

**Fiber growth of goats as influenced by the doe's genotype,
plane of nutrition and physiological stage (gestation and
lactation).**

Submitted in partial fulfillment for the degree M Inst Agrar

by

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Declaration

**I declare that this thesis for the
degree MInst Agrar- Animal Science- at the University of Pretoria has never been
submitted for a degree in any other university**

Signature:.....

Date:.....

Summary

The aim of this thesis was to investigate how fiber growth of goats is determined by genotype, (purebred Angora and crossbred between Angora and Boer goat), physiological stages of the females from mid pregnancy until fifty days after the kids had been weaned and the plane of nutrition. Twelve Angora (pure bred) and ten Angora x Boer goat doe's with an initial mass of 28.70 ± 4.42 , between three and five years of age were used.

Half of them received 120% NRC energy requirements and the other half received 80% requirements. Mohair patches of 100cm^2 were collected from the animals at parturition, mid-lactation, weaning and fifty days post weaning.

The fiber greasy weight started declining with commencement of lactation in crossbred animals of both high and low nutrition. The greasy mass again increased from the period of weaning until fifty days post weaning suggesting that crossbred animals do not produce a lot of fiber at the expense of fetal and kid growth. Since fiber production from the crossbred animals is lower, I recommend that the Angora genotype be increased to gain more fiber and futher research be done on the topic.

Chapter one

1. Aims and motivation

1.1 Problem statement

The nutrient drain of pregnancy and lactation demand more nutrients from the animal, which in case of non-pregnant and non-lactating ewes are used for fiber production. The nutrients that are diverted to maintain pregnancy in terms of pregnant animals are derived from the same source, even during lactation the nutrients found in milk are synthesized from the animal body, being derived from the feed the animal eats. As Herselman *et al.*, (1998) put it, adaptation to an environment is reflected in reproduction, survival and growth. Many researchers have worked on the effects of pregnancy and lactation on fiber growth. Reid (1978) reported that in conjunction pregnancy and lactation have more effects on the reduction of fiber growth than when considered individually.

It has been suggested that Angora goats are poor mothers. In some cases, even under adequate nutritional conditions, individual animals may be inherently poor milk producers with insufficient milk to raise twins or even a single kid (Van der Westhuizen, 1981). An adequate milk intake is crucial to the survival of young mammals. As in any other production system, the production of more offspring that survive up to weaning is crucial to the economic and biological efficiency of the system.

In the Angora, 12% of all kids die before weaning, and 85% of these deaths occur during the first few days after birth (Van der Westhuizen, 1981). This is mainly due to the inability of the kid to ingest sufficient milk or colostrum, which is often aggravated by low milk production.

On the other hand, the Angora is very effective in the conversion of feed to fiber, and because of this metabolic priority for mohair production, mohair does not develop a break in the fiber during under-nutrition to the same extent as wool.

South Africa currently produces approximately 50% of world mohair and is considered to be the undisputed world leader in terms of breeding and clipping quality. The clip is exported virtually in its entirety and is an important earner of foreign exchange. It is clear

that a need exists for fiber producing goats, which can produce good quality fiber without a high incidence of neonatal mortality.

Boer goats, on the other hand, are very hardy under tropical or subtropical range grazing conditions. Twin or triplets are frequent, and under good husbandry conditions, milk yield is sufficient to enable kids to reach live-weights of 40 kg by 12 months of age or less.

A cross between the Angora and the Boer goat may therefore, represent a genotype that will produce both mohair and milk in balanced quantities.

When dealing with fiber production however, nutrition also plays a significant role so the farmer should not expect his animals to perform beyond their maximum capabilities due to the fact that the plane of nutrition is high. This is mainly due to the fact that animals respond differently to the plane of nutrition according to their genotype. Many workers, by the results they found out after the investigation of the effects that these physiological stages have on fiber production, agree or have found the same effects on fiber growth (Sahlu, Fernandez, Carneiro & Flasher, 1992).

These effects of nutrition of sheep on the amount of fiber grown, on the components of fibre growth (length and diameter) and on the protein composition and strength have been studied extensively, in contrast, the effects of nutrition of Angora goats on the amount of fibre grown, and particularly on the length growth and diameter of fibres (Reis and Sahlu, 1994) have received limited research attention.

1.2. Effects of pregnancy on fiber growth

Corbett (1979), compared fiber growth results from other authors who compared ewes that bore one or two lambs but lost them at birth so that no lactation ensued, and ewes that were fertile but were withheld from the ram. Ewes that were pregnant were fed at maintenance. Fiber growth was reduced by 30% during the second half of pregnancy. The reduction during this period probably accounted for most of the whole term reductions of 25-55%. Slen and Whiting (1965) concluded that the effects of gestation on nutrition are manifest at an earlier stage (first trimester of gestation) at a low plane of nutrition.

The reduced fiber growth due to gestation expressed in terms of annual fleece production falls within the range of 3-10% for both greasy and clean fleece weight (Corbett, 1979).

Corbett and Furnival (1976) found that the effects of pregnancy on wool growth were greater at high compared to low stocking rates. There was a reduction of 9.8% in annual clean fleece weight under poor nutritional conditions when live-weights of pregnant ewes showed negligible change during the last months of gestation, compared with a 2.3% reduction under better conditions when live-weights during the last months of pregnancy increased by 3kg. It is likely that the nutritional environment was poorer in those studies where the greatest effects of pregnancy on fleece mass were observed (Doney, 1964; Brown, Turner, Young & Dolling, 1966).

Bosman (1935), however, reported that pregnancy did not influence wool fibre diameter in Merino sheep, although lactation did result in a decrease in fibre diameter. A staple of wool from lambing ewes, will therefore, show no difference between the fiber growth produced from months during pregnancy and that produced normally (Bosman, 1935). However, (Oddy & Annison, 1979; Oddy, 1985) found that both gestation and lactation reduce fiber diameter and fiber length.

Reid (1978) found that barren ewes and pregnant ewes at 51-108 days of pregnancy grew 0.26 mm and 0.23 mm of fiber per day respectively. At 108-142 of pregnancy, barren ewes still grew 0.26 mm/d and the pregnant ewes only 0.19 mm per day. This shows that barren ewes had no other extra place to divert nutrients to, other than normal maintenance and fiber production and hence they had more fiber growth while others were pregnant. This concludes that more nutrients are used by the animal during pregnancy than when the animals are dry.

Doney (1964) compared barren sheep, pregnant sheep, non-lactating sheep and lactating sheep under different nutritional conditions (hill grazing conditions versus down the hill with supplementary feeding). Under hill grazing conditions, non-pregnant ewes produced 20% more wool per unit area of skin than those carrying a single lamb. The rate of wool production per unit skin area during the winter period was 30% of the peak value in late summer and autumn in ewes with lambs and 37% in barren ewes. Supplementary feeding during pregnancy resulted in the much smaller weight loss in ewes rearing a single lamb, wool production was however not affected by supplementary feeding. Under uncontrolled

grazing conditions, the nutrition was very poor and hence the animals there lost more of their live weight than did the animals that were receiving supplementary feeding. This shows the importance of nutrition during the pregnancy period for fiber producing animals.

1.3. Effects of lactation on fiber growth

Fiber production during the first weeks of lactation for ewes in the harsh environments of the Pilbara districts of Western Australia (Williams and Suijendorp, 1968) was 44% less than that of non- lactating ewes, and was 26% less over the complete lactation of 20 weeks. Comparisons with ewes that gave birth to, but did not rear their lambs, show a 16% reduction in fiber growth during a three-months lactation (Corbett, 1979). Langlands (1977) compared lactating and non-lactating Merino ewes at different stocking rates. Clean wool production during a 12-week lactation was reduced by 29%, but there were no apparent effects of stocking rate. However, the major part of the reduction occurred during the first few weeks of lactation and the effect became less as lactation advanced (Corbett, 1979). Corbett (1979) also reported that suckling a single lamb reduces annual fleece grown by 5-8%. The suckling of twins would on the other hand, double the reduction of fiber growth.

Langlands (1977) observed that grazing Merino ewes with single lambs ate 80% more organic matter during their 105-day lactation than did non-lactating ewes. Efficiency of wool production in lactating ewes (1g clean wool per 356g organic matter consumed) was only 40% of that of non- lactating ewes (1g wool per 137g organic matter consumed). Efficiency of wool production is reduced during lactation, the extent of the reductions being determined mainly by the extent of change in feed intake and its reduction after weaning (Corbett, 1979).

Corbett (1979) also reported that non- lactating ewes produce 60- 150% more fiber per unit of feed intake than those that are lactating. On an annual basis, efficiency is reduced by 32%.

Doney (1964), found that ewes rearing a single lamb increased their production to 53% of the peak value during the first two months period after weaning period, and during this

time live weight increased from the winter minimum to the previous pre-mating level. The barren ewes increased their live weights to a level higher than their previous autumn peak and produced 92% of peak wool production.

The ewes which had their lambs removed were between the barren and lactating ewes both in live weight gain and in wool production (Doney, 1964). A higher level of nutritional provision, in the form of low land grass, did not have as much effect on live weight relative to the other groups during lactation as it did in the pregnancy period.

1.4. Effects of pregnancy and lactation on fiber growth

Compared with non breeding ewes, the full cycle of reproduction reduces annual fleece growth by 10 to 14 %, the higher values applying in general to ewes rearing twin lambs and the lower ones to ewes rearing singles (Corbett, 1979). Corbett (1964) found a reduction of 15.9% in fibre growth over the whole lactation. This reduction may result from competition for nutrients between milk and wool, but it is possible that some other aspects of physiological stage of lactation is involved (Corbett, 1964). Reproduction has only a small and variable effect on the percentage clean and scoured yield of the fleece.

