

Chapter 5

Supplementation of grazing sheep with lupin and barley during low pasture growth period in Winter/Spring

5.1. Introduction

Nutrition is a key factor that determines the level of production of sheep. For grazing sheep, inadequate supply of feed due to seasonal fluctuations in pasture growth and quality usually results in reduced production. This situation occurs in grazing sheep particularly during the dry season in Australia when forage is dry and mature and low in both protein and digestibility (Leng, 1989). However, low temperatures also limit the growth of pasture. This situation occurs in the New England region during late-autumn and winter when temperatures are low and do not support pasture growth. In this region, temperatures are the main limiting factor of pasture growth from mid-May to mid-October (Department of Agriculture NSW, 1979). Thus there is a “feed trough” or “feed gap“ at this time of year. Therefore, a decision must be taken whether to feed only for maintenance, or to increase feed supply to support higher levels of production.

Low temperatures during winter and a lack of soil moisture during spring brings about low pasture growth on the Northern Tablelands of New South Wales, Australia (Department of Agriculture NSW, 1979). Low pasture growth usually affects animal liveweight gain and also wool growth. The low in nutrition during this period may affect the rate of change of mean fibre diameter within a staple. This may then affect staple strength. Therefore, supplementation of grazing sheep during this period may be necessary to enable the sheep to survive or to produce meat and wool. Supplementation of grazing sheep can be in the form of non-protein nitrogen or as dietary protein or a combination of both true protein and NPN.

Lupins are supplement fed extensively for ruminants during low pasture growth. Supplementation with lupins has been shown to increase liveweight, lamb growth rate, wool growth, milk production and ovulation rate of grazing sheep (Arnold *et al.*, 1977; Kenney *et al.*, 1980; Butler, 1981; Kenney, 1985; Rowe *et al.*,

1989). Lupins are considered as a source of energy and rumen degradable nitrogen but not as a source of by-pass protein (Leng, 1989). Barley grain is widely fed to sheep during drought in Western Australia (Nagaraja *et al.*, 1995). Feeding this grain in a large amount without an introductory period usually causes acidosis in sheep. This is because of low pH, the accumulation of lactic acid, and a reduced rate of fibre digestion that results in reduced feed intake and lower feed efficiency (Rowe *et al.*, 1989; Godfrey *et al.*, 1992). This negative effect can be overcome using antimicrobial compounds, such as virginiamycin (Nagaraja *et al.*, 1981). Virginiamycin is a fermentation product of *Streptomyces virginiae* (Boon and Dewart, 1974 in Nagaraja *et al.*, 1995) and is a member of the streptogramin family of antibiotics (Nagaraja *et al.*, 1987). Rowe *et al.* (1989) stated that virginiamycin can control the fermentation of starch in the rumen during the period when ruminants are adapting to grain supplements. In vitro experiments have shown that virginiamycin reduced lactic acid production during the fermentation of sugar and starch (Nagaraja *et al.*, 1987).

In this study, lupin and barley (plus 1 % urea and virginiamycin) were compared as supplementary feeds for grazing sheep during the “feed trough” in the New England region. Liveweight and mean fibre diameter were measured, as well as the supplementary feed intake of individual sheep, using the lithium chloride technique (Suharyono, 1992; Kahn, 1994).

5.2. Materials and Methods

5.2.1. Experimental animals and feeding

This experiment was conducted at “Kirby” Experimental Farm (10 km North of Armidale, New South Wales). Fifty four mature grazing Merino ewes (mixed age of 3 - 6 years and weight range 31 to 49 kg) were randomly allocated to one of three dietary treatments. The treatments were: 1. control (unsupplemented), 2. supplemented with barley (200 g/h/d) + urea (1%) + virginiamycin (40 mg/kg grain) and 3. supplemented with lupin (190 g/h/d). Virginiamycin was dissolved in about 50 ml of water and then mixed with the barley in a cement mixer for 4 - 5 minutes. There were three replications of each treatment (6 sheep per replication group). Supplements were given to the sheep twice a week on Monday and Friday in troughs placed on the

ground. Each group of animals was maintained in a 0.4 ha plot where the pasture availability was estimated at approximately 0.5 tonnes DM per ha. The dead : green ratio ranged from 50 : 50 to 25 : 75 within plots during experiment. The sheep remained in the same plot throughout the experimental period of 57 days.

5.2.2. Wool dye banding

Dye-banding solution was prepared by dissolving 0.8 g Durafer Black in 100 ml distilled water, and mixed with 2.5 ml H_2O_2 prior to use (Chapman and Wheeler, 1963). Dye-bands approximately 10 cm long were applied to wool staples on upper mid-side of each animal at the commencement and the end of the experimental period using a syringe.

5.2.3. Measurements

5.2.3.1. Liveweight change

In this experiment, sheep were weighed at the beginning (1 August) and the end of the experiment (26 September) and three times in between (14 August, 29 August, and 11 September), to monitor the effect of the supplements on liveweight change. Daily liveweight gain was calculated by the subtraction of the liveweight at the commencement of the experiment from the liveweight at the end of experiment. Liveweight change between weighing was also calculated by the subtraction of the liveweight at the previous weighing from the liveweight at the last weighing. This was done in purpose to have the picture of liveweight change during the experiment.

