

## THE APPLICATION OF NEW TECHNOLOGY FOR THE PROTECTION OF AMINO ACIDS TO IMPROVE WOOL PRODUCTION AND BODY GROWTH IN SHEEP

L.D. STAPLES\*, S.R.MCPHEE\*, A.H. WILLIAMS\*\*, AND R.J. JOHNSON\*\*\*

### SUMMARY

Microspheres consisting of a central core of amino acid and binding agents which are coated with a pH sensitive (neutral stable/acid unstable) polymer have been developed by Rhone Poulenc. This new technology allows orally administered amino acids to avoid exposure to and degradation by, **rumen** microbes but allows bio-availability following release and absorption at the abomasum and distal gut sites. The microspheres can be mixed with grain supplements and fed to grazing sheep by using molasses as an adhesive.

Three trials were conducted to evaluate the potential of **rumen-protected DL-methionine** ("Smartamine", Rhone Poulenc Animal Nutrition) to achieve effective supplementation of sheep under a variety of physiological and nutritional conditions. Trial 1 assessed the effects on growth and wool production in weaner lambs. Trial 2 evaluated responses in breeding ewes which received medicated grain supplements in late pregnancy and early lactation while grazing summer pasture. The influence of diet was evaluated in Trial 3 by measuring responses in **wethers** maintained in an experimental **feedlot** on diets containing different types of grain and levels of roughage. Overall, the trials showed that an average daily dose of 2.0 gram of product per head (approximately 1.5 gram of methionine), given as a medicated grain supplement three times per week, increased the volume growth rate of wool during **treatment** by 6 to 27%. This was due to significant stimulation of both length growth and fibre diameter in all circumstances tested. Annual greasy fleece weights were increased by up to 7.8% (in weaners) from a ten week period of treatment. In trial 2, enrichment of supplements with protected methionine also resulted in a 7 to 10% increase in the tensile strength of wool grown by treated single or twin-bearing ewes when treatment was given during late pregnancy and early lactation. In trial 3, the stimulatory effects of the protected methionine treatment in mature **wethers** on near maintenance energy diets were independent of the type of grain (oats, wheat or lupins) and of the level of roughage in the diet (20, 40 or 60% of ME), suggesting that protected methionine may be used effectively in a wide range of dietary circumstances. Treatment was also associated with a transient increase in the rate of live weight gain and condition score of merino weaners grazing good summer pasture. These trials illustrate the potential for the new protected formulations of methionine to provide a practical solution to methionine insufficiency and thus to at least partially overcome a common cause of sub-optimal performance of sheep in Australia.

### INTRODUCTION

The majority of sulphur present in wool protein is present as the **dimeric** sulphur amino acid, cystine. Therefore, it is well known that cysteine monomer is the first limiting amino acid for wool growth in sheep. Many studies have shown that the administration

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\* Applied Biotechnologies Pty Ltd, Unit 1, 52-60 Export Dr., Brooklyn VIC 3025

\*\* Department of Agriculture, Victorian Institute of Animal Science, Werribee VIC 3030

\*\*\* Rhone Poulenc Animal Nutrition Pty Ltd, 19-23 Paramount Rd, West Footscray VIC 3012

of sulphur amino acids can significantly increase the rate of wool growth since **Marston** first demonstrated a 35% increase 1935. Cysteine can be provided directly or may be obtained by metabolism of methionine to cysteine via the transulphuration pathway described by **Reis** (1988). Methionine is the preferred supplement since it is an essential amino acid with important metabolic functions in addition to being a source of cysteine and as a structural component of wool protein. However, oral doses of either amino acid are ineffective since they are both readily degraded by the **rumen** microbes (**Bird and Moir** 1972) and this reduces the bio-availability from the oral route.

The potential to improve wool production by oral supplementation with methionine has tantalised researchers for many years since there is substantial evidence showing that **rumen** bypass sulphur amino acids are highly effective. Most research used abomasal infusion as the **rumen** bypass delivery technique (eg **Reis and Schinkel** 1963, **Reis et al.** 1973, **Reis and Tunks** 1974). These studies, and others, consistently demonstrated substantial increases of 10-100% in wool growth during treatment, with typical responses of around 20-30%. These results were broadly confirmed when sulphur amino acids were given by **parenteral** routes such as by sub-cutaneous injection (**Langlands** 1970), by per-cutaneous arterial infusion (**Hoey et al.** 1984), by intra-peritoneal infusion or injection (**Downes et al.** 1970, **Ferguson** 1975), by intra-peritoneal pellets (**Langlands** 1970), and by intra-venous infusion (**Dryden et al.** 1969, **Reis et al.** 1973, **Barger et al.** 1973).