The effect in South Australian strong woolen ewes raising one lamb was to drop daily fiber growth rates from 14.0 to 13.4g, while wool growth in ewes rearing twins declined to 1.26g fiber per day (Mcguirk, Paynter & Dun, 1966). Wethers, on the other hand might be expected to grow about 1g wool / day more than reproducing ewes (Hogan, 1970).

In commercial flocks, the carrying and rearing of a lamb generally decreases fiber production in ewes by 10- 15 % (Oddy and Annison, 1979), this is in contrast with a report by Corbett, (1979) who reported a reduction of 3-10% and the findings of (Doney 1962) who reported 25 – 55% reduction. The largest reduction in the wool growth rate of ewes occurs in late pregnancy and early lactation, and is greater in twin bearing ewes than in ewes with single lambs, suggesting that the nutrient demands of reproduction exceed the ability of the pregnant and lactating ewes to increase feed intake.

Oddy and Annison (1979) concluded that it is more likely that increased competition for essential nutrients stemming from the requirements of foetal and mammary tissue is the

causal factor of reduced fiber production during pregnancy and lactation, rather than the reduced affinity of wool follicles for circulating nutrients.

Brown, Turner, Young & Dolling (1966) reported reductions on both greasy and clean fleece weight while Sanderson, McFarlane & Pratley (1976) found that the overall effects of rearing a lamb to weaning was a reduction of 1.5% units. In Brown's experiment, he found that the combined effects of pregnancy and lactation is a loss of 1.50lb greasy or 1.25lb clean fleece, representing 17 and 22 percent respectively of all mean values for ewes which failed to lamb.

The pregnancy losses are 11 and 15% and the lactation losses 6 and 7 % (Brown *et al.*, 1966).

He concluded that about one-third of the reduction in wool growth by Merinos during pregnancy and lactation stems from a decrease in fiber numbers and two-thirds from a decrease in fiber volume. The decrease in volume is due partly to a shorter length of staple and partly to a reduction in fiber diameter (Brown *et al.*, 1966). These changes affect wool quality characteristics, including an increase in the incidence of coting and breaking.

The reduction in fiber diameter appears to be greater in ewes bearing and rearing twin lambs than in ewes rearing only a single lamb (Slen and Whiting, 1956).

Turner *et al.* (1968) estimated the decrease as about 12% in ewes rearing twin lambs and 6% in ewes rearing single lambs.

Again the effect of twin lambs is much higher in the reductions of fiber growth than that of single lambs, either in pregnancy, lactation, or both.

Brown *et al.* (1966) observed the number of fibers per unit skin area and indicated that there may be a greater decrease during pregnancy than during lactation.

Corbett and Furnival (1976) reported an inverse relationship between wool production during the last seven weeks before lambing and birth of the lamb: an increase of 1kg in birth weight was associated with a reduction during this period of 0.22g/day in clean wool grown by Corriedale ewes.

All in all, the combined effects of pregnancy and lactation result in a 25% loss in clean wool weight, of which one third derives from a fall in total number of fibers and two thirds from a lower fiber volume (Brown *et al.*, 1966).

1.5. Relationship between fiber growth in pregnancy and lactation

The effects of pregnancy and lactation are confounded by the non- nutritional environmental factors involved in the annual rhythm of wool production (Doney, 1964).

It seems that in the hill environment, the nutritional drain of a single lamb pregnancy during winter produced only a small reduction in wool production, whereas the drain consequent on lactation was much greater (Doney, 1964).

During lactation, however, the evidence suggests that the level of feed intake can affect wool production as shown by the unexpectedly low level of wool production in the spring of 1962 corresponding with an outstandingly poor grazing season, and also by the increase shown in each year corresponding to the provision of low ground grass.

Sharkey, Davis & Kenny (1962) concluded that the effect of increasing the stocking rate is to reduce total wool growth per sheep and increase variation in wool growth through the year.

Pregnancy and lactation are associated with a reduction in wool growth and this is greater in ewes with twins than with single lambs (Kenny and Davis, 1975).

1.6. Relationship between milk protein secretion and wool production

The response in wool growth to a protein supplement will depend on the amino acid made available for absorption from the intestines relative to those required for wool (Neutze, 1990).

During lactation of various lengths, the clean wool grown by well fed ewes on average decreased by 0.002g per gram milk protein, and with undemourished ewes by about 0.008g per gram milk protein (Corbett and Furnival, 1976). This may have indicated

greater utilisation of amino acids by the undernourished ewes as a source of energy, and the remaining supplies being used more for the synthesis of milk than fiber proteins.

Synthesis of wool, however, is dependent particularly on the supply of sulphur - containing amino acids (Corbett, 1979).

However, Williams, Tyrell & Gilmour (1978), after supplementing casein or methionine and cystine in the abomasum, concluded that the availability of these nutrients was not a primary limitation to wool production by breeding ewes.

1.7. Fiber growth recovery

The recovery in fiber growth that occurs as found by Corbett and Furnival (1976), when lactation ceases is therefore probably due both to an increase in the volume of individual fibers and to an increase in the number of fibers consequent on reactivation of follicles such as occurs when undernourished fiber producing animals are again well fed. The recovery is not complete until some weeks after the end of lactation and occurs more slowly in animals that are in poor than in good nutritional conditions (Corbett and Furnival, 1976).

In good nutritional conditions it is probably hastened by the persistence for some times after weaning of the substantial increase in the feed intake of the grazing ewes that generally occurs during lactation (Langlands and Donald, 1977).

In poor grazing conditions, the slow recovery of follicle activity may be related to the lack of opportunity to increase intake, and the small quantity of nutrients that would be spared by the cessation of lactation.

1.8. Fiber growth rate and feed intake

A positive relationship between wool growth and feed intake was first demonstrated in the 1930's and has been noted by many others since. There is, however, no unanimity on the precise form of the relationship (Allden, 1979).

Marston (1948) noted a linear response in fiber growth rate to different amounts of a ration, which supplied from half to twice the energy required for maintenance. Within this range, the nitrogen retained as fiber increased five fold from 0.23-1.17g / day, while the changes in nitrogen retained in the body tissue were more substantial, increasing from -2.23 to +2.29g/day; both responses were closer to linear (Allden, 1979).

In the experiments of Daly and Carter (1955), they found that the regression of wool growth on feed intake was essentially linear. There are, however, many experiments in which the efficiency of conversion of feed to fiber has been greater in low intakes than in high intakes of the same diet (Allden, 1979).

Allden (1979) highlights the importance of the difference between the different forms of responses of fiber growth exhibited by animals to changes in feed intake. The evidence of direct proportionality between intake and fiber growth rate implies that the fiber production from an area of land will be proportional to the amount of herbage consumed, and independent of intake per animal (Langlands and Donald, 1977).

On the other hand, the evidence that the efficiency of conversion of feed to wool declines as intake increases, implies that a large number of animals each receiving a small amount of feed will produce more fiber than a few animals consuming the same total quantity (Allden, 1979).

Williams (1966) provided evidence that when the feed intake of Merinos in selection experiment was changed from a restricted to an unrestricted amount, the efficiency of conversion of feed to fiber fell by 40%, from 0.81g to 0.46g wool per 100g dry matter consumed.

1.9. Reasons for the variation in the form of a relationship between fiber growth and feed intake

Changes in digestibility with increasing intake may account for a substantial portion of the observed differences in the efficiency of feed utilisation for fiber growth (Nagorcka, 1977). To support this view, Blaxter (1964) shows a reduction of up to 12 digestible units when the intake of pelleted hay was increased from maintenance to twice maintenance.

The other reason for the variations in the form of the relationship between fiber growth rate and intake relate to the technical problems of estimating carryover effects from the previous diet, to the experimental procedures concerned with feeding sequences, to the possible influence of body weight change on conversion efficiency, and to interaction between nutrition and the environment (Allden, 1979).

Nagorcka (1977), analyzing the results of Ferguson (1972), detected a lag of about 25 days before wool production and feed intake came into equilibrium after a dietary change, and other workers have reported that the carryover effects from the previous diet may persist for a period of one to three months (Allden, 1979).

Changes in the fiber follicle population in response to nutrition may also affect the time taken to establish a new equilibrium (Allden 1979).

Nutritional deprivation during early life has been shown to depress permanently the number of fiber producing follicles in an animal thereby influencing its future productivity (Allden, 1968b; Corbett, 1979), whereas under nutrition in later life causes only a temporary reduction in the number of active follicles with consequent fiber shedding (Lyne, 1964).

The changes in the wool follicle population and the time taken for follicle generation possibly account for the delay in the response of wool growth after prolonged periods of severe under nutrition. Although previously undernourished sheep commonly grow faster and eat more than their previously better fed mates during the recovery period, the increased feed consumption is not immediately reflected in greater wool production (Allden, 1979).

1.10. Feeding regimes

In many studies, the experimental animals have received their feeding treatments sequentially, either commencing at a lowest intake and progressing in successive increments until the maximum intake is attained in the final period, or vice versa (Ferguson, 1972). Consequently, changes in fiber growth rate are confounded with both fiber growth rhythms and the residual effects of the previous treatment.

When an animal changes from a high to a low intake the residual fiber growth enhances efficiency at the lower level, and when the change is from low to high, the slower fiber growth rate is carried in to the period of high feeding. Thus, in this circumstance, carryover effects always temporarily reduce the efficiency of high intake treatments relative to the low intake treatments (Allden, 1979).