5.2.3.2. Feed intake

To determine the intake of supplement by individual sheep, the supplements were labelled with lithium chloride (5 g/kg supplement), and lithium concentration was estimated in blood samples taken from the sheep on the day after LiCl-labelled supplements were given. The labelled supplements were used on three occasions, e.g. at the beginning, middle, and at the end of the experimental period. The method used

by Suharyono (1992) and Kahn (1994) was used to estimate the feed intake of individual sheep.

5.2.3.3. Mean fibre diameter Measurement

The sheep were shorn two weeks after the end of the experimental period. Dye-banded staples were taken for mean fibre diameter profile measurements. Each dye-banded staple was cut using segmenter into 2 mm snippets. Each snippet was washed with chloroethane and then dried before it is measured using a Sirolan Laserscan. Mean fibre diameter was measured using a Sirolan Laserscan at the CSIRO Chiswick wool testing centre, Armidale, NSW. One snippet was measured to determine mean fibre diameter in the pre-experimental period. Mean fibre diameter of each snippet in the experimental period was measured to determine the rate of change of mean fibre diameter as the result of supplementary feeding. Each snippet in the post-experimental period was also measured. This was done because the effect of supplementary feeding remain until one week after the end of the experimental period.

5.3. Measurement of feed intake using LiCl as a marker

5.3.1. Lithium chloride labelling of the supplement

Lithium chloride was used at the rate of 5 g/kg supplement. It was dissolved in 500 ml water before it was mixed with supplements. It was mixed in a cement mixer for 5 - 10 min to make sure the supplement was uniformly covered with lithium (Suharyono, 1992). The labelled supplements were fed to the sheep after the mixing.

5.3.2. Collection of blood samples

Blood samples were collected from the sheep about 24 h after the labelled supplement was fed to the sheep. The blood was taken from the jugular vein using a 10 ml vacutainer containing heparin and then centrifuged for 10 min at 3000 g. Blood plasma was taken and stored at -20 °C.

5.4. Analytical procedures

5.4.1. Determination of dry matter, crude protein and energy.

The nitrogen content of the feed was determined by the Kjeldahl method. For dry matter analysis, samples were dried in an oven at 70 °C for 48 h on until the sample weight was constant. The energy content of the feedstuffs was determined using calorimeter (Atomic calorific processor, model CP500). The composition of lupins and barley is shown in Table 10.

Table 10. Dry matter, crude protein and energy content of lupin and barley

Grain	Dry matter (%)	Crude protein (%)	Energy (MJ/kg)
Lupin	91.8	33.0	18.6
Barley	88.4	15.7	16.0

5.4.2. Analysis of lithium chloride content

Analysis of lithium chloride content in the blood plasma was done using the Atomic Absorption Spectrometer (Perkin Elmer, Model 360). Blood plasma was diluted with water in the ratio 1 : 5 before analysis. A standard solution of lithium chloride were prepared for 1, 3, 7, and 10 $\mu\text{g/ml}$. This lithium standard solution was used to adjust the machine (A.A.S.) after each sample analysed. Three replications were done of each sample and the average value was used in the final data for statistical analysis.

5.5. Statistical analysis

The randomized complete block design was used to analyse the data for liveweight change and wool mean fibre diameter. The initial liveweight and age were only used if they had a significant effect, but were excluded if there was no significant effect on liveweight change. The Minitab program (release 8.2) was used to analyse

the data. The difference between the treatments was tested using Duncan's New Multiple Range Test (Steel and Torrie, 1981).

5.6. Results

5.6.1. Liveweight gain

There was no significant effect of initial liveweight and age on liveweight gain of sheep during the experimental period. Thus these factors were excluded from the analysis model. Plot or block within the treatment influenced liveweight gain ($P=0.03$). Supplementation with lupins or barley affected ($P<0.01$) liveweight change. Sheep in the control group lost weight (-15 ± 5.2 g/h/d) during the experimental period and their mean liveweight change was significantly different ($P<0.01$) from that of sheep supplemented with lupins or barley. Sheep supplemented with lupins and barley gained weight by 32 ± 6.4 g/d and 24 ± 5.3 g/d respectively (Figure 14). Sheep supplemented with lupins tended to produce higher daily liveweight gain than those supplemented with barley.

Liveweight gain change during the experimental period is shown in Figure 15. All sheep decreased their liveweight after two weeks of commencement until four weeks later. There were significant differences in liveweight changes between successive weighing in the unsupplemented sheep ($P<0.05$). There were significant differences in liveweight between the third weighing and the first, second and fourth weighing in the sheep supplemented with lupin. There was no differences of liveweight between the first weighing and the second and fourth weighing in the sheep supplemented with barley, but third weighing was significantly different from the fourth weighing but not different from the first and second weighing. In the sixth week, unsupplemented sheep lost liveweight by -40 ± 13.9 g/d, sheep supplemented with lupins by -33 ± 18.6 g/d, and barley-supplemented sheep by -3 ± 12.6 g/d. The sheep supplemented with lupins and barley increased their liveweight gain by 77 ± 18 g/d and 56 ± 15 g/d respectively during the last two weeks of the experiment. Unsupplemented sheep increased their liveweight gain by 13 ± 10.2 g/d, but this gain was 57 % lower than liveweight gain during the first two weeks of the experiment.

