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Wool growth and elemental composition

J. LEE, A.R. BRAY[1] AND N.D. GRACE

AgResearch, Fitzherbert Science Centre, Private Bag 11030, Palmerston North, New Zealand.

ABSTRACT

Genetic and nutritional factors that cause marked changes in wool growth influence the content ($\mu g\ g^{-1}$) and rate of uptake ($\mu g\ cm^{-2} d^{-1}$) of inorganic elements into wool. When sheep fed a basal diet (L level) of chaffed ryegrass hay and crushed barley were supplemented (H level) with additional methionine (+ 1.2 gd^{-1}), protein (+11 g N d^{-1}) and energy (+3.9 MJME d^{-1}), the elemental content of the wool responded [(H-L)/L x 100] differentially to increases in wool growth. Dietary treatments resulted in a reduced elemental content of Ca, -13%; Fe, -14%; K, -16% and Mg, -11% while changes in Cu, -8%; Na, -4%; P, -5%; S, +2% and Zn, +2% approached or matched the increase in wool growth.

Relative to the increases in wool growth as a result of supplementation with methionine (34%), protein (34%) and energy (16%), the uptake into wool of Cu, Na, P, S and Zn were generally greater for sheep fed additional methionine (40%, 39%, 57%, 49% and 61 respectively), while protein (27%, 32%, 22%, 39% and 29% respectively) and energy (8%, 14%, 10%, 11% and 15% respectively) supplements gave a lesser response. A group of sheep selected for increased staple strength also had increased wool growth relative to controls but no significant changes in elemental composition were observed. The possibility that the large changes in elemental concentrations may have effected fibre properties is yet to be addressed.

Keywords Wool growth, elemental composition, elemental uptake, nutrition.

INTRODUCTION

Wool accumulates inorganic elements during its growth. It is clear that elements such as Cu, Na, P, S and Zn form an integral part of the wool protein structure and that their transport into the wool follicles is influenced by changes in conditions of wool growth (nutrition, environment, season, genetic) (Grace and Sumner, 1986; Lee and Grace, 1988, Masters *et al.*, 1985; Purser, 1978), but direct effects of trace elements on the function of wool follicles and properties of wool fibres are generally poorly understood.

Seasonal changes in the content of S, Zn and other trace elements were not affected by Zn supplementation (Grace and Lee, 1992). Similar seasonal changes in wool S concentrations (a bimodal distribution with the lowest levels in September) were described by Antram *et al.*, (1991), who also showed that S concentration was lower in fleece-weight selected rams than control rams. This difference was significant only in January and September.

To further demonstrate changes that occur in wool elemental composition in response to nutritional and genetic factors, we report here the effects of methionine, protein and energy supplements and selection for staple strength on the elemental composition of wool over winter.

METHODS

Forty rams (1.5 years) from lines of Romney sheep (Rogers *et al.*, 1990) selected for high and low wool staple strength were compared at two levels (L and H) each of methionine, dietary protein and energy intakes, using a factorial design. The animals had been reared on pasture and were introduced to the basal diet and individual pens indoors over a 4 week period before 10 weeks treatment from June 28 to September 6, 1989, after which they returned to pasture.

The basal diet consisted of chaffed ryegrass hay (80%), crushed barley grain (17%) and minerals and vitamin mix (3%). Blood meal (9% of DM, 11 g N d^{-1}) was included in the high protein diets. Tallow was added to the basal diets at the rate of 6% of the dry matter (DM) fed (3.9 MJME d^{-1}), to provide the high energy diet. Individual animals were fed in proportion to their size with the rate per unit metabolic liveweight being adjusted weekly to maintain the mean liveweight of the group receiving the basal diet. They were fed once each day between 0800 and 0900 hours.

Methionine was injected into the peritoneal cavity at the rate equivalent to 1.2 g/d in sterile saline (Barry, 1976) immediately before feeding each Monday, Wednesday and Friday during the treatment period. Details on daily supply of methionine, protein and energy are described elsewhere (Bray *et al.*, 1990).

Wool clipped from midside patches at 4 week intervals from May to November was used to determine changes in clean wool growth and elemental concentrations. To allow time for fibre emergence above skin level, wool clipping was delayed 9 days after treatment initiation (June 28) and 14 days after its completion (September 6). Elements were determined by plasma emission spectrometry (Antram *et al.*, 1991; Grace and Lee, 1992). The data were analysed using analysis of variance and covariance (Genstat versions 4 and 5). Values obtained in the pretreatment period were used as covariates to adjust treatment means.