Simultaneous comparisons of fiber growth are preferable to sequential feeding treatments, unless the experimental design permits the estimation of residual and period effects (Saville and Roberts, 1972).

It should be recognized that contemporary comparisons may also be influenced by the carryover effects of the pre- experimental feeding regime, so that, irrespective of the method of feeding adopted, ample time must always be allowed for diet and fiber growth rate to reach a new equilibrium (Allden, 1979).

Adjustments have been made for seasonal rhythms either by reference to a group receiving a uniform amount of feed throughout the experiment or by use of regression analysis relating fiber growth to non-nutritional factors of the environment (Ferguson, 1972).

Such corrections are commonly based on the belief that there is no interaction between the level of intake and seasonal rhythms of fiber growth, an assumption that has not been validated (Allden, 1979).

Adams, Briegel & Ritchie (1997) after a comparison of two groups of sheep in pasture indicated that the relative wool growth rate appeared to depend more on whether the pasture was green or dry, rather on the total feed availability.

1.11. Body weight status

Several workers have suggested that the efficiency of conversion of feed to wool may be influenced by the body weight status of the animal. This concept is based on the assumption that circulating substrates supplied from weight loss have the same effect on fiber growth as the nutrients supplied from the diet, thereby enhancing the apparent conversion of feed to fiber; the reverse would be true for the storage of nutrients during weight gain, which would cause an equivalent loss in fiber growth (Ferguson, 1972).

Williams and Winston (1965) noted that 100g feed produced 1.07g wool when sheep lost 1.5% of body weight, 0.92g wool at body weight maintenance, and only 0.78g wool when body weight increased by 5%. In these results, it can be assumed that when the animal loses weight, most of the nutrients lost from the body go for fiber production.

A causal relationship between fiber growth rate and weight change is difficult to establish because the two variables are closely related to feed intake (Aldden, 1979). However, there has not been any convincing evidence that weight change alone has any effects on fiber growth. If it is shown that the apparent conversion of feed to wool is enhanced by tissue depletion, the greater efficiency should be related to the feed associated with the storage of that tissue and not to the current level of nutrition or feeding (Aldden, 1979).

1.12. Interaction between nutrition and environment

Although most workers agree that changes in feed intake are likely to affect fiber growth, the extent to which nutrition interacts with the non-nutritional components of the environment is clearly understood. Some breeds are more affected than others (Aldden, 1979).

Doney (1964) noted that variations in feed intake were reflected in variation in fiber growth at all times in Merinos, whereas for the Cheviot breed, there was a close relationship between intake and fiber production in the summer but not in the winter. The same work by Doney (1964) showed that improved nutrition in the winter produced no

increase in fiber growth in Scottish Blackface although it had a marked effect on live weight.

The important point that arises out of these observations is that the same amount of feed provided to a sheep may result in different rates of wool growth according to both season and genotype (Nagorcka, 1977). This in turn precludes the possibility of deriving a general equation relating intake and fiber growth for animals receiving the same diet.

1.13. Feed intake and fiber characteristics

The ratio of length growth to a diameter (L/D ratio) is independent of the amount of fiber grown under natural feeding conditions. However, changes in the L/D ratio have been induced experimentally by abomasal infusions of zein and by the omission of lysine, leucine or isoleucine from amino acids infusions; the omission of lysine resulted in the growth of weaker fibers (Alden, 1979). Reis and Tunks (1976) observed that Zein increased the L/D ratio. The adverse effects of zein on fiber strength were corrected by the addition of lysine (Reis and Tunks, 1976).

Reis (1992) indicated that wool fibers can be weakened substantially by treatments that vary the supply of Lysine or Methionine to wool follicles.

Sahlu *et al.*, (1996), after the infusion of lysine together with a constant level of methionine in Angora goats, found that there was no difference between treatment groups in fiber diameter. However, the percentage of medullated fibers in this study decreased, which is beneficial to the mohair industry as medullated fiber is not desirable due to its poor dye absorbing quality (Sahlu *et al.*, 1996).

Oddy (1985) also found that cortisol depresses the growth of both length and diameter of fibers, and the rate of change in fibre diameter has been closely related to staple strength (Hansford and Kennedy, 1988).

Reis & Schinckel (1963) found that the highest producing sheep in a flock generally have wool with the lowest sulphur content, showing that more wool production does not necessarily mean that it is wool of good quality.

Wool sulphur content increased during pregnancy but not during lactation (Oddy, 1985).

When wool growth is limited by the amounts of Cyst(e)in, some animals can presumably produce more wool than others by favouring the synthesis of those proteins relatively low in cyst(e)in (Hogan, Elliot & Hughes, 1979).

1.14. Effects of protein and energy on fiber growth

It is still not very clear on the roles of dietary energy and proteins on fiber growth. However, different authors observed appreciable responses in wool growth when maize starch was added to the diet. Other workers have noted changes in wool growth rate with increasing dietary protein and interpreted these changes as responses to protein, even though protein and energy were confounded (Ferguson, Carter & Hardy, 1949).

Allden (1969) also observed a linear relationship between wool production and energy intake in two field experiments involving supplementary feeding. In these experiments 1.96g and 1.85g fiber was produced for each 100g digestible matter. In pen studies, Allden (1968b) in Allden (1979) found that 2.04g wool /100g digestible dry matter was produced.

As far as protein is concerned, Leng & Leonard (1965) found that wheat gluten meal was more resistance to rumen degradation and thereby allowing more protein to be digested in the intestine and therefore available for various body functions, and he cited this as the reason why wheat gluten meal was found to increase wool growth by other researchers. This can be concluded as that the additional dietary crude protein fed to animals does not reach the abomasum in enough quantities.

To further supplement this, Kempton (1979) said that when the rumen is bypassed, or protein passes the rumen undegraded, there are clear-cut responses in fiber growth to

protein and only small responses associated with energy, a reversal of the effect noted in diets digested in the rumen.

Hogan (1970) in Allden (1979) showed that the microbial protein available for digestion and absorption in the intestines is more clearly related to the intake of digestible energy by the animal than to protein content by the diet.

The need for protein in relation to energy appears to be satisfied in concentrations of about 1% nitrogen in diets of low digestibility; as digestibility increases, a proportionality between metabolizable energy and intestinal protein absorption is established, and for this reason energy commonly appears to be the main factor correlated with the growth of wool (Ferguson, 1972).

1.15. Relationship of feed intake to body weight change and stage of growth

The prediction of wool growth rate by animals of different genotypes, or at different stages of growth, requires an understanding of the relationship between voluntary feed intake and body weight (Allen, 1979).

Edwards and Hynd (1992) after comparing fine wool and strong wool Merino for the genetic difference in the structure and function of wool follicles, concluded that genotype determines the volume of potential mitotically-active tissue in the skin, however the dynamic mechanism of fibre production is not controlled by a single factor, but rather a combination of a number of characteristics.

Allden (1979) found that a maximum dry matter intake of 90- 100g/ kg maximum weight was attained at about 35% of mature body size, declining to about 40g/ kg maximum weight at maturity. He also stated that wool production of a sheep under *ad libitum* should be greatest when about 40% of adult weight is attained and intake is at its peak. The feed used in this experiment had 65- 75% digestibility. Thereafter wool production might be expected to decline.

1.16. Relationship between bodyweight, weight change and fiber production

Allden (1969) noted a linear relationship between the intake of digestible energy and wool production on the one hand and intake and weight gain on the other, for sheep of similar initial weight. There is a possibility of simple association between wool growths, body weight (which reflects the energy expenditure for maintenance).

Adams *et al.* (1997) observed increased stability in wool growth rate, which was accompanied by greater relative changes in liveweight in sheep. It appears that the group with an increasing liveweight had a greater buffer for the supply of amino acids available for wool, thereby reducing the variation in the rate of wool growth.

Marston (1948) and Black and Thompson (1973) compared nitrogen retention in wool and in body tissue by using feeds, which passed through the rumen and diets in which the rumen was completely or substantially avoided respectively. The ratio of nitrogen retained as body tissue to nitrogen in wool differed in these two experiments, with Marston finding 6,3:1 and Black finding 2,8:1. These differences therefore show us that differences in the partitioning of nitrogen between wool and other body tissue is not similar in all diets, but differs according to where the ingesta were digested, with the highest correlation being found where the rumen was bypassed.

1.17. Competition between milk and fiber production

Doney (1964) on his study with Scottish Blackface sheep concluded that lactation does have inhibitory effect on fiber production. In all groups that he compared, the regression of wool production on lactation index did not differ, despite the differences in conditions under which they were reared.

Lactation increased the intake of the ewe but reduced its wool production (Langlands, 1977).

It was concluded therefore that whilst lactation has a depressive effect on wool or fiber production from grazing ewes, those ewes that were producing more milk didn't necessarily do that at the expense of wool production.

Demands of foetal development, live weight maintenance and presumably temperature regulation are all satisfied before wool production can be raised above the minimum (Doney, 1964).

As according to Doney (1964), both increases in live weight and lactation demands are satisfied before wool production can benefit, it implies that a genetic difference exists amongst breeds in their responses to nutritional and non-nutritional seasonal factors.

This is so when we consider the results of Ferguson *et al.* (1949) working with Merino, which shows there is a considerable increase in wool production when the diet changes from one which results in the loss of body weight to one that maintains it, whereas in the study of Doney (1964) there seems to be no change in wool production with changes in diet below maintenance level.

1.18. Nutrient partitioning between milk and fiber

Sahlu *et al.* (1992) compared Angora goats receiving 9; 12; 15 and 18% crude protein (CP) during their lactation. He found out that milk increased in a linear fashion with increase in dietary protein and then decreased at the 18 percent crude protein level, however percentage milk protein and solids not fat were not affected.