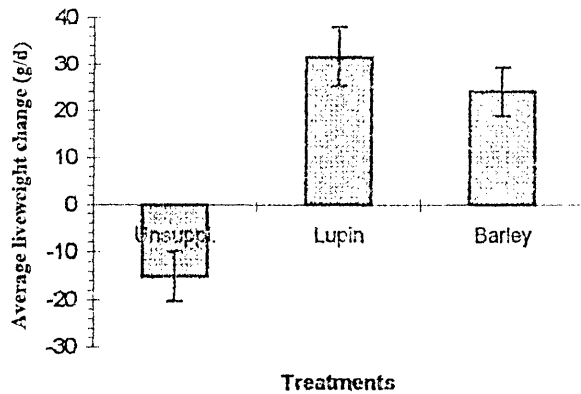


Figure 14. Average liveweight change during the experimental period.

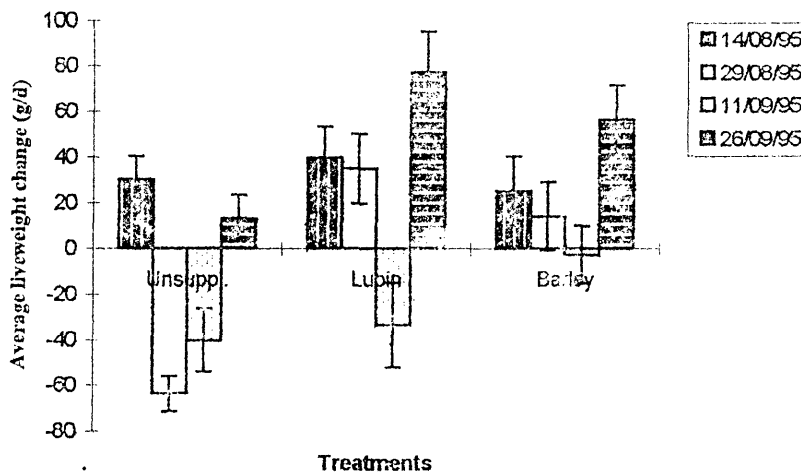


Figure 15. Average liveweight change in four weighing times during the experimental period (14 August, 29 August, 11 September, 26 September)

5.6.2. Feed intake

All sheep in this experiment consumed the supplements offered and there were visually no clinical effects arising from ingestion of lithium. When lupins were first offered, all sheep consumed the supplement and only three sheep (sheep No. 2, 4 and 5 in plot No. 1) consumed less than 100 g/d, that is 18.4, 3.3 and 99 g/d respectively. The range of lupin intake was from 3 to 1481 g/d. Eleven sheep increased their intake of lupin at the time of the second estimation (29 days after the first estimation) but eight of them (66.7 %) decreased their intake at 28 days after the second period. The ranges of intake in the second and the third period were from 388 to 1227 g/d and

from 307 to 1598 g/d respectively. Two sheep (sheep No. 6 in plot No. 1 and sheep no. 6 in plot No. 3) continuously decreased their intake until the last feeding. The coefficient of variability of intake among the sheep within the treatments was very high. The variability in intake of lupin was very high (68.3 %) at the beginning of feeding period and then reduced to 32.4 % in the middle of the experiment, but increased again to 41.8 % at the end of the experiment. The range of intake of barley smaller from the first period to the last period. The range of intake in the first period was from 8. to 1226 g/d, second period from 331 to 1187 g/d, and the third period from 799 to 1333 g/d. Variability in intake of barley was lower than that of lupins (35 %) and was relatively constant throughout the experimental period (Table 11).

Table 11. Coefficient of variation (SE as % of mean) in intake of supplement in sheep in each dietary treatment during feeding period

Supplement	01 August	29 August	26 September
Lupins	68.3	32.4	41.8
Barley	35	30.2	32.8

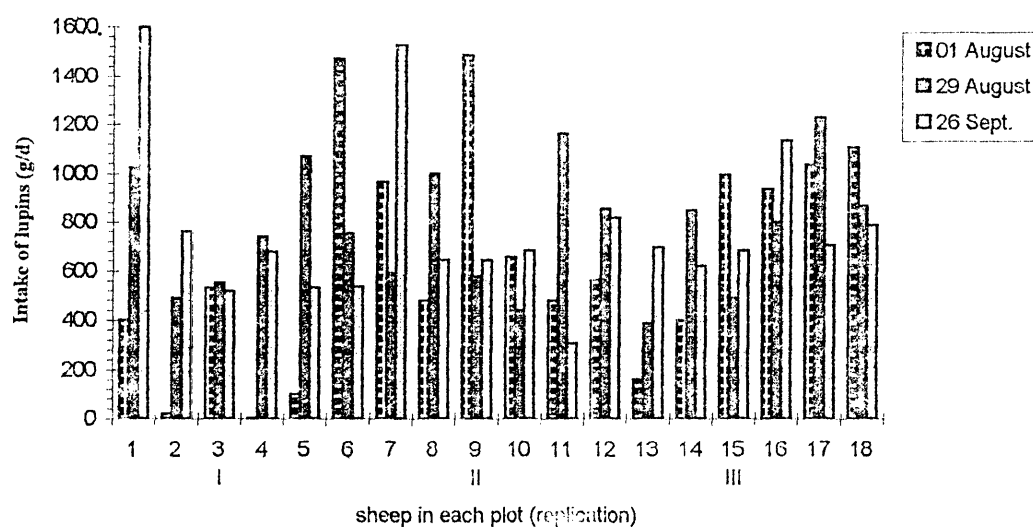


Figure 16. Intake of lupins by 6 sheep in each of three plots measured on three different days (1 August, 29 August, 26 September)