Unfortunately, none of the delivery techniques mentioned above are practical for the administration of methionine to unrestrained grazing animals. Attempts have been made to achieve at least partial **rumen** protection by the use of analogue forms of sulphur amino acids such as hydroxy methionine analogue (MHA, **Langlands**,1972), or short chain esters of cysteine (**Radcliffe et al.** 1985) or methionine (**Wheeler et al.**,1979), but none appear to be reliably effective and simple to administer under grazing conditions.

Apart from a recent study of the effects of methionine-in-oil emulsions and methionine with bentonite (**Cobon et al.** 1992), the lack of a suitable means to deliver methionine in a bio-available form has largely prevented systematic research of a number of important issues concerning the practical application of methionine supplements in the field. Many laboratory studies have provided data on the responses of mature **wethers** fed high quality roughage diets in metabolism cages but provide little insight into the potential of protected methionine to enhance wool production under farm conditions with unrestrained sheep grazing pasture of various quality and receiving the grain supplements. Also, the previous research provides little information on the wool growth responses in animals in various physiological states. Particular deficiencies are found in the area of responses in late pregnancy, where wool growth is well known to be reduced (**Corbett** 1979) but where response to sulphur amino acid supplements or protected protein have been inconsistent (**Williams et al.** 1978, **Wickham** 1970), and in early lactation where competitive partitioning of methionine to milk protein may limit wool production (**Oddy** 1985). The possible additional benefits of growth stimulation in growing lambs has not been thoroughly evaluated apart from a recent study showing that supply of encapsulated methionine to nursing ewes increased growth rates in their lambs (**Lynch et al.** 1991) and an early report by **Wright** (1971) which showed increased weight gain and food conversion efficiency following intra-peritoneal injection of methionine in lambs.

Limitations of the delivery system prevented previous studies from fully evaluating the importance of the amount and quality of basal diet to the response to methionine supplements. This may be crucial to the adoption of methionine supplementation in the field. **Reis** and **Tunks** (1974) reported that abomasal infusion of methionine actually reduced wool growth in animals on a pure wheat diet, whereas **Ferguson** (1975) found a 23% increase in wool growth in animals given an intra-peritoneal infusion of methionine

while on a 75% wheat diet. Clearly, the type of background diet will be important if the "wheat effect" was also seen in other grain based diets which are commonly used in Australia during periods of pasture feed shortage. Logical arguments can predict that maximal responses to methionine may occur on good diets (because all other nutrients are in adequate supply) and on poor diets (because methionine may be particularly limiting in this circumstance). The existing data on these aspects is fragmentary and does not permit a definitive analysis. In the few studies where more than one type of diet have been compared, highest responses have been found on good quality rations (Dove and Robards 1974, Wheeler et al.,1979) or on poor quality diets (Dryden et al.,1969). Moreover, the dose-dependence of response may vary between diets (Langlands 1970, Ferguson 1975).

Finally, the method of dosing may assume significance, particularly in the practical situation of infrequent dosing of groups, if variable dose compliance occurs. Most laboratory studies have used continuous infusion or daily dosing in animals which have continuous access to feed or are fed daily. This is quite different from the field situation where supplements are usually offered on two or three occasions per week. The discontinuous administration of methionine has implications for potential acute or chronic toxicity and for optimisation of the stimulatory dose. While some researchers have found that responses are similar if methionine (or an **analogue**) is given as an infrequent large dose or as a frequent small dose (Robards 1971, Wheeler et al. 1979), others have found higher responses when doses are small and frequent (Langlands 1970, Wickham 1970).

The present trials were designed to investigate some of the factors which are important to the practical application of methionine to grazing sheep. Specifically, we have evaluated the bio-availability of methionine from polymer-encapsulated microspheres, tested the wool and body growth responses to a predicted optimal dose in weaner lambs and in non-pregnant, single or twin bearing ewes. We have also tested oral methionine supplementation in **wethers** which received maintenance energy from diets based on oats, wheat or lupins with a range of level of clover hay roughage.

The trials were conducted in 1991 and preliminary accounts of parts of this data were presented to the Australian Nutrition Society (Staples et al. 1992a,b,c).