As far as mohair production is concerned, it was found out that it responded differently to different CP levels in the diet. In the 15 and 18% CP groups, milk yield increased for 10 weeks after parturition and peaked at 1.099 and 945g/day respectively at week six of lactation; however, milk production did not increase above the pretreatment level for does in the 9 and 12% CP groups (Sahlu *et al.*, 1992), whereas mohair production was drastically depressed to the lowest in the group fed the 15% CP and did not return to pretreatment level until week eight of lactation.

The does receiving 9 and 12% CP diets gained the most body weights compared to the 15 and 18% CP and Sahlu attributed this to the lower metabolic demand of their lactation, and hence these goats showed a steady increase in body weight and fiber production at the expense of milk yield (Sahlu *et al.*, 1992).

The does in the higher protein groups were able to divert both protein and body reserves into milk production, and at the highest level of dietary CP, they were able to increase both milk and mohair.

1.19. The Effects of pregnancy and lactation on feed intake

The physiological state of the animal affects feed intake, with intake generally higher if the physiological state is associated with increased demand. Forbes (1977) after a consideration of interrelationships between physical and metabolic control of feed intake in pregnant and lactating sheep, found that feed quality and litter size as well as stage of pregnancy could affect intake.

The predictions indicate that with low quality roughage intake will decline continuously during pregnancy, the decline being greater in ewes bearing twins than with those bearing singles. With medium quality roughage, increase in feed intake is expected until week twelve of gestation followed by a decline, with ewes bearing twins again being more affected.

With high quality feed, a progressive increase is predicted until week 16 followed by the decline, unaffected by the number of foetuses. Werston (1979) found the intake of medium quality roughage to be unaffected by the litter size. It seems likely that the increase in the rate of oestrogen secretion, together with an accompanying decrease in rumen capacity, could be important for the decrease in feed intake during late pregnancy (Werston, 1979).

Lactation in the sheep is always consistently accompanied by enhanced feed intake (Werston, 1979). Forbes (1979) found that the increase in intake is directly related to feed quality and litter size. It is presumed that the additional feed intake is related to the increased energy output in milk (Werston, 1979). There is little doubt that changes in hormone secretion are involved in mediating the intake response (Werston, 1979).

1.20. Interaction between physiological state of the animal, the protein to energy ratio of absorbed nutrients and fiber growth

The protein requirements are influenced by such factors in the animal as the potential rates of tissue growth, foetal growth and milk production (Kempton, 1979).

Assuming a biological value of 0.7 for absorbed protein and a ME requirements of 5.8 MJ/day, Kempton (1979) says that the ratio of absorbed nutrients required for maintenance would be 4g digestible protein/MJ of ME. Again assuming an efficiency of utilisation of ME for pregnancy of 0.2 and a biological value of absorbed protein of 0.7, then 17g digested protein would be required for conceptus gain, in a twin bearing ewe 30 days from term, 33g absorbed protein and 3.63 MJ of ME would be required for conceptus gain.

The requirements for pregnancy would therefore increase the required balance of nutrients to 5.0 and 5.7g digestible protein/MJ of ME in single and twin bearing ewes respectively (Kempton, 1979).

To achieve a maximum wool growth of 13g clean wool/day as well as maintain foetal development, Kempton (1979), an additional 80g absorbed protein would be required, assuming an efficiency of utilization of absorbed nutrients for wool growth of 0.1.

The balance of absorbed nutrients required for supporting maximum wool growth in single and twin-bearing ewes would therefore be 15.5 and 14.2g digestible protein/ MJ of ME.

In lactation, Kempton (1979) further said that assuming milk contains 5% crude protein and 4.8MJ/Kg, and the efficiency of utilisation of ME for lactation in ewes is 0.75, eight g digestible protein/MJ of ME would be required for peak lactation. In ewes with twins, milk production would be increased by 30% and the balance of absorbed nutrients required for lactation would be increased to 8.5g digestible protein/MJ of ME. Therefore the balance of nutrients required to support maximum wool growth at peak lactation would be 13.8 and 13.4g digestible protein/MJ of ME in ewes suckling singles and twin lambs respectively (Kempton, 1979).

Kempton (1979) further indicated that, where the major source of amino acids is from microbial protein, the amino acid supply would not meet the requirements for growth, late pregnancy, early lactation and wool growth.

Therefore in order to obtain maximum wool growth, live weight gain and milk production, at least 6g digestible protein/MJ of ME must be available to the duodenum in addition to the 6.6g digestible protein/MJ of ME supplied from microbial protein (Kempton, 1979).

1.21. Conclusion of literature review

Fiber growth has been reduced by about 30% during the second half of pregnancy, and where the level of nutrition is poor, the effects of pregnancy on wool growth manifest themselves very late.

Barren ewes have always been found to be superior in fiber production when compared to pregnant ewes during the pregnancy and also during lactation period. This can be attributed to the low requirements of nutrients in the body of barren ewes.

Lactation has different effects on the animal, dry matter intake increases, and more than 80% dry matter can be consumed by a single animal. On fiber production, lactation causes a reduction of 44%, this was seen when lactating ewes produced 44% less fiber than the ewes made sterile, for the first six weeks of lactation. In overall, complete lactation caused reduction of 26%. In the first few weeks of lactation, there is a major part of fiber production reduction and the effect becomes less as lactation advances. It therefore shows that up to the peak of lactation, there is much reduction of fiber growth than after the peak. The full cycle of reproduction reduces annual fleece growth by 10-14%, with the higher values applying more to the ewes rearing twin lambs. In this reduction in fiber growth during pregnancy and lactation, about one- third stems from a decrease in fiber number and two- thirds from a decrease in fiber volume.

The evidence from studies of the relationship between feed intake and wool growth rate indicates that the experiments based on contemporary comparisons, and which allow sufficient time for wool growth and diet to come into equilibrium, are likely to provide more reliable estimates than experiments that involve sequential feeding regimes. In the

experiments where fiber growth rate has been related to dry matter intake, the efficiency of feed conversion to fiber has usually diminished with increasing intake.

However, other evidence from Sahlu *et al.* (1992) suggests that the Angora goats receiving diets of about 9-12 CP increased their body weights and fiber production at the expense of milk production during lactation. Thus, it can be concluded that it depends on the amount of CP being received by the animal during lactation as less amount result in reduced milk production.

The major limitation in fiber production is the amount and composition of the amino acids available to wool follicles. Most of the protein fed to the animal ends up being degraded by microbes in the rumen of all ruminants. Therefore there should be a balance between the protein in the diet and the amount that ends up available to the animal, including microbial proteins, if maximum wool growth is to be attained in pregnant and lactating animals.

1.22. Hypothesis and aim

The hypothesis of this thesis is that the growth of hair on female goats is a function of genotype, physiological stage and plane of nutrition.

The aim of this study was to investigate the growth of fiber on goats as determined by genotype, (purebred Angora and crosses between Angora and Boer goat), physiological stages of the female from mid pregnancy until fifty days after the kids had been weaned and by plane of nutrition.

Chapter two

2.1. Methods of estimating fiber growth

Wool is a fiber and therefore methods of estimating wool growth are used here. Methods of estimating fiber growth date back to the early fifties where more researches concentrated on it due to the then new technology like dyebanding and tattooed patches. Up to this day, we have different methods of estimating wool growth rate, and on top of these, the fibre characteristics have to be determined with various methods that have been invented for that particular trait. There are various methods of estimating fibre diameter that we have today, this is because researchers concentrated on fibre diameter as the most important characteristic of fibre in economic importance. All the methods that exist today have some disadvantages and advantages and it depends on a particular researcher's choice, whether to use one of the methods or their combination.

The determination of fibre growth by these methods helps wool farmers to choose their breeds according to wool production and also expect changes in fibre production during different physiological stages of animal like lactation and pregnancy and also during different seasons.

2.2. Dye-banding

This method was developed after researchers tried to find an alternative to the tedious and time-consuming close clipping, which was generally used. Used in conjunction with fleece weight, dyebanded staples enable the amount of fibre produced by the animal over small periods to be estimated, provided the banded staples represents the period of fleece growth (Williams & Chapman, 1966).

This method uses a weak aqueous solution of Durafur Black R, which has the capacity to die greasy wool on the animal at skin temperature (Williams and Chapman, 1966). The length growth rate of the fleece is routinely determined by measuring the length of wool between two bands of dye, each applied to the fleece at skin level at different times (McCloghry, 1997)

The solution is prepared immediately prior to use by dissolving 0.8% of Durafur Black R flakes in cold water. When the flakes are dissolved, 0.8% of concentrated hydrogen peroxide (100 vol) is added as an oxidant. The resulting darker amber solution produces a black coloration in wool fibres in approximately four hours (Williams and Chapman, 1966). The prepared solution also darkens gradually and loses its dyeing efficiency as this occurs, hence the necessity of using a freshly prepared solution. Separate dye-bands can be produced with clear demarcation between them, by applying as frequently as 3-6 weeks a thin layer of the solution to the fibres at skin level from a Pasture pipette. Slight agitation of the solution at the skin surface with the tip of the pipette ensures adequate wetting of the base of the fibres without undue distortion of crimp and staple structure (Williams and Chapman, 1966). Fifty millimeters of the solution is sufficient to dye stripes on about 100-150 animals. Excess solution is removed from the skin surface by suction with the pipette and discarded, this leaves only a thin layer and helps to minimize spread of the solution along the fibres.

