±4.9	52.2±4.8	NS	4.60
OMD (%)	49.7±2.4 ^a	56.6±4.6 ^b	50.9±2.5 ^a	*	53.1±3.3	56.0±5.0	54.1±4.6	NS	4.42

* p<0.05. NS = Not significant. Values within rows with different superscripts are significantly different (p<0.05).

Table 3. Nitrogen intake and balance in sheep and goats fed *A. saligna* and straw with or without a supplement of PEG 4000 or 1% urea

Nitrogen (g/d)	Sheep				Goats				Between species LSD
	Control	+PEG	+Urea	Sign.	Control	+PEG	+Urea	Sign.	
N intake (mg/kg 0.75/d)	28.7±4.31 ^a	31.0±2.68 ^a	35.3±6.05 ^b	***	24.2±2.62 ^a	26.1±2.18 ^{ab}	30.6±6.88 ^b	***	
Faecal N (mg/kg 0.75/d)	1,232±185 ^a	1,333±115 ^a	1,498±257 ^b	***	1,340±145 ^a	1,434±120 ^{ab}	1,692±380 ^b	***	
Urine N (mg/kg 0.75/d)	21.2±2.91 ^b	13.4±2.56 ^a	22.2±3.65 ^b	***	16.4±2.41 ^b	10.2±1.98 ^a	16.6±4.05 ^b	***	
N balance (mg/kg 0.75/d)	911±125 ^b	575±110 ^a	943±155 ^b	***	909±133 ^b	562±109 ^a	917±224 ^b	***	
	6.2±1.49 ^a	12.2±2.49 ^c	8.6±3.53 ^b	***	5.8±1.18 ^a	9.8±1.62 ^c	7.7±2.44 ^b	**	
	268±85 ^a	523±105 ^c	366±86 ^b	**	318±65 ^a	538±89 ^c	426±135 ^b	**	
	1.2±1.98 ^a	5.5±2.44 ^b	4.4±2.03 ^{ab}	**	2.0±1.45 ^a	6.1±2.15 ^b	6.3±3.02 ^b	**	
	53±85 ^a	235±105 ^b	189±86 ^b	***	113±80 ^a	335±118 ^b	349±167 ^b	***	127.7

** p<0.01; *** p<0.001. Values within rows with different superscripts are significantly different.

Table 4. Ammonia concentrations and pH of ruminal fluid from sheep and goats fed *A. saligna* and straw with or without a supplement of PEG 4000 or 1% urea

	Sheep				Goats				Between species LSD
	Control	+PEG	+Urea	Sign.	Control	+PEG	+Urea	Sign.	
NH ₃ -N average (mg/L)	15±9 ^a	48±24 ^b	47±24 ^b	**	21±12 ^a	66±27 ^b	51±26 ^b	**	18.84
NH ₃ -N range ¹ (mg/L)	9-21	24-97	27-72		15-28	32-127	23-102		
pH average	6.9±0.2	6.8±0.1	6.8±0.1	NS	7.0±0.2 ^b	6.7±0.1 ^a	6.8±0.1 ^a	**	0.17
pH range ¹	6.7-7.1	6.6-7.0	6.7-7.0		6.8-7.2	6.5-6.9	6.6-7.0		

** p<0.01. NS = Not significant.

Values within rows with different superscripts are significantly different.

¹ The variation over a 24 h period.

CP contents of the feed and faecal samples. Total extractable phenolics were determined using the folin-ciocalteu method, as described by Makkar et al. (1993). Analyses of condensed tannins were undertaken on tannin extract diluted with 70% acetone and using butanol-HCl reagent (95:5 v/v) and ferric reagent (2% ferric ammonium sulphate in 2 N HCl) as per the method of Porter et al. (1986). Protein precipitation capacity (PPC) was according to the method of Makkar et al. (1988), based on the use of bovine serum albumin.

Ruminal fluid was centrifuged (3,000 g for 10 min) and analysed for ammonia concentration. The procedure used an automated segmented flow Technicon instrument and was based on the modified Berthelot reaction (Searle, 1984).

An analysis of variance of the results was carried out using Genstat[®]. The P level of 0.05 was used when testing for significance.

RESULTS

The nutritive value of the 2 feeds is shown in Table 1. Sheep supplemented with PEG consumed more *A. saligna* than either the control group or those supplemented with urea (p<0.05, Table 2). This was reflected in differences in the total DMI (p<0.05). All sheep readily consumed the *A. saligna* in preference to straw. The consumption of straw did not differ amongst treatment groups. The animals consumed <25% of the straw offered. The addition of urea

failed to increase the intake of straw.