RESULTS

Wool production (measured as clean wool growth per unit skin area of midside patches) was lowest for all treatments in July (< 0.5 mg $cm^{-2} d^{-1}$). Growth then gradually increased over the next two months with a rapid increase after return to pasture in October (> 1.5 mg $cm^{-2} d^{-1}$).

[1] AgResearch, Canterbury Agriculture & Science Centre, P.O. Box 60, Lincoln, New Zealand.

Table 1 shows the response to each treatment for elemental concentration and uptake (for all elements pooled within a treatment), and wool growth over the treatment. Wool growth was increased at the high level of all four treatments. Mean elemental concentration was reduced at the high level (L) of staple strength, protein and energy treatments, as the response in elemental uptake did not match the increase in wool growth. For methionine supplementation, on the other hand, the mean elemental concentration was maintained as the increase in uptake was similar to wool growth response.

TABLE 1 Wool growth, elemental concentration and element uptake for sheep selected for staple strength and supplemented with methionine, protein and energy. Data are expressed as percentage response [(H-L)x100/L] and averaged for all elements (Ca, Cu, Fe, K, Mg, Na, P, S, Zn).

Treatment	Wool growth	concentration	uptake
Staple Strength	+23	-12	+10
Methionine	+34	+2	+39
Protein	+39	-11	+24
Energy	+16	-9	+7

Specific elements responded differentially to nutritional treatments. When elemental data was pooled across treatments (Table 2) the response in uptake of K, Mg, Ca and Fe was considerably less than the wool growth response, so that their concentrations were reduced. In contrast the response in uptake of Na, P, S and Zn was similar to the wool growth response and, therefore, concentrations approached or matched increase in wool growth.

Concentrations and uptake of elements, and wool growth, during the trial period for individual treatments are given in Table 3. Of note were, significant increases in concentration of

TABLE 2 Percentage changes in concentration and uptake for each element averaged or sheep selected for staple strength and supplemented with methionine, protein and energy. Data expressed as in Table 1.

Element	concentration	uptake
K	-16	+14
Mg	-11	+14
Ca	-13	+13
Fe	-14	+11
Cu	-8	+19
Na	-4	+24
P	-5	+23
S	+2	+31
Zn	+2	+32
Wool growth	+28	

Zn, P and S and decreased Ca concentrations recorded at the high level of methionine. The only other significant effect of treatments on elemental concentration was an increase in protein which decreased concentrations of Cu, Zn and P. Uptake for Cu, Na, P, S and Zn were generally greater for sheep given methionine (40%, 39%, 57%, 49% and 61% respectively) than protein (27%, 32%, 22%, 39% and 29% respectively) or energy (8%, 14%, 10%, 11% and 15% respectively) supplements. The responses for these elements were parallel to wool growth responses. Although sheep selected for increased staple strength also had increased wool growth, significant changes in elemental composition were not observed.

Significant first order interactions for methionine and protein on P and S concentrations in wool were also observed, with high methionine in the presence of low protein enhancing concentrations in wool (23.5% and +36% respectively) to greater

TABLE 3 Mean concentration (µg g^{-1}) and uptake (µg cm^{-2} d^{-1}) of elements by wool, and wool growth for sheep selected for staple strength and supplemented with methionine protein and energy during the treatment period. Values for nutrient treatments have been corrected for differences that existed prior to the start of treatments.