The black colour in the fibres is retained in the fleece of the animal either in the field or indoors and “bleeding” of the colour is not evident with the dye. The colour is unaffected by either the aqueous detergent solutions or the organic solvents commonly used for degreasing wool. No adverse effect has been observed so far on the skin of any of the numerous animals treated (Chapman, 1966).

2.3. Patching

In this technique, the production per unit area is determined by clipping an area of approximately 100cm² on the midside portion using animal clippers. The area of clipped skin is taken after clipping as the product of the means of three horizontal and three vertical measurements (Morley, Lockart & Davis, 1955). These measurements are taken with the animal reclining on a table in a relaxed condition, with no attempt to straighten folds on the skin. The clipped samples are taken in containers and weighed in the laboratory. These animals' samples are taken from the area on the animal after each period (Morley *et al.*, 1955).

2.3.1 Disadvantages

- (i) The technique is time consuming and only a limited number of animals can be sampled on each occasion (Clark and Kohn, 1964).
- (ii) The effect of frequent cutting probably alters subsequent regrowth of wool and may bias estimates of seasonal production (Bennet, Hutchinson & Manika Wodzika-Tomaszewska, 1962).
- (iii) Wrinkly animals are difficult to clip and frequently the wrinkles are damaged during cutting (Clark and Kohn, 1964).
- (iv) If tattooed area is used, considerable time can be spent in locating the tattoo. If a tattoo is not used, there is a danger of enlarging the area cut at each clip and later cuts may overestimate the growth (Clark and Kohn, 1964).

2.4. Measurement of fibre growth rate using Cystine labelled with Sulphur-35

This method arises due to the fact that when sulphur- 35 was injected intravenously into an animal, radioactivity was detectable in the wool follicles, just above the bulb, within a few minutes and appears in the fully keratinized fibre some hours later. If the rate and position of entry of Cystine into the fibres can be presumed to be constant, repeated injections of labelled Cystine at known intervals of time followed by autoradiography of the fibres should provide a method of measuring fibre growth. This provides a method that can measure fibre growth at intervals as short as 8 days.

After all these, the wool is clipped as evenly as possible from these defined areas. Each sample of fiber is washed well with ether, alcohol and also water, allowed to dry, and mounted on microscope slides. The amount of adhesive used, egg albumen at 0.1 mg/cm^2 caused negligible absorption of the α particles. About 20 separated fibres could be mounted on each slide. To measure the rate of wool growth, the slides are examined with a projection microscope ($\times 125$) and the distance between points of increasing silver grain density are measured with a flexible ruler. In this experiment, the mean growth rates of 10 fibres measured independently by four different observers differed by less than $\pm 2\%$.

This autoradiographic method of estimating growth of wool has two main advantages; the growth of wool fibres can be measured with good accuracy over short periods, of the order of few days; and repeated measurements of growth rates can be made without having to remove the fibres from the animal until the end of the experiment, thus avoiding possible side effects due to frequent shearing and shaving.

2.5. Methods of fibre diameter measurement

2.5.1(a) Projection microscope methods

This method was developed in various European laboratories over many years (Ryder and Stephenson, 1968). In this method a representative sample of wool is mounted as short lengths in cedarwood oil on a glass slide which is then placed on a projection microscope (Ryder and Stephenson, 1968).

The diameters of the projected images of the fibres are measured at a magnification of 500 with a transparent ruler. A standard sampling and randomization routine has been evolved to ensure that the sample is representative and the choice of fibres to be measured on the slide is made at random.

As wool fibres swell when they take up moisture, it is essential that the sample is conditioned in an atmosphere of 65% relative humidity (r. h.) at 20°C before the slide is made. Extreme atmospheric conditions can increase fibre diameter (Ryder and Stephenson, 1968).

Heated rooms have an r. h. of less than 65% and the table of factors supplied with the W. I. R. A. fineness meter shows that a change of 10% in r. h. can cause a change of 1% in mean diameter.

It has been found, however, that provided the length of fibre is greater than 0.8 mm it does not “lie on its side” to present only the major axis, and has no particular orientation with respect to the axis of cross-section (Ryder and Stephenson, 1968). When both edges of the fibres can be focused sharply at the same time there is no difficulty in measuring the distance between them. Frequently, however one edge is out of focus and appears as a

diffuse black or white line (known as Becke line). The correct way of measuring in this instance is to change the focus until the edge is sharply in focus, and the other edge has a white Becke line. The true diameter is then obtained by measuring the distance from the sharp edge to the inside of the white Becke line.

2.5.1 (b) The Automation of the projection-microscope method of fibre-diameter measurement

The modification of this type of measurement comes from the original one described above. One of the modifications was therefore a limitation of the numbers of fibres measured to 100, which is adequate to describe the distribution.

The apparatus used for this is a Gillet & Sibert 'Lynx' conference microscope used with a wall-mounted mirror to project an image vertically on to a levelled Bit-pad.

The system is calibrated by touching each end of a projected 300- μm scale with the Bit-pad stylus. The default setting the system is: fibre diameter, no medulla, and no pigmentation. In this setting, the diameter of non-medullated, non-pigmented fibres is measured by touching the projected image of each edge of each fibre with the stylus. The system is programmed to produce an audible tone to acknowledge the recording of that position. The presence of medullation or pigmentation or both is indicated to the system by touching the appropriate control of the Bit-pad with the stylus. With medullation, the diameter of the fibre is measured before that of the medulla. On completion of each measurement, the system displays the number of measurements made, the fibre diameter, the medulla diameter and the presence or absence of pigmentation.

Gross errors, such as a fibre diameter less than 1 μm or more than 200 μm or a medulla diameter greater than the external diameter, are detected by the system and rejected. The operator is alerted to the rejection by an audible tone.

The system is programmed to terminate measurement after 100 successful measurements, and again the operator is alerted by an audible tone. Termination after fewer than 100 measurements is possible by touching the stylus on the 'terminate' control area of the Bit-pad.

2.5.2 The Gravimetric method

This method was developed by W. I. R. A and involves the measurement of the length of a known number of non- medullated fibres, which are then conditioned and weighed from the weight of the sample, its density, and the total length, the mean cross- sectional area can be found, and hence the root- mean- square diameter D by the following formula:

$$\sqrt{4 * \text{wt of sample} / d * \text{total length}}$$

Where d = the density of wool = 1.31 at 20°C and 65% r. h.

2.5.3 The Compressor meter method

This simple and rather rapid method described by Wilson (1951) involves the compressing of a sample of wool fibres from a measured area of skin into a metal slot and the making of a cast impression of their cut ends. This was primarily developed to give a rapid method of determining fleece density, but measurement of fibre diameters on the cast on a slide with a projection microscope gives a useful method of comparing the fibre diameter of a group of fleeces.

2.5.4. The Porous plug method

This method depends on forcing air under a standard pressure through a plug of wood weighing about 6g, and measuring the rate of flow of air through it. From this, and the weight of the fibres, their surface area and hence the diameter can be determined. One apparatus for carrying out this method has been developed by the Sheffield Corporation in the U. S. A and another by W. I. R. A in Britain (Anderson, 1954).

2.6. Measurement of fibre length

The staple length can be measured to the nearest 0.5 cm by placing the staple against a ruler, but the accuracy depends very much on how close the fibres have been cut to the skin and on the extent of length variation. Thus in very 'tippy' wool the staple length will refer to the longest fibres only, and although the length of the tip can sometimes be measured separately, it is usually difficult to define the length of the bulk of the fibres.

(I) In this basic method of measuring fibre length, the fibre is gripped at each end by forceps held in each hand, and laid against a black scale. The pointed tips of one pair of forceps are made to coincide with a mark on the scale, and then the fibre is drawn out until the crimp is removed. The position of the second pair of forceps allows the length to be measured to the nearest 0.5 cm, the length being recorded in length groups, 1- 1.5cm, 1.5- 2cm and so on (Ryder and Stephenson, 1968).

(ii) The semi- automatic length-measuring machine developed at the W. I. R. A allows fibre length to be measured under controlled tension. Other advantages of the machine are that it is necessary to grip the fibre at one end only, making measuring quicker and easier, and that measurement and the assignment to a length group are automatic, so minimizing observer differences.

In order to measure a fibre it is gripped at the very end with special forceps; the fibre is led through a guide and an operating button is depressed. The forceps are introduced in to a groove in a revolving screw, which carries them to the right. The operating buttons cause a wire-tensioning arm to come down and rest on fibre. When the free end of the fibre slips from under the arm, the end of the wire drops in to a pool of mercury and makes an electrical contact which causes the screw to stop, so indicating the fibre length (Ryder & Stephenson, 1968).

(iii) The use of Fibre Length Meter or Fibre Diagram Machine, designed to work with samples of combed wool produced during processing. In this machine, the draw is traversed between the electrodes of the machine and an indication is given of the amount of fibres at different distances from the aligned ends of the draw. At the same time a

permanent record on a paper is obtained on a standardised form from which the percentage of fibres of different lengths can be read off.

Chapter three

Materials and methods

3.1. Objectives:

An experiment was conducted at the University of Pretoria, Hatfield Experimental Farm, which lasted for 300 days. The purpose of the study was:

- To investigate the rate of growth of fiber during different physiological stages of ruminants (pregnancy and lactation).
- To establish the effects of genotype (Angora and Angora x Boer goat) as far as fiber growth is concerned, coupled with different planes of nutrition.

