

**DIFFERENCES BETWEEN MERINO SELECTION LINES IN MICROBIAL YIELD
FROM THE RUMEN AND UTILISATION OF PROTEIN FOR WOOL
GROWTH.**

by

I. LEWIS PHILLIP KAHN

Bachelor of Rural Science, Honours Class I
(University of New England, Armidale)

January 1996

A thesis submitted for the degree of Doctor of Philosophy of the University of New England.

Certificate

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

A large black rectangular redaction box covers the signature area. To the right of the box, there is a faint dotted line indicating the end of the signature.

L.P.Kahn

Acknowledgements

This work was conducted whilst the author was in receipt of a scholarship from the International Wool Secretariat. Funding of the research was made available by Australian woolgrowers through the International Wool Secretariat.

I wish to thank my supervisors, Professors R.A.Leng and L.R.Piper for their help and supervision during the period of my candidature. I also thank Associate Professor J.V.Nolan and Dr. S.Bird for valuable discussions during the course of my research and for help during the preparation of this thesis. The comments of Professor. J.Rowe on Chapter 10 are also gratefully acknowledged.

I extend my thanks to all those who provided technical assistance, and in particular, Mr. F.Ball, Mr. S.Stachiw, Mr. R.Woodgate, Mr. M.Porter, Mr. D.Olde, Mr. P.Littlefield and Mr. M.Crestani. The assistance provided by members of the Meat Quality group, including Mr. A.Ball and Mr. M.Weber, for the computer aided tomography reported in Chapter 10 is also acknowledged. I also thank my wife, Carol, for interpreting and measuring the cat-scans that were reported in the studies described in Chapter 10

I thank the members of the Sheep Breeding Program, C.S.I.R.O, Chiswick and in particular, Dr. A.Swan, for allowing use of the Sirolan-Laserscan and the Merino bloodlines and experimental design used in Chapters 12 and 13. The experiments conducted with these animals were performed at the C.S.I.R.O. property, Longford, and I thank the field staff at Longford, Mr. N.Gibson, Mr. K.Aicher and Mr. B.Towells, for their assistance during these experiments.

I thank my friends, Janet and Douglas Beckers, for proofreading the final version of this thesis. I am also very thankful to Carol for keeping me aware that work is only a part of one's life. Thankyou.

Table of Contents

Certificate	ii
Acknowledgements	iii
Table of Contents	iv
List of Figures	xi
List of Tables	xiv
Summary	xvii

Literature Review

1. INTRODUCTION	1
2. WOOL GROWTH	3
2.1 Biology of wool growth	3
2.1.1 Introduction	3
2.1.2 Effects of nutrition on the biology of wool growth	3
2.1.2.1 Initiation of wool follicles	3
2.1.2.2 Follicle bulb, derma papilla and cortical cells	5
2.1.2.3 Proportion of follicle bulb cells that differentiate to form fibre	6
2.2 Rate of wool growth	7
2.2.1 Introduction	7
2.2.1.1 Stimulation of wool growth by amino acids	8
2.2.1.2 A specific role for methionine: polyamines	9
2.2.2 Effects of protein and energy supply on wool growth	10
2.2.3 Divergent selection for clean fleece weight	14
2.2.3.1 Feed intake and the efficiency of wool growth	14
2.2.3.2 Metabolism of cysteine	18
2.2.3.3 Digestibility and rumen function	18
2.2.3.4 Variation in the sulphur content of wool	19

2.3 Conclusion	21
3. PROTEIN SUPPLY TO THE RUMINANT	23
3.1 Microbial protein	23
3.1.1 Quantitative importance of microbial protein to the ruminant	23
3.1.1.1 Amino acid composition of microbial protein	23
3.1.1.2 Composition of bacterial cells	24
3.2 Dietary protein	25
3.2.1 Proteolysis	27
3.2.2 Conclusion	28
4. COUPLING OF ATP AVAILABILITY AND MICROBIAL GROWTH	29
4.1 Maintenance energy requirements	29
4.2 Uncertainties of Y^{ATP} estimates	30
4.3 Uncoupling of fermentation and microbial growth	32
4.4 Conclusion	33
5. NITROGEN REQUIREMENTS FOR MICROBIAL GROWTH	35
5.1 Introduction	35
5.2 Nitrogen source	35
5.2.1 Ammonia	35
5.2.1.1 Ammonia concentration	37
5.2.2 Amino acids and peptides	41
5.3 Other factors that influence microbial yield from the rumen	42
5.3.1 Protozoa	42
5.3.2 Dilution rate	44