In sheep both DMD and OMD were higher (p<0.05) where PEG was included in the diet compared to the other two treatments. In contrast, the addition of PEG had no effect on these parameters in goats. The addition of urea also had no effect on DMI, DMD or OMD in goats. In corresponding treatment groups there was no difference in DMI, DMD or OMD between sheep and goats.

The sheep supplemented with urea had a higher N intake than the other two groups (p<0.001, Table 3). Faecal N from both the control and the urea treatment groups was greater (p<0.001) than for the PEG group. The urinary N was significantly different (p<0.01) between all groups, the greatest being for the PEG group, followed by the urea and then the control group. Both faecal and urinary N displayed the same trends for goats as they did for sheep.

All sheep were in positive N balance, the greatest being for the PEG group, which was significantly higher (p<0.05) only than the control sheep. In goats the N balance was significantly higher (p<0.01) for both the PEG and urea groups compared to the control group. There was no difference in the N balance (g/kg^{0.75}) in sheep and goats in corresponding treatment groups.

In sheep, the average rumen ammonia concentration was lowest in the control group (p<0.01), as it was for the goats (Table 4). There was no difference in the average rumen ammonia concentration between the PEG and urea groups for either sheep or goats. There was no significant

Table 5. Wool growth and fibre diameter in sheep fed *A. saligna* and straw with or without a supplement of PEG 4000 or 1% urea

	Treatment			Sign.
	Control	+PEG	+Urea	
Wool growth ($\mu\text{m}/\text{d}$)	292 \pm 42	304 \pm 37	310 \pm 43	NS
Fibre diameter (μm)	20.65 \pm 1.11 ^a	21.55 \pm 1.10 ^b	20.73 \pm 1.21 ^a	**

** $p < 0.01$. NS = Not significant. Values within rows with different superscripts are significantly different.

difference in the average pH of rumen contents from sheep in any of the treatment groups, however, in goats the average pH was higher ($p < 0.01$) for the control than the other two groups. There was no difference in the average rumen ammonia concentration or pH from sheep and goats in corresponding treatment groups.

There was no difference in the live weight changes of any group of sheep, as was the case with the goats. There was no difference in the live weight changes of sheep and goats from corresponding treatment groups. Overall, animals maintained live weight.

There was no difference in the linear wool growth of any group of sheep, however, the average fibre diameter of wool from sheep supplemented with PEG was greater than either the control or the urea group ($p < 0.01$, Table 5).

DISCUSSION

Composition of foliage

The DM of *A. saligna* foliage recorded in this trial (350 g/kg) was lower than those recorded by Abou El Nasr et al. (1996) and Ben Salem et al. (1999) (435 g/kg and 392 g/kg, respectively). The OM recorded in the present trial (943 g/kg) was similar to the higher value in the range of values (776-928 g/kg) reported in other trials (Degen et al., 1995; Degen et al., 1997; Ben Salem et al., 1999). The CP reported in this trial (138 g/kg) exceeds the range of CP reported elsewhere for *A. saligna* foliage i.e. 105 g/kg-132 g/kg (Abou El Nasr et al., 1996; Ben Salem et al., 1997; Chriyaa et al., 1997). This higher CP content could contribute to better animal performance (in terms of maintenance of live weight).

Total phenolics and CT (73.8 g/kg and 24.6 g/kg, respectively) in *A. saligna* foliage used in the present trial were less than the values reported by Degen et al. (1995) and Degen et al. (1997) (103-150 g/kg total phenolics and 83-156 g/kg CT). It is not the mere presence of phenolics and CT in *A. saligna* that would influence its utilisation but more their biological activity, therefore it is likely that differences in the PPC have a significant impact on results.

Intake and digestibility

The *A. saligna* fed in this study was highly palatable. This was in contrast to the findings of Abou El Nasr et al. (1996) and Chriyaa et al. (1997) who suggested that low voluntary intake of *A. saligna* is an indication of its lack of

palatability. In the current study the DMI of *A. saligna*, on a metabolic body mass basis, when fed as a sole diet (control), was 6.0% in goats and 5.5% in sheep (although this difference was not statistically significant). These intake levels were considerably higher than those reported by Degen et al. (1995), where intake was 1.05% in goats and 0.80% in sheep. The DMD was greater in the present trial than in Degen's (approximately 48% compared to 31-40%, respectively), as was CP (13.8% compared to 11.1-13.2%), and total phenolics and CT were both lower. All these factors, plus the probability that PPC was lower in the present trial, would have contributed to the higher intake of *A. saligna*. The higher intake would also have contributed to animal live weights being maintained.