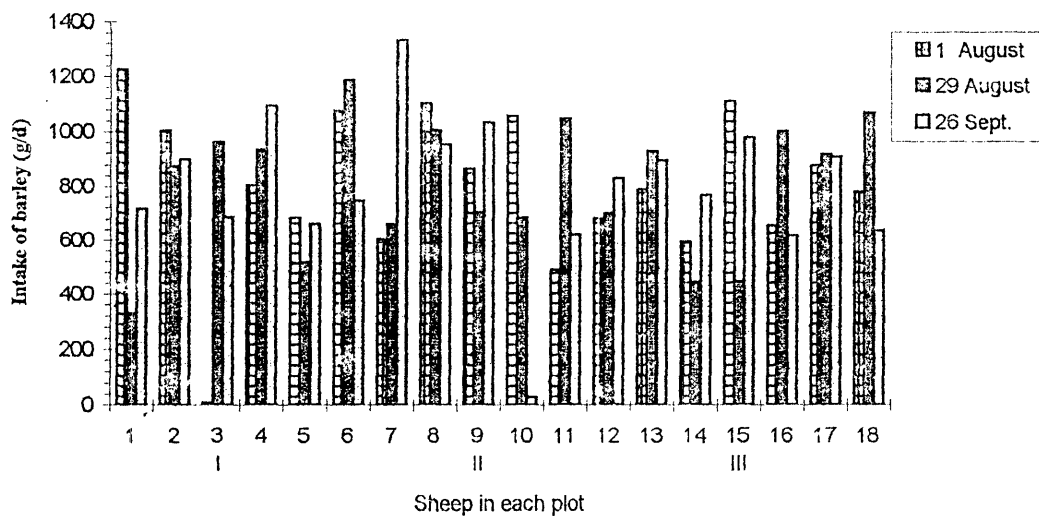


Figure 17. Intake of barley by 6 sheep in each of three plots measured on three different days (1 August, 29 August, 26 September)

5.6.3. Wool mean fibre diameter (μm)

There was no effect of supplementary feed on mean fibre diameter ($P > 0.05$). Supplementation of lupins or barley tended to increase the mean fibre diameter higher than unsupplemented group during the experimental period (Figure 18). As with liveweight gain, mean fibre diameter was also influenced by plot within treatment ($P = 0.03$). The rate of change of mean fibre diameter along the staple as the effect of treatments are shown in Figures 19, 20, and 21 for the unsupplemented, lupins, and barley groups respectively. The variation in mean fibre diameter of these Groups was 0.14 ± 0.15 , 1.03 ± 0.41 , and $0.35 \pm 0.24 \mu\text{m}$ respectively.

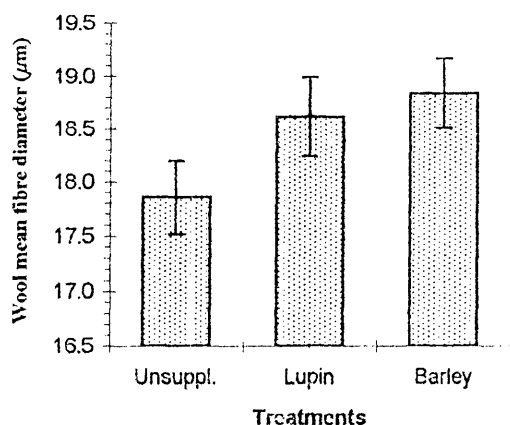


Figure 18. Wool mean fibre diameter of grazing sheep supplemented with lupins and barley (1 August - 26 September)

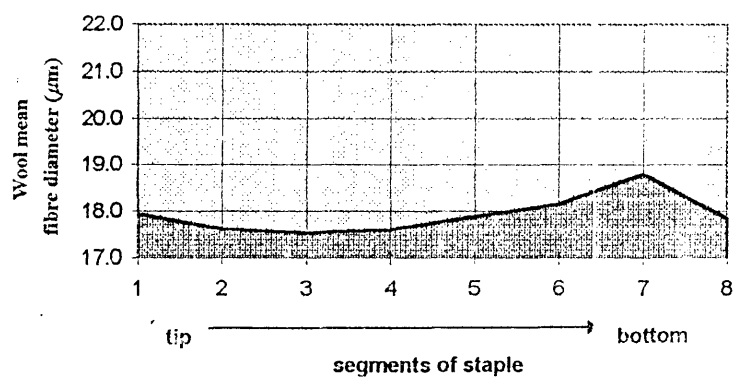


Figure 19. The pattern of change in wool mean fibre diameter of unsupplemented grazing sheep (1 August - 26 September)

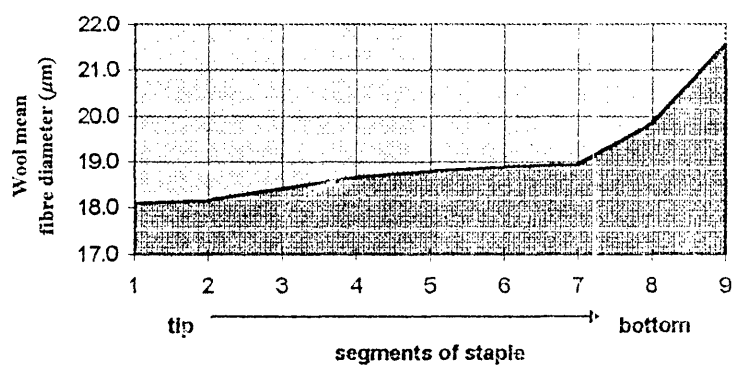


Figure 20. The pattern of change in wool mean fibre diameter of grazing sheep supplemented with lupins (1 August - 26 September)