6. METHODS TO ESTIMATE THE YIELD OF MICROBIAL CELLS FROM THE RUMEN	45
6.1 Introduction	45
6.2 Diaminopimelic acid	45
6.3 Ribonucleic acid	46
6.4 Isotopic markers	47
6.5 Amino acid profile	47
6.6 Urinary purine derivatives	48
7. PREDICTION OF MICROBIAL YIELD FROM THE RUMEN USING URINARY EXCRETION OF PURINE DERIVATIVES	49
7.1 Introduction	49
7.2 Nucleic acids as precursors of purine derivatives excreted in urine	50
7.3 The origin and fate of nucleic acids in the rumen	51
7.3.1 Variations in the nucleic acid content of rumen micro-organisms	52
7.4 Intestinal digestion of nucleic acids	53
7.5 Synthesis of purines in the ruminant host	54
7.6 Degradation of purines in the ruminant host	55
7.7 Relationship between purine absorption and excretion in urine	55
7.7.1 The contribution of endogenous purines to urinary purine excretion	58
7.7.2 Dietary effects on urinary excretion of purine derivatives of endogenous origin	59
7.7.3 Changes in the proportions of purine derivatives in urine	61
7.7.4 Non-renal excretion of purine metabolites	61
7.7.4.1 Salivary loss of purine derivatives	63
7.7.4.2 Loss of purine carbon via expired gases	63
7.8 Conclusions	64

Experimental Section

8. ALLANTOIN METABOLISM IN SHEEP	66
8.1 Introduction	66
8.2 Materials and Methods	66
8.2.1 Animals and conditions	66
8.2.2 Experimental procedure	67
8.2.3 Sample collection and storage	67
8.2.4 Tracer purity	68
8.2.5 Analytical procedures	68
8.2.6 Separation and quantification of allantoin in plasma	69
8.2.7 Specific radioactivity of allantoin	69
8.2.8 Calculation of allantoin kinetics	70
8.3 Results	70
8.4 Discussion	73
9. SENSITIVITY OF ALLANTOIN FLUX TO CHANGES IN ALLANTOIN SUPPLY	76
9.1 Introduction	76
9.2 Materials and Methods	77
9.2.1 Animals and conditions	77
9.2.2 Experimental procedure	77
9.2.3 Sample collection and storage	78
9.2.4 Tracer purity	78
9.2.5 Analytical procedures	79
9.2.6 Calculation of allantoin kinetics	79
9.3 Results	79
9.4 Discussion	82

10. THE IMPORTANCE OF MICROBIAL YIELD FROM THE RUMEN IN ACCOUNTING FOR DIFFERENCES IN THE RATE OF WOOL GROWTH BETWEEN SHEEP SELECTED EITHER FOR OR AGAINST CLEAN FLEECE WEIGHT	85
10.1 Introduction	85
10.2 Materials and Methods	87
10.2.1 Animals and conditions	87
10.2.2 Experimental design, feeding and sequence of events	87
10.2.3 Wool parameters	89
10.2.4 Collection of rumen fluid	89
10.2.5 Ammonia-N	89
10.2.6 Volatile fatty acids	90
10.2.7 Plasma ammonia concentration	90
10.2.8 Live weight	90
10.2.9 Computer-aided tomography	90
10.2.10 Total collection for in vivo digestibility and N retention	91
10.2.11 Determination of dry matter and total-N	91
10.2.12 Urinary purine concentrations	91
10.2.13 Calculation of the yield of microbial nitrogen	91
10.2.14 Statistical analysis	91
10.3 Results	93
10.3.1 Differences between selection lines averaged across experimental diets	93
10.3.2 Treatment effects averaged across selection lines	97
10.3.3 Physiological components of wool production	100
10.3.4 Body composition	101
10.4 Discussion	103
10.4.1 Body composition	110