3.2. Experimental design

Twelve female Angora (pure-bred) does with an initial average mass of $28.70 \text{ kg} \pm 4.42$ with ages varying between three and five years were used. Before the experiment began, all the animals were shorn using the fine clippers. Care was taken during shearing not to harm the animals by avoiding pinning them down hard. To get them pregnant, these does were synchronized using vaginal sponges. The sponges were inserted into their vaginas and remained inside for a period of 14 days. There was a string of cord attached to the each sponge and the cord was left hanging outside for the smooth removal of the sponge. After the removal of the sponges, each doe was given an intramuscular injection of PMSG (Pregnant Mare Serum Gonadotropin) on the same day of the sponge withdrawal. They were then left for a period of two days, after which they were showing strong heat signs. On the same day (2nd day after injection), they were artificially inseminated using purebred Angora buck semen.

Ten Angora x Boer goat doe's were brought to the Hatfield Experimental Farm from the Jansenville Experimental Farm. These crossbreds were 75% Angora and 25% Boer goat cross. These does had been mated naturally to a buck of the same genotype that had been

performance tested in March and April and the pregnant does only arrived on the Hatfield Experimental Farm in June, the beginning of their last quarter of pregnancy.

These animals were on the veld in Jansenville, and on their arrival in Hatfield Experimental Farm, they were given an adaptation ration that was comprised of 80% hay and 20% concentrates. The concentrate percentage was increased gradually until only concentrates were fed. This was to avoid acidosis (McDonalds, 1992). They were also patched and dybanded the day they arrived. The first samples of fiber from the resultant patches were discarded because they represented a growth that had started before the animals had conceived. The growth of fiber was therefore measured over the last quarter of pregnancy to parturition.

The twelve crossbred does were also used by my colleagues to take blood samples for their experiments. There were twenty-four housing pens with concrete floors and demarcated by rails to avoid mingling. Each pen contained a trough of clean water, a small feeding trough, and all the pens were cleaned twice a week. There was a roof on their house to protect the animals from rain. Bedding was provided during the winter months.

Feeding was according to the body mass as recommended by the (NRC, 1981), until kidding. After the does kidded, they were divided into two groups, one group receiving 80% of the NRC requirement and the other group receiving 120% of the NRC requirements. All the animals were weighed weekly.

3.3 Dye-banding

The dyebanding technique as described by Williams *et al.*, (1966) was the method used to measure the animal's fiber growth.

3.4 Preparation of the dye-band solution

Phenylene diamine (0.4 grams) was dissolved in 50 ml of distilled water and 10 drops of concentrated hydrogen peroxide were added. It was swirled and mixed until dissolved. That provided enough to dye-band 50 animals, depending on mohair type. The mix then would take a few minutes to develop, and was protected from sunlight as much as

possible. This solution would take between 30 minutes and an hour to be strongly visible on the fiber. The prepared solution was only viably effective for a period of 30 days after which the strength of the dye was reduced to a point where it couldn't dye the fiber visibly enough. Usually a new one had to be prepared during each session because there was always an interval of more than 30 days between dyebandings.

3.5 Application of the dye-band solution

A period of 40 to 50 days, depending on the physiological stage, was allowed to lapse between the applications. The dye was applied at beginning of the last trimester of pregnancy, kidding, mid-lactation and at weaning. The solution was applied at skin level. Care was taken to avoid the solution from smudging the previous demarcation.

3.6 Harvesting the dye-bands

This was done only once, thus after weaning of the kids. The sample with the dye-band solution was harvested at skin level, and then measurements of the dye-band length were taken using a ruler. The measurements taken were the differences in length from one bottom of the dyeband to the other.

3.7 Patching

Patching was coupled with dyebanding at each session. Samples were taken from the shoulder as well as the midrib, using a fine clipper. Patches of 10 by 10 centimeters were made. The patches were measured on the animal using a graph paper as to obtain an accurate patched square. The samples from these patches were conditioned in a wool room for a period of 24 hours in order to absorb moisture. The temperature of the room was 22°C and the humidity was kept at 60% as described by (Masters, Mata, Liu and Peterson, 1998). These samples were then measured in grams thereafter without scouring.

The pregnant ewes were clipped within a day of parturition in order to separate pregnancy effects from those of post pregnancy and lactation as described by (Williams and Suijdendorp, 1968).

3.8 Nutritional planes

Three animals that kidded were given a high plane of nutrition (120% NRC energy requirements) and the other three were in a low plane of nutrition (80% NRC energy requirements). The diet contained 10.7MJ ME/kg and 12% protein (commercial winter ration, Silgro Feed Company). This went on until all the animals' kids had been weaned.

3.9. Parity

Three animals from the crossbreds had twins that were raised successfully, and the other animals in the experiment had singles only. Only three animals from the purebred Angora conceived and only one doe raised the kid successfully. The other two had kids that died during the first day of life due to cold.

3.10. Calculation of the fiber weight

All the patch samples that were harvested were weighed without being washed to determine their greasy weight. The area of skin from which the mohair samples were harvested was measured in square centimeters. The figure that was obtained was a greasy wool growth in milligrams/ cm²/ day.

The mohair production over a period of time was calculated using the following formula:

$$\frac{\text{Mohair sample weight} \times 1000}{\text{Harvested area (cm}^2\text{)} \times \text{period of growth}}$$

3.11. Chemical analysis

The chemical analysis for nitrogen content was done on all the samples, in duplicate, according to the approved methods of (AOAC, 1990). Macro-Kjedahl method was used and the mean values were the ones considered.

Chapter four

RESULTS

4.1 Mohair growth

4.1.1 Locality difference in mohair growth during different physiological stages

Statistical analysis:

Data was analyzed by General Linear Models Procedure (SAS, 1993). The model took the effect of the locality and fiber growth into account.

Table 4.1. Least Square Means and Standard Errors for Growth Period (GP). All measurements are in mg/cm²/day.

EFFECT	Hair Growth Period			
	GP1	GP2	GP3	GP4
	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Locality				
Shoulder (S)	0.83±0.17	0.50±0.20	0.67±0.20	0.83±0.17
Midrib (M)	0.17±0.17	0.33±0.20	0.17±0.20	0.67±0.17
Nutrition				
Nutrition 1	0.67±0.17	0.67±0.20	0.50±0.20	1.00±0.17
Nutrition 2	0.33±0.17	0.17±0.20	0.33±0.20	0.50±0.17
Interaction				
Loc S*Nu1	1.00±0.23	0.67±0.29	0.67±0.29	1.00±0.23
Loc S*Nu2	0.67±0.23	0.33±0.29	0.67±0.29	0.67±0.23
Loc Mi*Nu1	0.33±0.23	0.67±0.29	0.33±0.29	1.00±0.23
Loc Mi*Nu2	0.00±0.23	-0.00±0.29	-0.00±0.29	0.33±0.23

GP1= 100 days before parturition to parturition; GP2= Parturition to mid-lactation; GP3= Mid-lactation to weaning; GP4=Weaning to fifty days post weaning.

Table 4.2. Least Square Means and Standard Errors for fiber Protein Content (PR). Protein content is measured in percentages.

	PR1	PR2	PR3	PR4
EFFECT	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Locality				
Shoulder (S)	83.00±1.43	87.33±0.73	86.50±0.73	87.83±0.86
Midrib (M)	85.17±1.43	86.67±0.73	86.50±0.73	88.33±0.86
Nutrition				
Nutrition 1	83.67±1.43	87.50±0.73	86.17±0.73	88.83±0.86
Nutrition 2	84.50±1.43	86.50±0.73	86.83±0.73	87.33±0.86
Interaction				
Loc S*Nu1	82.33±2.02	87.67±1.03	86.00±1.03	89.00±1.21
Loc S*Nu2	83.67±2.02	87.00±1.03	87.00±1.03	86.67±1.21
Loc Mi*Nu1	85.00±2.02	87.33±1.03	86.33±1.03	86.67±1.21
Loc Mi*Nu2	85.33±2.02	86.00±1.03	86.67±1.03	88.00±1.21

PR1= Protein content during GP1; PR2= Protein content during GP2; PR3= Protein content during GP3; PR4= Protein content during GP4.

Table 4.3 Analysis of variance for growth period (physiological stage)(GP)

Sources	GP1		GP2		GP3		GP4	
	DF	MS	DF	MS	DF	MS	DF	MS
Locality	1	1.33	1	0.08	1	0.75	1	0.08
Nutrition	1	0.33	1	0.75	1	0.08	1	0.75
Loc*Nut	1	0.00	1	0.08	1	0.08	1	0.08