Supplementation with PEG improved the intake of *A. saligna* by both sheep and goats, although this was significant ($p < 0.05$) only with sheep. This corresponded to an increase in DMD and OMD, again significant only with sheep ($p < 0.05$). Fujihara et al. (2005) also reported increased OMD, as well as increased metabolisable energy, with PEG supplementation. Rubanza et al. (2003) and Karabulut et al. (2007), in *in vitro* studies, also showed improved OMD with the addition of PEG. Whilst Silanikove et al. (1996b) also reported positive responses to PEG supplementation they found that, when fed a high-tannin diet, goats responded better than sheep to PEG supplementation and that the amount of PEG required to elicit the maximum response in intake was lower for goats than for sheep. It is not clear why the sheep responded to PEG while the goats did not. Supplementation with urea did not affect either sheep or goats in terms of *A. saligna* intake or digestibility.

Intake was generally not different between sheep and goats. This was in contrast to other studies where goats have been noted elsewhere for their higher intake of tannin-rich carob leaves compared to that of sheep (Silanikove et al., 1994; Silanikove et al., 1996a). Experimental design cannot be ruled out as the cause of the lack of differences in feed intake between sheep and goats in the current study. Confounding of results may have occurred as a result of the short time feeding (only 28 d) associated with each treatment period within the Latin square design.

Nitrogen intake and balance

The difference in N intake by the sheep was a reflection of the additional N from the urea, not because of differences

in intake. The lower faecal N with the addition of PEG in both sheep and goats corresponded to the higher DMD, but could also have been due to lower TPC. Where diets contain tannins these tannins bind with (dietary) protein resulting in less protein digestibility in the rumen. This results in lower rumen ammonia N and in turn lower urinary N, as was the case in this study where urinary N was lower in the control group compared to the PEG group. Faecal N from the animals supplemented with urea was similar to the control animals, yet urinary N was higher due to the greater supply of soluble N in the rumen. All animals in this trial were in positive N balance. This would account for all the animals maintaining live weight.

Ruminal ammonia concentration and pH

For both sheep and goats, rumen ammonia concentrations were improved with the use of either urea or PEG indicating an improved availability of rumen degradable N. In these groups the maximum ammonia concentrations exceeded 50 mg/L, considered the minimum required to maximise microbial growth (Satter and Slyter, 1974). This threshold, however, was exceeded only for a period of 8-11 h. Of those measured, rumen ammonia levels were generally the highest at 4 h post feeding. None of the measurements of ammonia for the control group approached 50 mg/L. Despite this, animals in the control group still maintained both a positive N balance and their live weight.

In general, ammonia levels were higher in goats than in sheep, but this difference was not significant. In spite of the low rumen ammonia concentration, DMI was high in all groups, as was DMD and OMD compared to other studies reported in the literature.

Dietary treatment had no effect on the average rumen pH in sheep, however, in goats the average pH was higher ($p < 0.01$) for the control than the other two groups. The addition of PEG or urea, therefore may indicate improved rumen fermentation in goats (despite relatively low rumen ammonia levels) as lower pH indicates higher production of VFA (Woodward and Reed, 1997).

Live weight

Regardless of dietary treatment, all animals maintained live weight in this trial. This is attributed largely to the relatively high levels of intake and relatively low levels of CT (compared to other studies). Loss of body weight and low intakes have been previously observed in animals eating leaves of *A. saligna* (fresh or dried), either as a sole diet or as an *ad libitum* supplement to straw. The negative effects were due to a combination of reduced intake and low digestibility of nutrients, attributed mainly to the high CT content (Degen et al., 1995; Chriyaa et al., 1997). Similar

effects were observed in sheep and goats fed dried *A. salicini*, another shrub with a high CT content (Degen et al., 1997). What is unclear in the present study is how and why feed intake and live weight were maintained and DMD and OMD were not compromised when rumen ammonia levels were often sub-optimal.

Wool growth

Addition of PEG resulted in an increase in fibre diameter but had no effect on linear wool growth. This is in partial agreement with results of Barry (1985) where daily dosing with PEG of sheep feeding on *Lotus pedunculatus* (tannin-containing) resulted in improvements in wool growth and live weight gain. In contrast, Terrill et al. (1992) report superior rate of wool growth in sheep fed (tannin-containing) *Hedysarum coronarium* apparently due to increased post-ruminal supply of amino acids. Sheep grazing the same pastures but dosed daily with PEG had significantly lower rates of wool growth.

IMPLICATIONS

The results from this trial suggest that *A. saligna* could be a useful feed source for ruminants. The substitution of straw with *A. saligna* indicates that its incorporation into a grazing system could significantly decrease grazing pressure on dry summer pastures.

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