11. EFFECT OF FEEDING FREQUENCY ON FEED INTAKE, FEEDING BEHAVIOUR, DIGESTION AND YIELD OF MICROBIAL NITROGEN FROM THE RUMEN OF MERINO SHEEP GENETICALLY DIFFERENT IN WOOL PRODUCTION.	112
11.1 Introduction	112
11.2 Materials and Methods	113
11.2.1 General description of studies	113
11.2.2 Animals and conditions	113
11.2.3 Experimental design and feeding	113
11.2.4 Analytical procedures	114
11.2.5 Measured variables	114
11.2.6 Statistical analysis	114
11.3 Results	115
11.3.1 Once per day feeding (Period 1)	115
11.3.2 Hourly feeding (Period 2)	115
11.3.3 Combined feeding regimes	116
11.4 Discussion	117
12. THE USE OF LITHIUM CHLORIDE FOR ESTIMATING SUPPLEMENT INTAKE IN GRAZING SHEEP: ESTIMATES OF HERITABILITY AND REPEATABILITY	120
12.1 Introduction	120
12.2 Materials and Methods	121
12.2.1 General description of studies	121
12.2.2 Preparation of the lithium-containing supplement	121
12.2.3 Kinetic study	122
12.2.4 Grazing study	122
12.3 Results	123
12.4 Discussion	126

13. DIFFERENCES BETWEEN MERINO BLOODLINES, GRAZING AT PASTURE, IN PRODUCTION RESPONSES TO PROTEIN SUPPLEMENTATION: ESTIMATES OF GENETIC AND PHENOTYPIC PARAMETERS.	130
13.1 Introduction	130
13.2 Materials and Methods	131
13.2.1 Animals and conditions	131
13.2.2 Experimental procedure	132
13.2.3 Analytical techniques	133
13.2.4 Statistical methods	134
13.3 Results	135
13.3.1 Raw means and standard deviation	135
13.3.2 Feed analysis	135
13.3.3 Supplement intake	135
13.3.4 Response to supplement intake	136
13.3.5 Results from analysis of variance	138
13.3.6 Differences between bloodlines	138
13.3.7 Parameter estimates	139
13.4 Discussion	139
13.4.1 The value of protein supplementation to the grazing animal	139
13.4.2 Response to supplement intake	143
13.4.3 Results from analysis of variance	144
13.4.4 Parameter estimates	145
14. GENERAL DISCUSSION	146
REFERENCES	151

List of Figures

- Figure 2.1. Effects of abomasal infusions of protein and energy on nitrogen balance and wool growth rate of adult Merino wethers. Prepared from the data of Black *et al.* (1973) with unfilled (20 g/d protein), hatched (60 g/d protein) and solid (100 g/d protein) histograms. 15
- Figure 5.1. Relative activities of glutamine synthetase (unfilled) and glutamate dehydrogenase (filled). Graph A based on the range of saturation constants (SC) of rumen bacteria (Schaefer *et al.* 1980) and graph B on Michaelis-Menton constants of 2.8 and 70 mg NH₃-N/l for glutamine synthetase (unfilled square) and glutamate dehydrogenase (filled square) respectively (Baldwin and Denham 1979). 38
- Figure 7.1. Relationships between urinary allantoin excretion (Y, g/d) and digestible dry matter intake (X, kg/d) of sheep, cattle and buffalo given forage based diets. The regression equations for each species are: 50
- Figure 7.2. Pathways of purine metabolism in ruminant tissues. (derived from Lehninger 1977; Stryer 1988). 51
- Figure 7.3. Excretion of purine derivatives in the urine of sheep intragastrically nourished with varying levels of protein (600, 900 or 1500mg N/kgW^{0.75}) when gross energy intake was 340 (circle), 450 (triangle) and 630 (square) kJ/kgW^{0.75}). Prepared from the data of Lindberg and Jacobsson (1990). Standard errors not given in the original paper. 60
- Figure 7.4. Urinary allantoin increases linearly with total purine derivative excretion in urine collected from sheep from a range of experiments (see text). The relationship between allantoin excretion (Y, mmol/d) and total purine excretion (X, mmol/d) was derived from 167 observations and is described by the equation $Y = -0.54$ (s.d. = 0.121) + 0.89 (s.d. = 0.014) X, $r^2 = 0.96$. The data of Chen *et al.* 1990b (filled triangle) and Balcells *et al.* 1991 (unfilled square) are superimposed for comparative purposes. 62