R^2 (GP1) = 0.55; R^2 (GP2) = 0.31; R^2 (GP3) = 0.31; R^2 (GP4) = 0.41

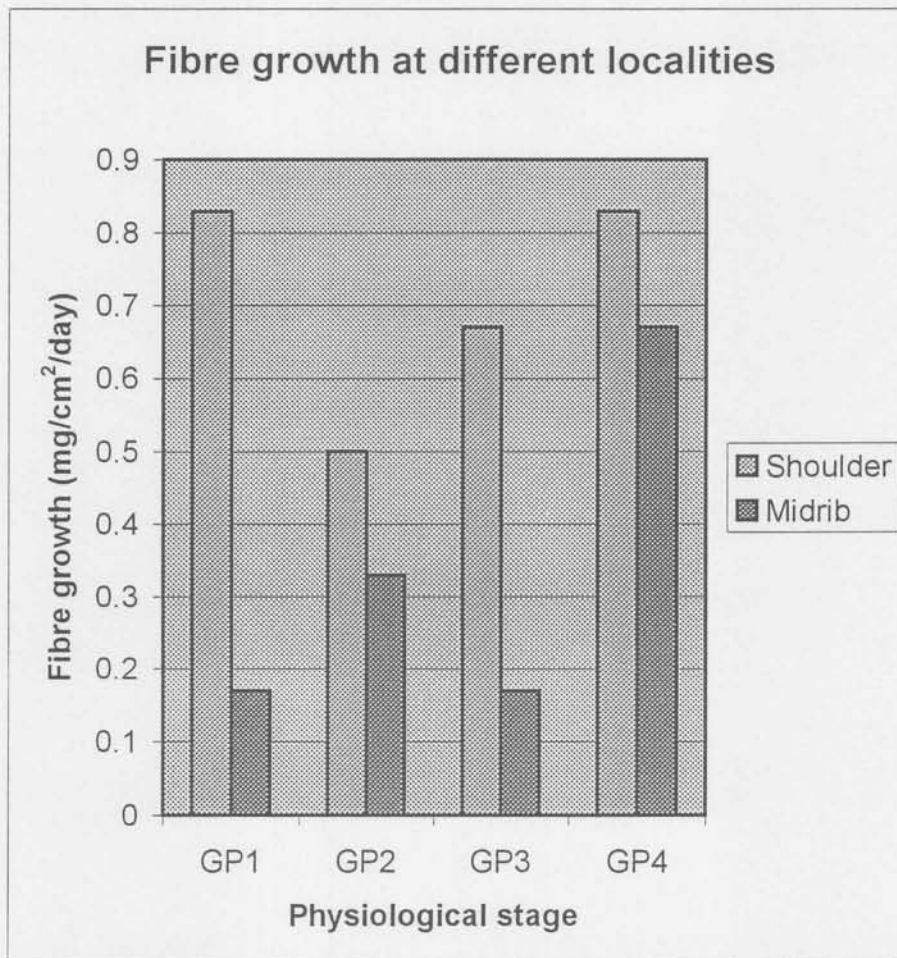
Table 4.4 Analysis of variance for protein content (PR) at various physiological stages

Sources	PR1		PR2		PR3		PR4	
	DF	MS	DF	MS	DF	MS	DF	MS
Locality	1	14.1	1	1.33	1	0.00	1	0.75
Nutrition	1	2.08	1	3.00	1	1.33	1	6.75
Loc*Nut	1	0.75	1	0.33	1	0.33	1	2.08

R^2 (PR1) = 0.14; R^2 (PR2) = 0.16; R^2 (PR3) = 0.06; R^2 (PR4) = 0.21

4.1.2 Locality differences

There was a significant difference in growth of mohair between localities during the first physiological stage before the kids were born ($P < 0.05$). However after the first physiological stage, thus from the time the kids were born onwards, the growth of fiber at the different locality patches didn't differ significantly (figure 4.1).



GP1= 100 days before parturition to parturition; GP2= Parturition to mid-lactation; GP3= Mid-lactation to weaning; GP4=Weaning to fifty days post weaning.

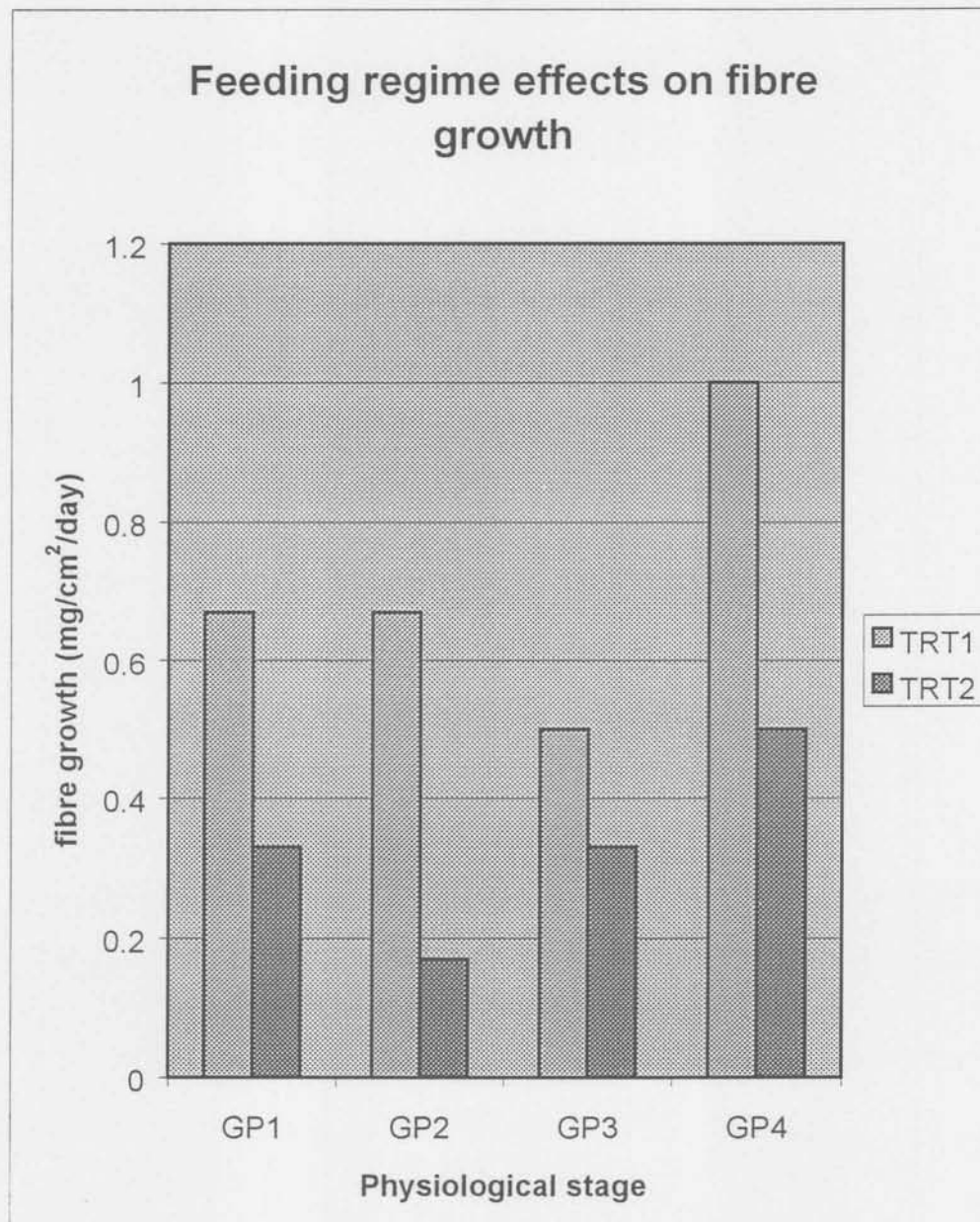
Figure 4.1 Growth of mohair at shoulder and midrib during different physiological stages. Locality difference was significant only during the first physiological stage, during the last one hundred days of parturition. Mohair patch at shoulder had a heavier greasy mass ($0.83\text{mg/cm}^2/\text{day} \pm 0.17$) as compared to the one at midrib ($0.17\text{mg/cm}^2/\text{day} \pm 0.17$). Of all observations, the Angora x Boer goat appears to have a lighter greasy fiber production on their midribs than the shoulders. As is shown in Table 4.1, locality M (midrib) during different physiological stages ranged from (0.17 ± 0.17) to (0.67 ± 0.17), while locality S (shoulder patch) ranged from (0.50 ± 0.17) to (0.83 ± 0.17).

4.1.3 Effects of feeding level on fiber growth

Least square means for this analysis are shown on Table 4.1 and the analysis of variance on Table 4.3.

During the first physiological stage (GP1), 120% requirements yielded (0.67 ± 0.17) average greasy fiber mass as compared to 80% requirements, which yielded (0.33 ± 0.17). There was no significant difference between the two treatments ($P > 0.05$). Feeding at 20% more than the recommended level resulted in increased fiber production during subsequent stages of lactation with lowered fiber growth at 80% requirements during the similar periods.

Figure 4.2 Effects of nutritional levels on fiber growth



GP1= 100 days before parturition to parturition; GP2= Parturition to mid-lactation; GP3= Mid-lactation to weaning; GP4=Weaning to fifty days post weaning.
TRT1= 120% NRC requirements; TRT2= 80% NRC requirements.

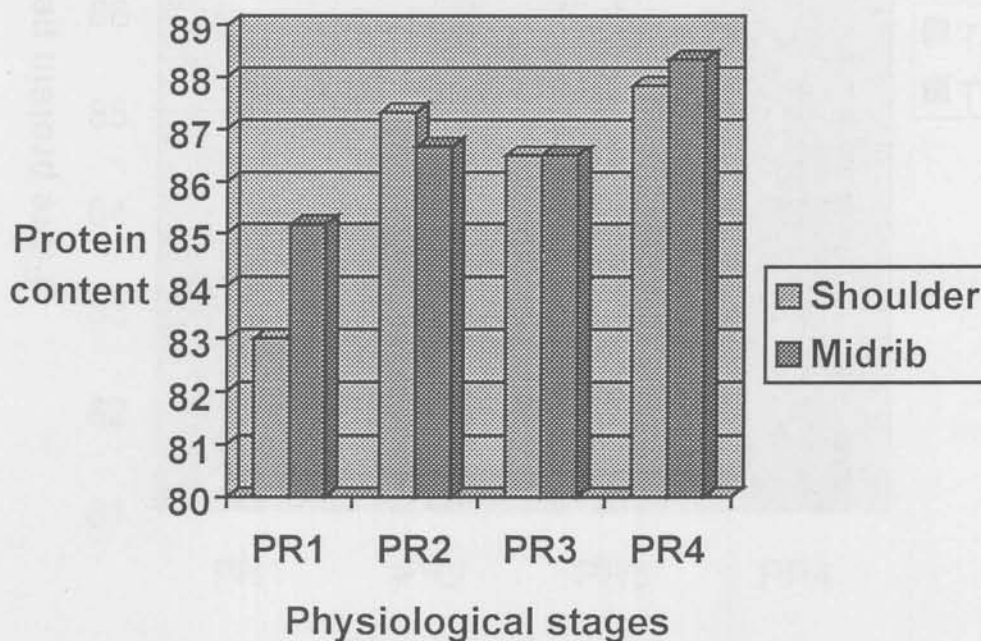
There were no observed significant differences between a high and a low nutritional plane during any of the physiological stages under this study ($P>0.05$).