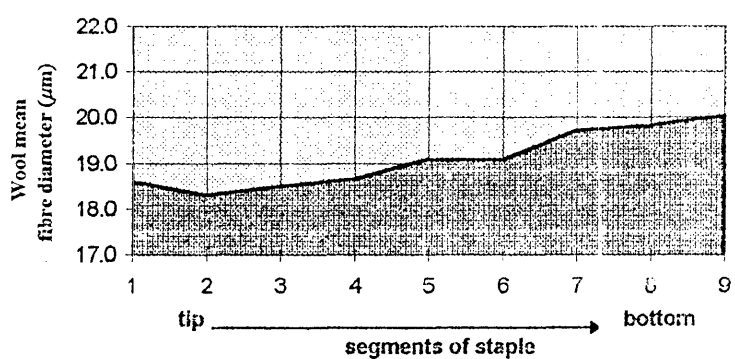


Figure 21. The pattern of change in wool mean fibre diameter of grazing sheep supplemented with barley (1 August - 26 September)

5.7. Discussion

Initial liveweight and age of sheep did not affect liveweight change during the experiment. However, plot within the treatment influenced liveweight gain. This indicated that liveweight gain of grazing sheep was significantly affected by supplementation of lupins and barley and pasture availability. Thompson and Curtis (1990) found that supplementation of lupins to grazing sheep reduced liveweight loss during summer/autumn in Western Australia. Murray *et al.* (1990) reported that supplementation of lupins (250 g/d) increased liveweight by 61 g/d for sheep fed wheat chaff. This might be due to lupins having a high digestible energy and protein content (Doyle *et al.*, 1992). The lower liveweight gain (32 ± 6.4 g/d) in this experiment than that found by Murray *et al.* (1990) may be due to the different amounts of lupins offered and differences in age and in stage of maturity those used by Murray *et al.* (1990) being younger, and thus giving more response in body growth. Liveweight gain of sheep supplemented with lupins was higher (but not significantly) than those given barley. This indicated that the nutritive value of lupins was better than that of the barley. Valentine and Bartsch (1988) found that the dry matter of lupins was degraded more than that of barley and the protein in lupins was degraded faster than that in barley. They also found that degradation of fibre in lupins was higher than for barley. Furthermore, supplementation of barley usually increases the number of protozoa in the rumen (Hynd *et al.*, 1985). This will usually lead to reduced numbers of bacteria (Leng and Nolan, 1984), thus reducing the amount of microbial protein available to the host animal.

The loss in liveweight of sheep in all groups between weeks two to six (Figure 15) was probably due to the decline in the green content of the pastures. The increase of liveweight after the sixth week may have been associated with the compensatory growth of those animals consuming less supplement in the first six week period subsequently consuming more supplement during the last period. This situation can be seen in a decrease of coefficient of variation of feed intake at the second measurement (day 29th). This may also be due to increased feed conversion efficiency of these sheep, and the growth of young leaves in the pasture after six weeks. Doyle *et al.* (1992) found that supplementation of lupins (150 g/d) to young grazing Merino

sheep, increased liveweight 30 g/d when the green feed in pastures was about 25 % DM, but lost liveweight by -30 g/d when there was no green feed available.

With the assumption that each sheep consumed the equivalent of about 190 g lupins/h/d and 200 g barley/h/d, and an average liveweight of about 40 kg, the level of lithium chloride consumed was about 25 mg/kg liveweight/d. This was lower than the tolerance level of 50 mg/kg liveweight/d suggested by Suharyono (1992). However, all supplement offered was finished at the time blood samples were taken (24 h after feeding). This indicates that almost all sheep consumed more than 400 g supplement when the blood samples were taken (Figure 16 and 17). It can be calculated that most of the sheep consumed more than 50 mg LiCl/kg liveweight/d. In this situation, the sheep finished supplement in one day and then grazed the pasture until the next supplement was offered. However, the sheep did not refuse the supplement given, thus indicating no feed aversion problems occurred in this experiment.

The past feeding history of the sheep in this experiment is unknown. The trend of intake of supplements (lupin and barley) from the first measurement to the second and third measurement indicated the response to an increasing intake in some sheep that initially ate little which resulted in a decrease of intake of the other sheep that mostly ate alot. Therefore, the coefficient of variation of supplement intake in the first measurement is higher than the second and the third. This indicated that an experience to feed in the first week influenced feed intake of supplement in the following weeks. Forbes (1995) found those sheep with experience to wheat started to eat quickly than inexperienced sheep. He also found that with more animals eating at once, feeding behaviour of individuals is mainly influenced by the competition for feeding space which leads to an increase in the rate of eating (Forbes, 1995). This situation may also have occurred in this experiment where the sheep consuming small amounts of supplement in the first week, consumed more in the following weeks. Foot *et al.* (1973) found the position of a ewe in the social order of a group also affected the intake of concentrate supplements given to those ewes. Lawrence and Wood-Gush, (1988) found social competition between younger and older hill sheep given block supplements, when younger ewes consumed less than the older ewes. This situation may have happened in this experiment because the age of sheep ranged between 3 - 6 years.