## MATERIALS AND METHODS

### Trial 1 a: Bioavailability

The bio-availability of methionine from 1mm microspheres containing 65% DL-methionine and coated with a co-polymer of 2-vinylpyridine/styrene ("Smartamine" Rhone Poulenc Animal Nutrition) was evaluated in six month old merino weaners weighing 25kg. The animals used for the bio-availability assessment were part of a larger study of the effect of protected methionine on weaner growth and wool production described below (Trial 1b). At 14.5-16 hours post feeding, heparinised jugular venous blood samples were taken from 10 randomly selected control untreated and from 15 weaners from each of two separate treated groups. Supplement for the control group sampled was 300 gm/head/feed of 80% oats:20% lupins (+ 3% molasses as an adhesive) and the medicated supplement was grain at 120 or 300 gm/head/feed plus 4.66gm of protected methionine. The supplements were given on Mondays, Wednesdays and Fridays to groups of 150-240 lambs grazing good quality summer pasture in the Western Victoria. The treatment thus provided an average daily dose of 2.0gm product per head. Supplements were fed as long trails and consumed totally within two hours of offering. The bio-availability study was conducted one month after the commencement of

treatment. After precipitation of plasma proteins, by mixing 0.5ml plasma with 0.05ml of 35% aqueous sulphosalicylic acid dihydrate, free methionine was determined by HPLC (Beckman 6300 at St Vincents Hospital Institute of Medical Research).

#### Trial 1b: Effects in Weaner Lambs

Merino weaners (as above) were allocated to four groups and stocked at the same rate (16.5 lambs/Ha) on adjacent areas of the same paddock. Two groups received a low quantity of oat/lupin supplement (120gm/head/feed) and two groups received a higher rate of supplement (300gm/head/feed) during the summer of 1991. On the 21st Jan the standing pasture was 3282 kg/Ha and 13% green. Green pasture was 68.3% digestible, contained 20.3% crude protein and provided 9.4 MJ/kg ME. Dry pasture was 46%D, 4.8%CP, and 6MJ/kg ME but voluntary intake would have favoured the green feed. Unseasonably high rainfall of 70-80mm on 4th and again on the 22nd Jan resulted in good quality green feed being available from early Feb until the return to dry summer feed in mid March. Commencing on the 9th Feb and continuing for 10 weeks one group at each supplement level received a medicated supplement as described above. Dye bands were applied to a mid flank staple at 6 weeks prior to the start of treatment, at the start, after 4 weeks and at the end of treatment and at one month post-treatment. Live weights and condition scores were recorded at the time of dye banding and fleece weights were recorded at the annual shearing on the 22nd July. Mid flank staples were collected in June and the distance between dye bands analysed for length growth (duplicate measurements of unstretched staple) and a sub-sample of 50 staples for each group were sectioned into 2mm segments, and analysed for fibre diameter by laser based FDA analysis (Gerner Scientific Instrument at the Melbourne College of Textiles). Another 10 portions of the same staple were measured for tensile strength. Fibre volume growth and growth rate was estimated by calculation of fibre length and diameter data.

#### Trial 2: Effects in Breeding Ewes

A flock of 1500 Nov joined 3-4yr old saxon merino ewes (45-52kg) underwent ultrasonic pregnancy diagnosis and 800 of these ewes were selected into four groups of 200 to make flock structures balanced for litter size distribution (20% dry, 50% single bearing and 30% twin bearing), ewe and fetal age and pre-trial ewe fleece weight. Mean lambing date was 4th May ( $\pm 2$  weeks), with an average lambing percentage in all groups of 110 lambs/100 ewes joined. One Control and one treated group was established on adjacent sections of a paddock on the Northern side and the other pair of groups on the Southern side of the host property in Western Victoria. Pasture availability varied between the Northern and Southern sides of the property (2871 and 1707kg/Ha respectively) with more green feed available on the North (17%) than on the South (0%) at the start of the trial. All groups received a supplement of 700gm/head/feed of oats (87.9%DM, 6.3%CP, 72.8% Digestibility and 10.7MJ ME/kg DM) pre-mixed with 2% (w/w) molasses and offered three times weekly. Treated groups received protected methionine at an average dose of 2.0 gm/head/day for a 10 week period commencing on the 8th April at four weeks prior to mean lambing date of the pregnant ewes and continuing through the first 6 weeks of lactation.

Dye bands were applied at one month before the start of treatment, at the start and end of treatment and at one month after the end of treatment. Dye banded fleece staples were collected when lambs were weighed at weaning on 24th Aug. Annual fleece

weights were recorded at shearing on 3rd Feb 1992. Samples were processed as for Trial 1b. Only data from ewes rearing a lamb were included in analysis of pregnant groups-

### Trial 3: Effect of Background Nutrition on Response in Wethers

The effect of a grain supplement containing 2 gm/head/day of protected methionine on wool growth and body weight was assessed in mature Merino wethers which were acclimatised to various diets in an experimental feedlot facility. The incomplete, replicated block design allowed non-orthogonal comparisons of the effect of treatment when animals were fed a near maintenance diet consisting of oats, wheat or lupin grain with 20, 40 or 60% of energy requirements provided by grass clover hay. Wethers (N=390) were ranked in order of pre-trial fleece weight the allocated to three blocks of high, medium or low fleece weight (n=130/block). Animals within each block were then allocated at random to 13 treatment groups (n=10 per replicate) as shown in Table 1.