- Figure 8.1. Cumulative recovery of ^{14}C -allantoin in urine of sheep 1 (unfilled square) and sheep 2 (filled square) following an intravenous injection of ^{14}C -allantoin. Values adjusted for dose purity of 0.966. 70
- Figure 8.2. Decline in the specific radioactivity of plasma allantoin following intravenous injection of $28\ \mu\text{Ci}\ ^{14}\text{C}$ -allantoin. Equations 2 (dashed line) and 3 (solid line) have been fitted to the data for sheep 1 (unfilled square) and sheep 2 (filled square) respectively. 72
- Figure 9.1. Specific radioactivity of allantoin in blood plasma over the experimental period. Data for sheep 1 (unfilled circle) fitted by dashed line for sheep 2 (filled circle) by a solid line. 81
- Figure 9.2. Specific radioactivity of allantoin in urine over the experimental period. Data for sheep 1 (unfilled circle) fitted by dashed line for sheep 2 (filled circle) by a solid line. 81
- Figure 10.1. Clean wool growth and average fibre diameter (means \pm s.e) of ewes from the F_m (unfilled histogram) and F_p (hatched histogram) flocks fed either, oaten chaff (T1), +1% urea (T2), +3% urea (T3) or +3% urea + 100g CSM pellets (T4). Means with a common letter do not differ significantly ($P > 0.05$). 100
- Figure 10.2. Estimate of body composition (mean \pm s.e.) of F_p (hatched histogram) and F_m (unfilled histogram) ewes before introduction to (estimate 1) and after 110 days (estimate 2) on the experimental diets. (t.prot represents total protein). 102
- Figure 10.3. Change in the mass of body components (mean \pm s.e.) of F_p (hatched histogram) and F_m (unfilled histogram) ewes over 110 days (t.prot represents total protein). 102
- Figure 10.4. Change in the mass of body components (means \pm s.e.) in sheep consuming a basal diet of oaten chaff (T1) (unfilled histogram) and supplemented with 3% urea and 100 g/d CSM pellets (T4) (hatched histogram). (t.prot represents total protein). 103
- Figure 10.5. Response in wool growth to the estimated yield of microbial-N by F_m (Figure A, circle) and F_p (Figure B, square) ewes consuming diets T1-T3 (open

- symbols) and T4 (shaded symbols). The line of best fit (Figure B, $Y = 3.3$ (s.d. = 1.81) + 0.63 (s.d. = 0.207) X; $r^2 = 0.43$) describes the relationship for F_p ewes consuming diets without CSM (T1-T3) 109
- Figure 12.1. Plasma lithium concentration in jugular blood taken from 8 Merino sheep, prior to, and a further 9 times after lithium ingestion. 124
- Figure 12.2. Frequency distribution of animals ($n = 366$) to pellet intake ranges when offered on average 55 g/hd/d. 127
- Figure 12.3. Frequency distribution of animals ($n = 366$) to pellet intake ranges when offered on average 110 g/hd/d 127
- Figure 13.1. Live weight gain (mean \pm s.e.) in response to increasing intake of CSM pellets. 137
- Figure 13.2. Change in average fibre diameter (mean \pm s.e.) in response to increasing intake of CSM pellets. 137
- Figure 13.3. Rate of greasy wool growth (mean \pm s.e.) in response to increasing intake of CSM pellets. 138