The coefficient of variation in intake of lupins was higher than for barley. This was probably influenced by sheep behaviour such as feed preference. Hutson and Van Mourik (1981), in behavioural studies of feed preference, found that sheep preferred barley to lupins. They also concluded that lupins was not highly acceptable to all sheep.

Wool mean fibre diameter was not statistically affected by supplementary feeding. However, supplementation appeared to increase mean fibre diameter and the sheep supplemented with barley tended to produce coarser wool than those supplemented with lupins. This is in agreement with the study of Champion and Robards (1994) who found that supplemented sheep produced coarser wool than sheep given oaten chaff. Reis *et al.* (1992) found that protein supply to abomasum had a significant effect on all components of wool growth. They concluded mean fibre diameter was significantly affected by the interaction between protein and energy supply to the abomasum. The rate of change of mean fibre diameter appears to be low in the unsupplemented sheep with the variation of change of $0.14 \pm 0.15 \mu\text{m}$. On the other hand, the variation of change in mean fibre diameter of the sheep supplemented with lupin or barley were $1.03 \pm 0.41 \mu\text{m}$ and $0.35 \pm 0.24 \mu\text{m}$ respectively. The large variation of mean fibre diameter in sheep supplemented with lupin was mainly affected by a sharp increase in mean fibre diameter during the last two weeks of the experimental period. This may affect the strength of the staples. Variation in fibre diameter along the length of the staple has been implicated as a determinant of staple strength in Merino sheep (Denny, 1990; Hansford and Kennedy, 1990; Ritchie and Ralph, 1990). Merino wool can incur a price penalty if staple strength declines below a certain threshold. Minimising mean fibre diameter changes due to pasture seasonality can maintain staple strength at an acceptable level.

5.8. Conclusions

Results of this experiment indicate that supplementation of grain to grazing sheep provides a means to maintain the production of meat and wool or liveweight gain during the winter/spring period in which pasture production is very low. Lupins tended to be better than barley in maintaining or increasing liveweight in grazing sheep. This result is in agreement with many studies reported by other workers for supplementation of lupins to grazing sheep.

Variation in individual intake of supplements may have been largely influenced by feeding behaviour including feed preference, experience to feed and competition for feeding. Coefficient of variation in intake for lupin tended to be higher than for barley, presumably due to greater variation on feed preferences by the sheep fed lupins.

Wool mean fibre diameter was influenced by changes in the availability of pasture and the quantity of protein consumed by the sheep. The inclusion of urea with the barley probably affected wool mean fibre diameter by the increasing of nitrogen supply for rumen microbes. The sheep fed with barley more likely to produce a coarser mean fibre diameter.

Chapter 6

General Discussion

In developing countries, the quality and quantity of feed appear to be the main factors limiting ruminant production. Arable land for pasture has been reduced considerably by the increasing world population. As a result, ruminant in certain parts of the world live mainly on low quality native grasses in public grazing areas and on the road sides. This situation has encouraged people to explore other feed sources to maintain or to increase ruminant production.

Agricultural and agro-industrial by-products are potential alternative sources of feed for ruminants. These materials (e.g. rice straw, crop stubble, cassava leaves, sugarcane tops) are often of low digestibility and low nitrogen and mineral content. When fed alone, these sources cannot support an economic level of production. Therefore, supplementation of nutrients deficient in these feeds is necessary to meet the requirements of the population of micro-organisms in the rumen and at times, supplements that deliver additional nutrients to the small intestine are also needed to optimize production.

Supplementation with urea, in limited amounts, to low quality diets such as rice straw, crop stubble, and the other low quality fibrous feeds, has been shown to increase the feeding value of basal feeds by improving the nitrogen availability for rumen microbes and to support economic levels of production. Some sources of protein which are not used for other purposes are by-products of agro-industries such as copra meal, cottonseed meal, sunflower meal, and palm kernel cake. These protein-rich feeds provide both nitrogen for rumen microbes and amino acids or bypass protein for ruminants.

The use of these protein-rich feeds as supplements for ruminants has been studied by many researchers. Copra meal has been successfully used as supplement for dairy cows (Ehrlich *et al.*, 1990), grazing steers (Gulbransen *et al.*, 1990), and lambing ewes (Bird *et al.*, 1990). Cottonseed meal is recognised as an effective source of supplementary protein for cattle grazing low digestibility roughages (Lindsay *et al.*, 1982; Hennessy and Williamson, 1988). Sunflower meal has been shown to increase

ammonia concentration in the rumen and increase the supply of microbial protein into the intestine (Erasmus *et al.*, 1994), and Cetinkaya and Ozcan (1994) found that supplementation of grass hay with sunflower meal increased staple length of mohair fibres. The use of palm kernel cake, in Malaysia, has been shown to increase intake of native grass and the growth rate of liveweight of sheep (Sethapukdee and Jalaludin, 1990 in Jelani, 1991).

However, a direct comparison of the efficiency of utilization of these sources of protein by sheep has not been made. Therefore, it was decided in the present study to evaluate these rich-protein sources by determining their effects on liveweight gain and wool production in sheep.

6.1. Effect of different sources of protein on liveweight and wool production

In these studies, because the feed offered was restricted, the effect of the supplements on feed intake and dry matter intake could not be determined. When the protein-rich supplements were compared in sheep given the same nitrogen intake (18.4 g per d), there was no significant effect on liveweight gain and wool production. However, urea-treated oaten chaff fed without supplements tended to support more liveweight gain than the diets containing supplements, where the diet with supplements tended to produce more wool.