TABLE 1 Experimental design for 13 treatment groups each of three replicates of 10 wethers

Roughage#	Treatment	OATS	WHEAT	LUPINS
60% (high)	control	--	5	--
	2.0 gm/head/day	--	6	--
40% (med)	control	1	7	11
	2.0 gm/head/day	2 + 13*	8	12
20% (low)	control	3	9	--
	2.0 gm/head/day	4	10	--

\* All groups fed as 3 replicates of 10 except for group 13 which was fed individually. # As % of total energy.

Treatment commenced after an 8 week period of progressive equilibration from pasture to the respective diets and a one month period of pre-treatment observations. Treatment continued for 8 weeks and observations were continued for a period of one month post-treatment, (with the last two weeks on pasture). Protected methionine was given with the grain portion of the ration after first dispersing the microspheres in 150gm/pen of wheat pollard as a diluent. One group of 30 treated wethers on the medium roughage oat diet were held in individual pens to provide comparative data on the efficacy in group versus individually fed animals. Procedures for collection of samples and determination of wool growth and wool quality were similar to those described above for Trials 1 and 2.

## RESULTS

### Trial 1 a: Bioavailability

Treatment of grazing merino weaners with a medicated grain supplement containing an average dose of 2.0 gm/head/day of protected methionine was associated with a significant increase ( $P < 0.0001$ ) in the plasma free methionine levels measured at 14.5-16 hours after feeding. Since feeding of the average weekly dose was achieved by dividing the total weekly dose into three feeds, the data refers to methionine levels measured after an acute dose of 4.66 mg of product per head. Also since the samples were taken after one month of treatment the data refers to the accumulated effect of a sequence of doses.

Nevertheless, the treatment was highly effective in increasing the mean concentration from  $21.3 \pm 0.9 \mu\text{M}$  in control to  $36.0 \pm 1.7 \mu\text{M}$  in the high grain group and to  $43.0 \pm 3.7 \mu\text{M}$  in the low grain treated group. Moreover, only three of the 30 treated lambs showed a blood methionine level within two standard deviations of the control mean and only one showed a methionine level greater than three times the control mean (Table 2).

Table 2 Effect of protected methionine (2 gm/h/d) on plasma free methionine levels ( $\mu\text{M/L}$ ) in weaner lambs

Group	grain	Number	mean $\pm$ SEM	median	range	% > 2 SD above C mean
Control	high	10	$21.3 \pm 0.9$	21.3	15.4-25.5	-----
Treated	high	15	$36.0 \pm 1.7$	34.7	22.6-48.5	93% (14/15)
Treated	low	15	$43.0 \pm 3.7$	40.5	19.3-77.2	87% (13/15)

#### Trial 1b: Effects in Weaner Lambs

Treatment with protected methionine was associated with a significant increase in live weight gain during treatment regardless of the level of supplement offered (high grain example, Figure 1) and despite the relatively good growth rates in the control group due to the high quality summer pasture. Condition score was also 10 to 12% higher ( $P < 0.001$ ) in both treated groups compared to control. Stimulation of weight gain resulted in a lower ( $P < 0.05$  Chi Square) proportion of lambs in the low live weight categories (20-25 kg) and more ( $P < 0.001$ ) lambs in the higher weight category (30-35 kg) at the end of treatment. Length growth of wool was also increased 6.4 and 9.6% in the first and second months of treatment ( $P < 0.001$  by ANOVA using pre-treatment values as co-variates) and fibre diameter was increased by 0.83 and 1.56 micron ( $P < 0.001$ ) with both effects being independent of the level of grain supplement (Figure 2).