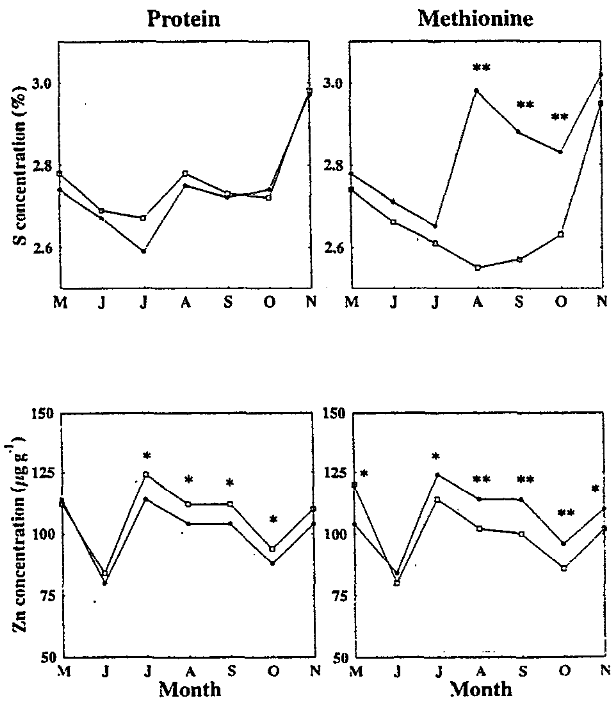
Treatment		Methionine		Protein		Energy	
Element	level	Concentration	Uptake[2]	Concentration	Uptake	Concentration	Uptake
K	L	243	0.45	301	0.58	270	0.57
	H	260	0.68	203	0.55	225	0.57
Na	L	37	0.08	39	0.08	39	0.09
	H	38	0.11 **[2]	37	0.11 *	37	0.10
Cu	L	9.1	0.018	9.8	0.019	9.6	0.020
	H	9.4	0.025 ***	8.8 *	0.024 **	8.9	0.022
Fe	L	11.3	0.024	11.7	0.023	11.8	0.02
	H	10.2	0.027	9.9	0.029 *	9.3	0.02
Mg	L	27	0.05	28	0.06	28	0.06
	H	25	0.07 **	25	0.07 **	25	0.06
Ca	L	578	1.15	558	1.09	549	1.23
	H	483 **	1.33	504	1.39 **	503	1.26
Zn	L	94	0.18	103	0.21	100	0.22
	H	107 ***	0.29 ***	98 *	0.27 ***	101	0.25 *
P	L	113	0.22	127	0.26	125	0.27
	H	128 ***	0.35 ***	114 **	0.32 ***	115	0.30
S	L	26071	52	27204	55	27630	63
	H	28739 ***	78 **	27606	76 **	27068	70 *
Wool growth	L	0.69		0.67		0.75	
(mg cm^{-2} d^{-1})	H	0.92 ***		0.93 ***		0.87 **	

[1]'Accumulated' variation over the 3 monthly treatment period.
[2]Significant differences are between L and H within a treatment: * P<0.05 ** P<0.01 *** P<0.001

excesses than the effect of high methionine supplementation alone (13% and 10% respectively). The only other significant interaction found was for low protein together with high staple strength which resulted in significantly ($P<0.05$) decreased Fe concentrations (13.9 to 9.4 $\mu g\ g^{-1}$) in the wool.

Changes in elemental composition of the wool are the result of a combination of seasonal and dietary effects. Examples of seasonal changes for Zn and S are illustrated in Fig. 1. Zinc concentrations in wool, as for all elements except S, were lowest in June regardless of treatment and this coincides with lowest wool growth. As a consequence rate of uptake was also reduced.

FIG. 1 The effect of treatments on S and Zn concentrations in monthly clean wool samples of sheep supplemented with methionine and protein (□, low level; ●, high level). Treatment main effects at each sampling date are compared by analysis of variance and are not adjusted for pretreatment differences.*, $P<0.05$; **, $P<0.01$.



Sulphur concentrations in wool continued to fall until July in all treatments (Fig. 1). Dietary treatment effects were most marked during August to October, with the high methionine treatment especially enhancing both Zn and S concentrations in wool for this period. The treatment differences observed in October represent nutritional carry over effects as treatments ceased prior to sampling in September. Although high protein significantly reduced Zn concentration in wool in late winter (Fig. 1), the significant effect of this supplement on wool growth also resulted in increased Zn uptake for August to October ($P<0.01$, data not shown).

Response for P were similar to those for S although not as marked.

DISCUSSION

The elemental analysis of wool suggests that the concentration and uptake of certain constituent elements, especially P, S and Zn of wool fibre are more sensitive to factors that cause changes in wool growth such as genetic, nutrition and seasonal factors than other elements (Fe, Mn, Mg, Ca, and K). Furthermore dietary effects are confounded with seasonal influences especially during the onset of the winter decline response (photoperiodicity/hormonal interactions) in June when there is decreased wool output and elemental content. This occurred despite the animals being held indoors and fed an adequate diet over the treatment period.

Enhanced elemental uptake, especially for S and Zn observed in the October and November samples (Fig. 1), after the sheep had been returned to pasture, cannot be attributed directly to enhanced supply of methionine or protein at the time of follicle initiation, as these samples represent wool grown well after treatments had ceased. Although the exact nature of these 'carry-over' effects are unknown, they must result from whole body status initiated during the treatment period, rather than transient supply to the developing wool follicle itself.

The large changes in elemental concentrations because of nutrition and season might reasonably be expected to be associated with substantial alterations in fibre structural components, which in turn could influence wool characteristics important to processors and consumers.

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