Sheep supplemented with cottonseed meal and sunflower meal lost weight. This is probably because these feeds have a low degradability in the rumen, thus providing insufficient energy for rumen microbes to capture the NH_3 released in the rumen and, as a result providing a low supply of microbial protein to the intestine. These diets probably supply more dietary protein to the small intestine for the animal, but a lack of energy (7.1 and 8.1 MJ per d respectively) may limit the efficiency of utilization of bypass protein by the animal because they are catabolizing protein to release energy. Therefore, in this experiment, a supply of about 18.4 g nitrogen per d did not ensure an increased production when other factors such as energy were not adequate. Kay (1983) stated that supplementation is required in low quality feeds, but in practice, growth often seems to be limited by insufficient energy rather than insufficient protein.

The gain in sheep supplemented with PKC and copra meal may be because much of the energy in these feeds is available in oil which can not be used by microbial rumen, but is available to the host. This may increase the efficiency of utilization of bypass protein by the host. Nolan (1987) and Poppi and McLennan (1995) stated that the availability of energy-yielding substrates for tissue use determines the efficiency of utilization of absorbed protein, which in turn influences the deposition of protein in the body of ruminants. Copra meal may also be superior to cottonseed meal because it is more protected from degradation in the rumen than cottonseed meal (Hennessy *et al.*, 1989 in Gulbrandsen *et al.*, 1990) and it may also provide more digestible energy. The oil content in copra meal and PKC may also have affected the utilization of feed by rumen bacteria because the oil content in the feed may reduce the rumen protozoal population (Knight *et al.*, 1978 in Feeding standards for Australia livestock, 1994), and may also reduce the rate of digestion of fibre.

Liveweight gain in the sheep supplemented with urea-treated oaten chaff may have occurred because the availability of microbial protein in the intestines was higher. This was may because of the rumen microbes were better supplied with ammonia than the sheep supplemented with protein-rich supplements.

The sheep fed with urea-treated oaten chaff were more efficient in using feed to increase their liveweight. This suggests that the higher feed conversion efficiency was due to the appropriate balance of absorbed nutrients in the control sheep in contrast to with the excess of bypass protein in the supplemented sheep. Nolan (1987) stated that a decrease in growth and feed conversion efficiency in liveweight is probably caused by an imbalance in the nutrients absorbed by the animals.

An increase in essential amino acid supply to the intestines may increase wool production of sheep fed high protein diets (Hemsley and Reis, 1984). In this experiment, supplementation of urea-treated oaten chaff with dietary protein tended to increase components of wool growth, i.e. weight of greasy wool and clean wool and mean fibre diameter, compared with the sheep fed only urea-treated oaten chaff. This indicated that, in this experiment, supplementation of dietary protein to urea-treated oaten chaff supplied rumen bypass protein to the lower digestive tract and thus amino acids to be absorbed from the intestine. However, the primary determinants of wool growth are the availability of the sulphur amino acids, cysteine, cystine, and methionine (Downes *et al.*, 1976). The sheep supplemented with cottonseed meal and with

sunflower meal tended to produce more wool than the sheep in the control group even though they lost liveweight. This is in agreement with Ferguson (1962) in Downes *et al.* (1976), who suggested that it is possible for sheep that are losing liveweight to have a greater wool production per unit feed intake than sheep that gain liveweight. This is because of the breakdown of tissue protein that occurs during weight loss which may provide amino acids as substrates for wool growth (Downes *et al.*, 1976).

6.2. Lithium chloride technique to estimate the intake of supplements

An experiment was undertaken to test the suitability of using LiCl for the estimation of supplement intake. Suharyono (1992) suggested that the accuracy of measurement of estimated feed intake is highest when the blood is obtained 6, 12 or 24 h after Li-labelled supplement is consumed by sheep. It was decided to take one blood sample at 24 h in this experiment and the results suggested that this sampling procedure was appropriate. The other factors that influence the accuracy of feed intake estimation using LiCl are variation in liveweight, the accuracy of the analysis for blood Li concentration and the total consumption of labelled feed by the sheep (Suharyono, 1992). The error in estimation of intake of copra meal in one sheep was probably influenced by the relatively low intake of the labelled feed by that sheep and possibly by non-homogeneous coating of the supplement with LiCl. If the supplement is not evenly labelled, prediction of intake is likely to be most affected if the amount of supplement consumed is relatively small.

6.3. Supplementary feeding during winter/spring

The feed was eaten by the individual sheep before it was used in this experiment was unknown. However, on a group basis, the sheep ate all the supplements given within 24 h of being offered. There were no indication of any negative effect from feeding LiCl to the sheep. The range of intakes by individual sheep was greater in the first measurement, and was reduced in the second and the last measurement. This may be for several reasons. Individual sheep may have been more apprehensive initially than others about the unfamiliar supplements and feeding environment, and this may have resulted in lower intakes by these individuals.

However, the level of intake by individuals may also reflect their individual needs for energy and nutrients. Their requirements would have been determined by their current physiological state and previous diet, as well as by the level of nutrition obtained concurrently from the pasture. Thus individual requirements may have differed, especially earlier in the experiment. It is likely that individual's requirements for supplement would have increased as the season advanced.