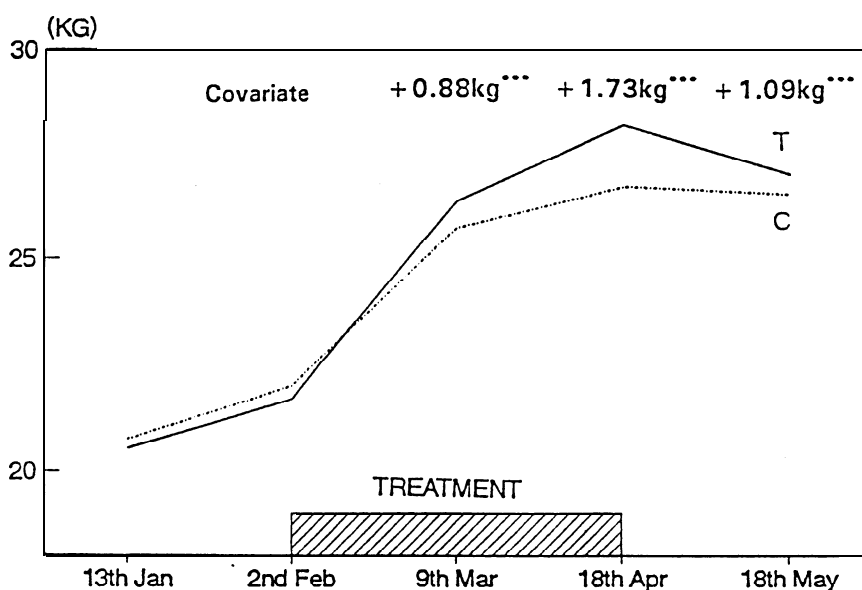


Figure 1 Mean live weights for control (C) and methionine treated (T) lambs during the pre-treatment, treatment and post-treatment periods (high grain example) with the co-variate analysed differences between treated and control groups at both grain levels shown above the means.

The combined effect on length growth and fibre diameter gave significant increases ( $P < 0.001$ ) in the volume growth rate of wool during the first four (+13.7%) and last six (+27.1%) weeks of treatment (Figure 3). Greasy fleece weights were also increased by 220gm and 180gm per head in the low and high grain groups respectively, for an overall effect of a 7.8% increase in fleece weight ( $P < 0.001$ ). There was no significant effect on tensile strength which was above 40 N/ktex during treatment for all groups.

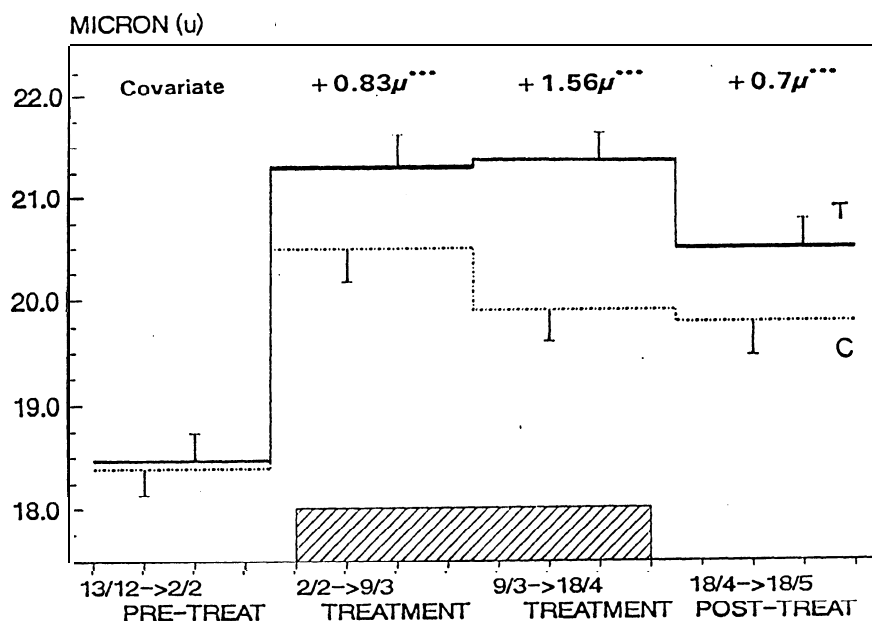


Figure 2 Mean ( $\pm$  SEM) fibre diameter for control (C) and treated (T) lambs during the pre-treatment, treatment and post-treatment periods (high grain example) with the co-variate analysed difference between treated and control groups for both grain levels shown above the relevant means.