List of Tables

Table 4.1. Energy costs for the synthesis and polymerisation of the major cellular materials	33
Table 8.1. Kinetic data from a single injection of ^{14}C -allantoin into the jugular vein of two sheep.	72
Table 9.1. Parameter estimates for allantoin SR versus time curves.	80
Table 9.2. The concentration of allantoin in blood plasma for period 1 and for the final 2 h of period 2.	82
Table 9.3. Kinetic data derived from blood plasma and urine of 2 sheep following intra-jugular continuous infusion of ^{14}C -allantoin (0–17 h) and unlabelled allantoin (10–17 h).	83
Table 10.1. Live weight and greasy fleece weight of 6 year old ewes from the F_m and F_p flocks. (live weight measured upon entry to animal house and greasy fleece weight was from shearing at 5 years of age).	88
Table 10.2. The sequence and duration of experimental events	89
Table 10.3. Analysis of the experimental diets.	94
Table 10.4. Intake and apparent digestibility of DM in the whole-tract of ewes selected for or against clean fleece weight (main effect of selection line is averaged across diets).	95
Table 10.5. Yield of microbial nitrogen from the rumen (calculated from urinary excretion of purine derivatives) of ewes selected for or against clean fleece weight.	95
Table 10.6. Response of wool growth rate and fibre characteristics to divergent selection for clean fleece weight	96

Table 10.7. Nitrogen utilisation of Merino ewes selected for or against clean fleece weight.	96
Table 10.8. DMI of Merino ewes as affected by addition of urea and CSM pellets to a basal diet of oaten chaff. (oaten chaff (T1), +1% urea (T2), +3% urea (T3), +3% urea and 100 g CSM pellets (T4)).	97
Table 10.9. The effect of adding urea and CSM pellets to a basal diet of oaten chaff on rumen and jugular ammonia concentrations, rumen pH and volatile fatty acid concentration and proportions. (oaten chaff (T1), +1% urea (T2), +3% urea (T3), +3% urea and 100 g CSM pellets (T4)).	98
Table 10.10. Yield of microbial-N from the rumen of ewes from the F _p and F _m flocks when fed a basal diet of oaten chaff (T1) and either 1% (T2) or 3% (T3) urea or 3% urea+100 g CSM pellets (T4).	99
Table 10.11. Weight gain and nitrogen retention of ewes from the F _p and F _m flocks	99
Table 10.12. Percentage of the variation (100 <i>b_i</i>) in MN attributable to the physiological components	100
Table 10.13. The proportion of wool-free and digesta-free body mass occupied by the body components at the start (estimate 1) and end (estimate 2) of the experimental period.	103
Table 11.1. Apparent digestibility of DM in the whole-tract and yield of microbial-N (calculated from the urinary excretion of purine derivatives) of F _m and F _p ewes when fed hourly a diet of oaten chaff and 1% urea.	115
Table 11.2. Effect of feeding frequency and selection line x feeding regime interactions for apparent digestibility of dry matter in the whole-tract, digestible dry matter intake and the yield of microbial-N per unit dry matter intake.	116
Table 11.3. Percentage of the variation (100 <i>b_i</i>) between the selection lines in the yield of microbial-N from the rumen that was attributable to the physiological components when ewes were fed once per day and hourly.	117