The sheep in the unsupplemented group lost weight during the experimental period and supplemented sheep had a significantly higher rate of liveweight gain. Liveweight change of sheep in this experiment was mainly affected by the availability of feed, both pasture and supplements, but was not correlated with initial liveweight and age. The effect of pasture production on liveweight is shown from the analysis of variance in which the plot or block significantly affected liveweight change. Animal production in grazing animals is mainly affected by quality and quantity of pastures on offer (Thomas, 1986) and is decreased when the pasture is low in quality and quantity (Hawthorne, 1980; Hennessy *et al.*, 1981).

The sheep supplemented with lupins tended to have liveweight gain more than those supplemented with barley. Lupins are a good source of digestible energy and protein (Doyle *et al.*, 1992). Teleni *et al.* (1989), in studies with ewes, found that supplementation with lupins increased VFA concentrations in rumen liquor, increased the plasma concentration of glucose, acetate and propionate, and increased the entry rate of glucose, acetate and CO₂, and glucose oxidation. This indicates that lupins are a good source of digestible energy. On the other hand, barley has a lower metabolizable energy than lupins and lower degradability of crude protein and fibre (Valentine and Bartsch, 1988). The response in liveweight gain of animals supplemented with barley is also relatively small for the first 6 to 8 weeks of feeding (Rowe *et al.*, 1989; Godfrey *et al.*, 1993).

The dead to green ratio of the pasture (which ranged from 50 : 50 to 25 : 75 at the beginning of the experimental period) and a high variability in intake of supplement between sheep at the first measurement were probably the main reasons for the loss of weight of sheep during the first 6 weeks of the experimental period. The reduction in variability in intake of supplements at the time of the second measurement (29th day) may be associated with the scarcity of pasture at that time. The increased liveweight at the last weighing indicated there was compensatory growth.

The rate of wool growth is considerably affected by the supply of amino acids to sheep, particularly the sulphur amino acids (Wright, 1971; Reis, 1979). A decrease in protein intake may bring about a decrease in wool production (Colebrook *et al.*, 1968; Black *et al.*, 1973). In this experiment, mean fibre diameter tended to be higher in sheep supplemented with barley than those supplemented with lupins. This is in contrast with the findings of Rowe *et al.* (1989) who showed that sheep supplemented with lupins produced coarser fibres than those supplemented with barley. This is probably because, in the present experiment, barley was mixed with 1 % urea and virginiamycin, and this affected the rumen microbial population and increased the microbial protein yield to the small intestine. The addition of nitrogen to barley possibly provided sufficient ammonia for rumen microbes. The inclusion of virginiamycin to barley probably reduced the protozoal population and, as a result, increased the bacterial population. Murray *et al.* (1992) found a decrease in the number of protozoa in sheep fed a diet containing virginiamycin. The treatment of barley with urea and virginiamycin probably increased the supply of bacterial protein to the small intestine for the host, and tended to produce coarser fibres than those consuming lupins.

The average fluctuation of mean fibre diameter appeared to be lower in unsupplemented sheep than those supplemented with lupins or barley. The sheep supplemented with lupins increased mean fibre diameter greatly during the last two weeks of the experimental period which affected the average variation of change or fluctuation of mean fibre diameter during the feeding period. This may be because the responses in wool growth occurred after 6 weeks of supplementary feeding. This was probably related to the variation in intake of lupins during the experimental period which affected the rate of wool growth by individual sheep and affected the fluctuation of mean fibre diameter along the staples in this group. The fluctuation in mean fibre diameter in the wool staple from sheep supplemented with barley tended to be smaller than those supplemented with lupins. This is probably due to the early response on wool growth which was probably due to the addition of 1 % urea to this diet. This may also be related to the low variation of intake of barley from the commencement until the end of the experimental period which resulted in a more constant rate of wool growth throughout the experiment.

6.4. Conclusions and future research

Supplementation with sources of by-pass protein in the first experiment tended to increase wool growth but had little effect on liveweight gain. The restricted ration given to the animals precluded then from obtaining a significant response, in liveweight and wool production, to the different sources of rich-protein supplement by increasing their digestible energy intake. The use of iso-nitrogenous diets in this experiment did not facilitate comparison of the efficiency of utilization of the different sources of protein-rich supplements probably because energy was limiting. The balance between protein and energy ratio may be more important when supplementation of by-pass protein to low quality fibrous diet is proposed to increase animal production.

Lithium chloride is a useful marker for the estimation of intake of supplements. The uniformity of coating may be an important issue influencing the estimation of intake of supplement, particularly if the amount of supplement consumed is relatively small. The use of lithium chloride to estimate intake of supplements by grazing sheep is very helpful in determining the reasons for differences in productivity of individual grazing animals.

Supplementation of grazing sheep with lupins or barley during winter/spring was successful in maintaining and increasing liveweight and wool growth compared with unsupplemented sheep. Barley treated with urea and virginiamycin is likely to produce coarser and possibly stronger fibres in sheep than those fed untreated lupins. The greater variation in mean fibre diameter of lupin supplemented sheep was apparently due to the variation in intake among the sheep. A longer experiment may be needed to provide a better evaluation of the effect of supplementary feeding on the rate of change of mean fibre diameter of wool from grazing sheep.

The potential sources of by-pass protein that are abundantly available in the developing countries need to be investigated further. Copra meal and palm kernel cake, in this experiment, have proved to be of similar value at the same level of N intake (18.4 g per d) as cottonseed meal, sunflower meal, and urea-treated oaten chaff (3 % urea). The value of using these sources in *ad libitum* feeding systems and in grazing ruminants is still unknown. The efficiency of utilization of these sources in housed and grazing ruminants needs further research.