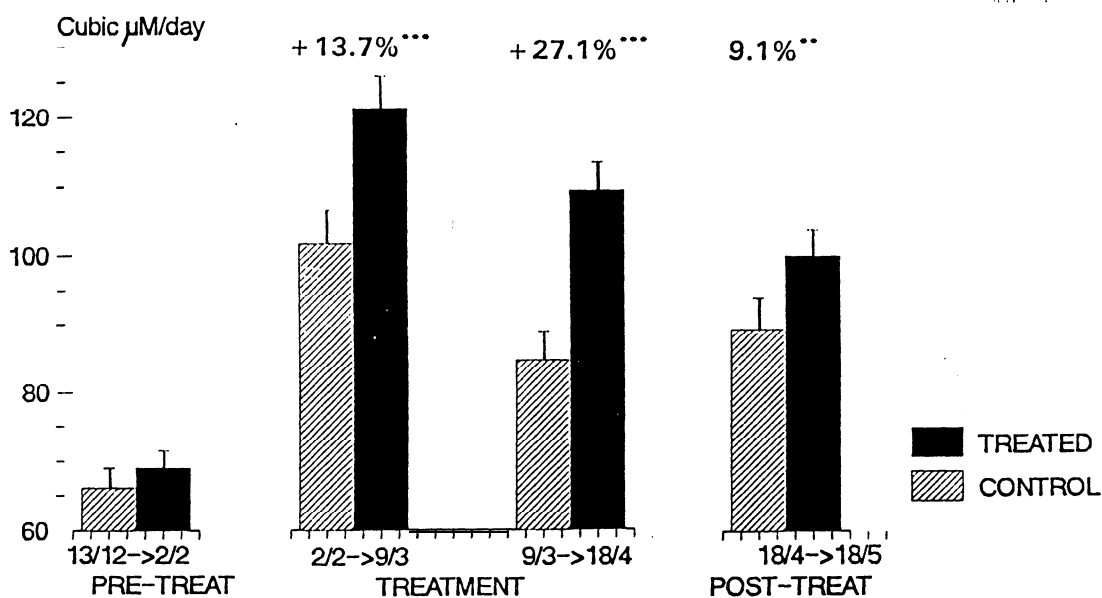


Figure 3 Effect of methionine treatment on estimated fibre volume growth rates in the pre-treatment, treatment and post-treatment periods (high grain example) with co-variate analysed relative difference due to treatment for both grain groups shown above the absolute means.

### Trial 2 Effects in Breeding Ewes

Treatment with protected methionine did not alleviate the large drop in live weight of the single and twin bearing ewes which lost approximately 14kg (from 48 to 34 kg) over the period from early April to late July due to the combined effects of parturition, lactation and the poor summer pasture conditions (with late Autumn break) which prevailed during this trial. Live weight was maintained in the non-pregnant ewes, and there was no significant effect of treatment.

Length growth of wool was increased by 4.9% ( $P<0.001$ ) by treatment in single bearing and by 7.3% ( $P<0.001$ ) in twin-bearing ewes but not in the non-pregnant ewes (-0.8%). Fibre diameter was increased during treatment by 0.76 ( $P<0.001$ ), 0.53 ( $P<0.01$ ) and by 0.41 micron ( $P<0.01$ ) in the single, twin and non-pregnant groups respectively but these increases in the pregnant ewes were not sufficient to completely compensate for the normal reduction of fibre diameter associated with the stress of late pregnancy and lactation (Figure 4). Fibre volume growth rates were increased during treatment by 13.7% ( $P<0.001$ ), 11.4% ( $P<0.01$ ) and by 2.1% (ns) in the single, twin and non-pregnant ewes respectively. Fleece weights at annual shearing in the year of treatment were 0.05kg higher in single bearing (+1.5%), 0.09kg in twin bearing (+2.7%) and 0.7kg in the non-pregnant ewes (+1.7%) but this effect was only significant after co-variate analysis (using pre-trial fleece weights,  $P<0.05$ ) for the single bearing ewes. On a whole flock basis the treatment increased fleece weights by 2% ( $P<0.025$ ). Tensile strength was high ( $>66\text{N/ktex}$ ) in the non-pregnant ewes and was not affected by treatment. In contrast, tensile strength was increased by 10.2% ( $P<0.025$ ) in the single bearing ewes and by 7.6% ( $P=0.2$ , ns) in the twin bearing ewes after analysis using pre-trial fleece weights as the co-variate. On a whole flock basis the increase in tensile strength was from 46 N/ktex in control to 50.1 N/ktex in treated ( $P<0.02$ ). Marking weights of lambs suckling the treated ewes were 0.4 and 0.81 kg higher in treated groups on the low and high quality pasture than for lambs from the respective control groups but, since single and twin lambs were not identified at birth a full statistical analysis of this data was not possible.