Table 12.1. Calculation of pellet intake based on lithium concentration in blood 4 h after sheep ingested lithium-containing CSM pellets.	125
Table 12.2. Transformation of pellet intake (g/d) to pellet intake category.	125
Table 13.1. Sources of the Merino bloodlines.	132
Table 13.2. Simple means and standard deviations (s.d.) of measured traits.	135
Table 13.3. <i>In vitro</i> ammonia production rates.	136
Table 13.4. Sources of variation, degrees of freedom (df) and significance of effects.	139
Table 13.5. Least squares means (\pm s.e.) for the eleven Merino bloodlines for Pintake, GWP, AVFD, CV and LGAIN. Least squares means are adjusted for differences in initial live weight and pellet consumption.	140
Table 13.6. Regression coefficients (\pm s.e.) between GWP, LGAIN and Pintake for a selection of bloodlines.	141
Table 13.7. Heritabilities (on diagonal) and genetic (above diagonal) and phenotypic (below diagonal) correlations and standard errors (below estimates) for growth and wool traits and pellet intake.	142

Summary

Introduction

With most diets, microbial cells are the major contributor to total non-ammonia nitrogen flowing to the intestines, and the latter is the primary determinant of wool growth rate. Consequently, at constant intake, variation in the yield of microbial cells, more specifically microbial protein, from the rumen may account for a proportion of the between-sheep variation in wool growth rate. Recently, urinary excretion of purine derivatives has been suggested as a non-invasive method for estimating the yield of microbial protein from the rumen. However, some doubts exist as to the validity of this technique. Thus the studies reported in Chapters 8 and 9 examined the metabolism of allantoin, the major purine derivative in the urine of sheep, in an attempt to determine if the urinary excretion of purine derivatives is a valid method for estimating the yield of microbial protein from the rumen.

In the studies reported in Chapters 10 and 11, the urinary excretion of purine derivatives was used to examine whether divergent selection for clean fleece weight had produced animals that differed in the yield of microbial protein from the rumen. In addition, the importance of yield of microbial nitrogen from the rumen and the efficiency of utilisation of absorbed amino acids, in accounting for differences between the selection lines in wool growth rate was calculated.

Finally, the suitability of lithium chloride as a marker of supplement intake in grazing sheep was assessed in the studies reported in Chapter 12. The studies reported in Chapter 13 used lithium chloride as a marker of supplement intake to determine whether genetic variation existed between fine-wool Merino bloodlines, grazing at pasture, in the response of wool growth rate, average fibre diameter and live weight gain to increasing amino acid intake.

Abstracts

Chapter 8

Allantoin metabolism was studied in two rumen-cannulated sheep by means of a single intravenous injection of [4,5-¹⁴C] allantoin. The decline in the specific radioactivity of allantoin in plasma was best described by a double exponential function, indicating that in sheep, allantoin moves between at least 2 kinetically distinct compartments. Recovery of ¹⁴C-allantoin in urine for the 12 h following tracer injection was about 80% of the ¹⁴C-allantoin

injected. Only negligible amounts of radioactivity entered saliva indicating that the transfer of allantoin to the rumen via saliva was quantitatively unimportant. In support of this, the mass of allantoin-C that was degraded and appeared in either blood or rumen HCO_3^- was on average less than 5% of the net flux of allantoin through the blood pool. This indicates that ruminal, post ruminal and tissue associated degradation of allantoin to carbon dioxide in the sheep is quantitatively unimportant. In light of this, use of allantoin excretion in urine to estimate the flow of microbial protein in rumen digesta will not have to be corrected for transfer to the gut and subsequent degradation.

Chapter 9

The sensitivity of estimates of allantoin net flux to changes in allantoin supply was determined on two rumen-cannulated sheep which were equipped with bladder catheters and received a continuous intra-jugular infusion of [4,5- ^{14}C] allantoin for 17 h. Unlabelled allantoin (tracee) was included in the infusate for the final 7 h of the infusion. Estimates of allantoin net flux derived from plasma and urine differed but these differences were largely removed during infusion of the tracee. Transfer of allantoin-C to bicarbonate in blood or rumen fluid was negligible and this was in agreement with the previous study reported in Chapter 8. The recovery of tracee which was taken to be the difference between the estimates of net flux prior to and after infusion of tracee was on average 55% and 83% for estimates made in blood plasma and urine respectively. This disparity is of concern, and suggests that the use of allantoin flux rates in blood to predict microbial yield from the rumen should be used with caution.