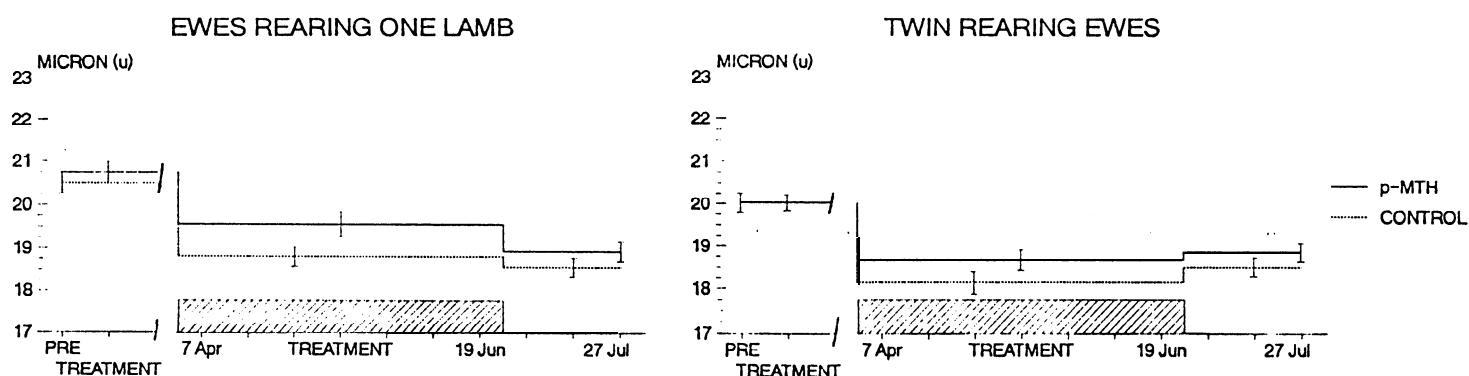


Figure 4 Effect of protected methionine treatment during late pregnancy and early lactation on the fibre diameter of wool. Data shows the mean  $\pm$  SEM for the pre-treatment period and the co-variate adjusted means for fibre diameter in the treatment and post-treatment periods.



Trial 3: Effects of Background Nutrition on Response in Wethers

Live weights of treated and control wethers were not significantly different at the start of treatment (24th Apr) but thereafter the live weights of treated wethers were higher (Table 3). The type of grain in the diet and proportion of roughage in the diet independently affected live weights even though all diets were calculated to be iso-energy but there were no significant interactions between response to treatment and the type of diet.

Table 3 Effect of protected methionine treatment (2 gm/head/day) on the live weight (kg) of mature merino wethers maintained on near maintenance rations consisting of wheat, oats or lupin grain and clover hay roughage. Data shown is mean ( $\pm$ SEM) for main effects after co-variate analysis using pre-treatment values as co-variate.

Effect	24 Apr Pre-Treat	19 May Treatment	14 June Treatment	13 July Post-Treat.
CONTROL	50.7 $\pm$ 0.5	50.0 $\pm$ 0.4 <sup>a</sup>	49.3 $\pm$ 0.5 <sup>a</sup>	51.8 $\pm$ 0.5 <sup>x</sup>
TREATED	50.4 $\pm$ 0.5	51.2 $\pm$ 0.6 <sup>b</sup>	51.5 $\pm$ 0.9 <sup>b</sup>	53.2 $\pm$ 0.6 <sup>y</sup>
Oats	50.3 $\pm$ 0.4 <sup>j</sup>	49.6 $\pm$ 0.5 <sup>j</sup>	49.0 $\pm$ 0.6 <sup>j</sup>	50.7 $\pm$ 0.5 <sup>j</sup>
Wheat	49.4 $\pm$ 0.5 <sup>j</sup>	49.3 $\pm$ 0.4 <sup>j</sup>	48.7 $\pm$ 0.7 <sup>j</sup>	51.1 $\pm$ 0.5 <sup>j</sup>
Lupins	52.2 $\pm$ 1.2 <sup>k</sup>	52.9 $\pm$ 1.1 <sup>k</sup>	53.6 $\pm$ 1.2 <sup>k</sup>	55.6 $\pm$ 1.0 <sup>k</sup>
20% Hay	50.8 $\pm$ 0.4	51.0 $\pm$ 0.3	51.0 $\pm$ 0.5	53.3 $\pm$ 0.4 <sup>a</sup>
40% Hay	50.5 $\pm$ 0.5	50.8 $\pm$ 0.6	50.3 $\pm$ 0.8	52.8 $\pm$ 0.7 <sup>a</sup>
60% Hay	50.4 $\pm$ 1.2	50.1 $\pm$ 1.1	49.9 $\pm$ 1.7	51.4 $\pm$ 1.0 <sup>b</sup>

a  $\neq$  b, P<0.05, x  $\neq$  y P<0.01, j  $\neq$  k P<0.001 by Co-Variate ANOVA

Fibre volume growth rate was increased due to methionine treatment to 8.4% (P<0.001) above control in the first and by 12.4% (P<0.001) in the second periods of treatment despite commencing at 9.4% lower (P<0.05) than control in the pre-treatment period (Table 4). This stimulation of wool growth resulted from significant effects of treatment on both length growth rate (P<0.001) and on fibre diameter (P<0.01-0.001) and all these effects of treatment were independent of the type of grain and level of roughage in the diet (Table 4). Wool volume growth was also significantly and independently influenced by grain type at all times (lupins > wheat > oats, P<0.001 in most comparisons) and, after the 19th May, was higher in the low roughage (high grain) diets than in the medium or high roughage diets (P<0.01-0.001).

Greasy fleece weights at shearing in Sept 1991 were 0.13kg (5.02%) higher (P<0.05) in treated than in control wethers even though treatment was applied for only eight weeks of a nine month interval from the previous shearing in Dec 1990. Tensile strength was high in all groups, as would be expected from the constant nutrition, and was not affected significantly by treatment. Fibre volume growth in the second month of treatment was 10% higher in the individually fed than in group fed wethers (P<0.005) and this may have been due to differences in the rate of consumption of the treated grain since the group fed animals ate their ration within an hour of offer whereas the individually housed animals were able to take several hours to consume their feed without competition.

Table 4 Effect of protected methionine treatment (2 gm/head/day) as a three times weekly supplement from 24 Apr to 14 June, on the length growth ( $\mu\text{M}/\text{d}$ ), fibre diameter ( $\mu$ ) and volume growth rate ( $\mu\text{m}^3/\text{d}$ ) in merino wethers fed near maintenance diets of oats or wheat or lupins plus clover hay roughage in a feedlot. Data shown are the least square means ( $\pm\text{SEM}$ ) adjusted for pre-treatment co-variate after the 24 April

Parameter	Treatment	Pre-Treatment	Treatment		Post-Treatment
		18 Mar. to 24 Apr.	24 Apr. to 19 May	19 May to 14 Jun.	14 Jun. to 13 Jul.
Length growth rate (micro m/d)	C	236 $\pm$ 3	251 $\pm$ 3 x	260 $\pm$ 3 j	257 $\pm$ 3 j
	T	234 $\pm$ 3	261 $\pm$ 2 y	277 $\pm$ 3 k	270 $\pm$ 3 k
Fibre Diameter (micron)	C	20.6 $\pm$ 0.3	20.3 $\pm$ 0.3 j	20.6 $\pm$ 0.3 j	20.6 $\pm$ 0.4 a
	T	19.9 $\pm$ 0.2	20.9 $\pm$ 0.2 k	21.5 $\pm$ 0.3 k	21.1 $\pm$ 0.3 b
Volume growth rate (cubic micro m/d)	C	82.1 $\pm$ 2.5 a	83.9 $\pm$ 3.1 j	90.8 $\pm$ 4.0 j	89.7 $\pm$ 4.2 a
	T	74.4 $\pm$ 2.1 b	91.0 $\pm$ 2.5 k	102.5 $\pm$ 3.0 k	95.8 $\pm$ 2.9 b
C/T %		-9.36%	+ 8.42%	+ 12.85%	+ 6.83%

a = b  $P < 0.05$ , x = y  $P < 0.01$ , j = k  $P < 0.001$  C = untreated T = 2 g/h/d pM

## DISCUSSION

The data from these three trials provides encouraging evidence that this novel form of methionine can provide a practical way to supplement unrestrained grazing sheep with a limiting amino acid. The data confirms that, under field conditions involving group feeding on a three times weekly basis, almost all animals receive sufficient supplement to give a modest elevation in plasma methionine without overdosing.

Treatment for 8-10 weeks has been shown to stimulate body weight gain and wool growth in weaners and wool growth in mature ewes and wethers. Although the maximum responses of around +30% increases in the wool volume growth rate were seen during the second period of treatment in the weaners on good pasture, the data does not permit strict comparisons between trials in view of the confounding effects of pregnancy for the breeding ewes and the restricted diets imposed in the feedlot wethers. The observation of modest wool growth responses in the single and twin bearing ewes treated during late pregnancy and early lactation suggests that methionine may have been limiting under the circumstances of this trial. The slightly increased tensile strength in wool of treated lambing ewes, suggests that this form of methionine supplementation may have application in prevention of at least some of the loss of wool quality commonly experienced in breeding flocks. This may assume greater economic significance if the fleece is of sufficiently low tensile strength to be penalised at sale but a benefit of methionine supplementation remains to be shown experimentally in such fleeces. Since responses were obtained in the breeding ewes while on poor quality summer pasture and in the feedlot wethers maintained on a wide variety of grain and roughage diets, the data suggest that the protected methionine treatment may be applied to a range of industry situations where supplementary grain feed is required. Although the present field trials show that the protected methionine can give responses in grazing animals fed three times per week, the observation of higher responses in individually fed animals which ate their

allotted ration over a period of hours, may indicate that more frequent feeding or dilution of product in greater quantities of feed to extend the period of intake of methionine could further improve responses.

Overall, this data extends the previously demonstrated experimental responses to effective rumen bypass methionine supplementation to the field situations which are experienced for extensively grazed stock on summer pasture, and suggest that this technology provides a practical means to overcome one of the critical nutritional limitations to sheep production.

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