Chapter 10

The physiological consequences of divergent selection for (fleece plus; F_p) or against (fleece minus; F_m) clean fleece weight were measured in 6 year old Merino ewes from the Trangie fleece selection lines when fed a roughage diet supplemented with differing levels of urea. Ewes from the F_p flock had a 15% greater voluntary intake (adjusted for metabolic weight) but there were no differences between the selection lines in the apparent digestibility of DM in the whole-tract. There were no differences between the selection lines in the concentrations of rumen ammonia or total volatile fatty acids, the ratio of propionate:(acetate + butyrate) or pH in rumen fluid taken 4 h after feeding. Urinary excretion of purine derivatives and the amount of purines excreted per unit dry matter intake (DMI) was greater in ewes from the F_p flock.

This suggests that the yield of microbial nitrogen from the rumen and the yield of microbial nitrogen per unit DMI was greater in these ewes.

The body composition of a representative sample of ewes from both flocks was estimated at the start and conclusion of the trial (117 d) by computer aided tomography. Ewes in the F_p group had a proportionally leaner body and also a greater mass of viscera (F_p 6.5, F_m 5.1 kg). In F_m ewes fat represented over 30% of the wool and digesta-free body mass compared to less than 20% for ewes from the F_p flock.

Chapter 11

Voluntary feed intake, apparent digestibility of DM in the whole-tract (ADMD), urinary excretion of purine derivatives and nitrogen retention were measured in 6 year old Merino ewes from the Trangie fleece plus (F_p) and minus (F_m) selection lines when fed, either once per day or hourly, an oaten chaff diet with 1% urea. When fed once per day, ewes from the F_p flock consumed 20% more feed by 4 h after feeding but differences between the selection lines for all other variables were not statistically significant. When the feeding regime was changed to hourly, ewes from the F_m flock had a greater ADMD but the yield of microbial nitrogen (as estimated from urinary purine excretion) per unit dry matter and nitrogen intake was greater in ewes from the F_p flock.

When the data from the two feeding regimes were combined, a significant selection line x feeding regime interaction was recorded for ADMD and digestible dry matter intake. Ewes from the F_p flock tended to have a greater yield of microbial nitrogen from the rumen but the selection line differences were not statistically significant.

Chapter 12

The suitability of lithium chloride as a marker for supplement intake was examined in grazing sheep. Eight merino weaners (8 months of age), grazing improved pasture, were individually fed cottonseed meal pellets sprayed with lithium chloride and plasma lithium concentrations were then measured over the next 29 h. The results of this study showed that after ingestion of lithium, plasma lithium concentrations rose to reach a maximum 4 h later. The concentration of lithium in plasma remained substantially constant between 4 and 14 h after lithium ingestion and thereafter declined slowly. The use of plasma lithium concentration (scaled for live weight) 4–9 h after lithium ingestion facilitated accurate prediction of supplement intake.

In a following experiment, 732 merino weaners (8 months of age) were split into two groups by randomised stratification. These groups were fed a cottonseed meal supplement at either 55 or 110 g/hd/d. In order to estimate individual supplement intake over a 62 day period, the supplement was sprayed with lithium chloride on three occasions at monthly intervals. The results of the three estimates of intake showed that within mobs (n = 366/mob) large variation in supplement intake existed.

Both the heritability (0.17) and repeatability (0.48) of supplement intake as estimated from paternal half-sib analysis were significantly different from zero.

Chapter 13

Greasy wool growth, average fibre diameter and live weight and the response of these traits to increasing amino acid intake were measured in a group of 1100 Merino weaners (8 months of age) comprising 9 fine-wool and 2 medium-wool bloodlines. Amino acid intake was increased by supplementation with a cottonseed meal pellet. Wool growth, average fibre diameter and live weight gain (fleece-free) increased linearly with estimated pellet intake. A significant bloodline x pellet intake interaction occurred for both wool growth and live weight gain (fleece-free). These interactions suggest that the bloodlines differed in the efficiency with which cottonseed meal was metabolised to either wool or tissue.