4.1.4 Locality differences and fiber protein content

Least square means and analysis of variance are shown in Tables 4.1 and 4.2 respectively.

Figure 4.3 Shows the differences were no significant difference between localities

Locality differences in protein content of mohair at different physiological stages



PR1= Protein content during GP1; PR2= Protein content during GP2; PR3= Protein content during GP3; PR4= Protein content during GP4.

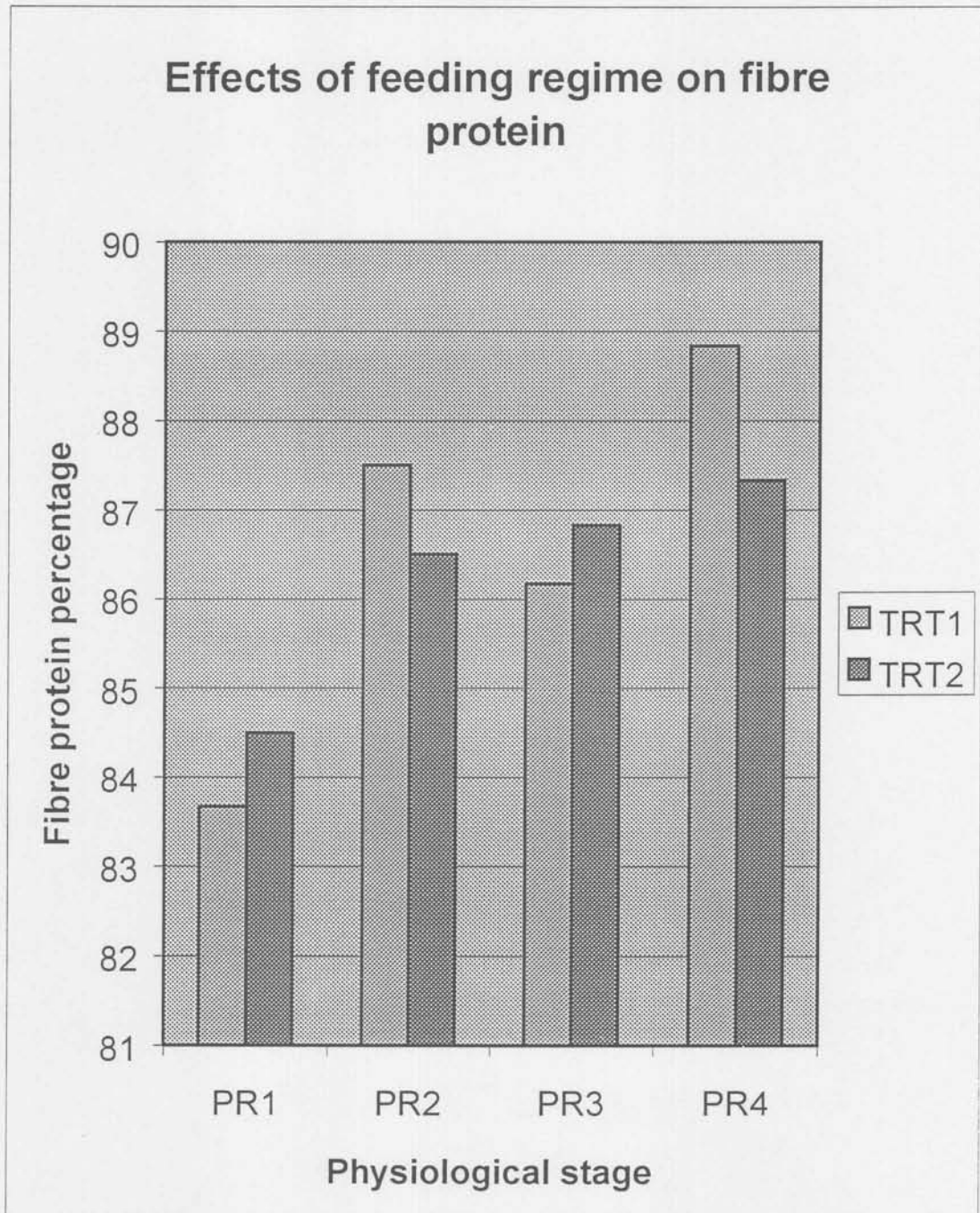
Protein percentage appeared to increase after parturition (83.00 ± 1.43 for shoulder patch and 85.17 ± 1.43 for midrib) in all localities until mid-lactation (87.33 ± 0.73 , shoulder and 86.67 ± 0.73 midrib) and was at highest in the patches harvested fifty days after weaning of kids (87.83 ± 0.86 for shoulder and 88.33 ± 0.86 for midrib). It again increased after the kids were weaned. There were no significant differences between fiber protein contents for the shoulder patch and midrib patch during the physiological stages under this study.

4.1.5 Nutritional plane effect on fiber protein content

Although there were slight differences between protein contents at various feeding regimes and physiological stages, there appear to be no significant difference between a higher and a lower level of nutrition ($P > 0.05$).

During the first stage before parturition, the fiber protein content was (83.67 ± 1.43 for a higher nutritional plane and 84.5 ± 1.43 for a lower nutritional plane). There was no R^2 which was greater than 0.21. The protein percentages are shown in figure 4.4, peaking up at 88.83 ± 0.86 for a higher nutritional level and 87.33 ± 0.86 for a lower nutritional levels during the last period of the experiment.

Figure 4.4. Level of feeding and protein content



PR1= Protein content during GP1; PR2= Protein content during GP2; PR3= Protein content during GP3; PR4= Protein content during GP4.

TRT1= 120% NRC requirements; TRT2= 80% NRC requirements.

4.1.6 Interaction between locality and level of feeding

Analysis of variance for the interaction between these two factors is shown in Table 4.3 and Table 4.4, while the least square means are found in Table 4.1 and Table 4.2.

Interaction between (the high level of nutrition and locality 1 (shoulder)) and (low level of nutrition and locality 1) didn't have a significant difference ($P>0.01$) during the first physiological stage. The interaction between (a high level of nutrition x locality 1) and (a low level of nutrition x locality 2) yielded significant difference ($P<0.05$).

There were no significant differences between locality and level of feeding interaction during the period from parturition to mid-lactation and all the subsequent growth stages ($P>0.05$).

Fiber protein content was also not affected by the interaction between the level of feeding and locality.

4.2 Discussion

In studies that have been conducted over the past years, it has been shown that purebred Angora goats have high nutrients requirements and give nutritional advantage to fiber growth at the expense of other demands like body growth and fetal development (Johnson, 1998). Where the demand for lactation was higher e.g. from parturition to mid-lactation, mohair production dropped by 39.7%. Cameron *et al.* (2000) also found that crossbred animals between Angora goat x Boer goat had better performance after weaning than the resultant cross with other goats. Corbett, (1966); Ray and Sidwell, (1964); Brown *et al.* (1966); Mullaney *et al.* (1969) found that the reduction in fiber growth among lactating does occurs even though the feed intake is greater. This was not the case in this experiment with the crossbred animals as the increased feeding level also meant increased fiber production.

The crossbred animals were larger in frame and hardier than the Angora. Waldron *et al.* (1996) also found that even at 100 days of age the purebred Angora kids weighed 6.3 pounds less than kids sired by meat breeds.

At low levels of nutrition the Boer x Angora cross, had a reduced greasy fleece weight than at a high level of nutrition. This shows that the crossbred of the two genotypes is better adapted to nutrient partitioning during pregnancy and lactation. Mohair production from animals under the low plane of nutrition was 50.7% lower compared to a high plane of nutrition during the first period. Restriction of feed intake had a more adverse effect on mohair growth at peak lactation. The restricted animals produced 74.6% less mohair than the animals that had a higher plane of nutrition and this performance was also 48% lower than during the pregnancy period. From the peak of lactation to weaning mohair production increased by 48% for the animals under the low plane of nutrition and continued increasing steadily after the animals were weaned (34%). There were no long-term effects on feed intake restriction on these animals. Feed intake restriction was attributed to having a longer term effect on fiber growth than body weight change, suggesting that special attention be given to avoiding even short-term periods of low feed intake if maximal fiber production is to be achieved (Sahlu *et al.*, 2000). The crossbred animals do not appear to have such effects on this experiment.

A higher nutritional level resulted in heavier greasy fleece weight, as highlighted before. The animals showed a 25% reduction was recorded at weaning. Mohair growth from these animals after weaning increased by 50%. Where nutrient supplies were low, fiber production was also lower amongst the crossbred as highlighted before. This shows that the crossbred do not have imbalances that occur in present day Angora purebred and can present a solution to the problem faced by mohair farmers. However, for the maximum fiber production, animals should not be restricted to feed, particularly during lactation as this will have an adverse effect on the expression of their true genetic potential for fiber production. Selection for improved mohair fiber production from the cross animals needs to be practiced together with other aspects of fertility like milk production, kid survival and abortion rate.

Body area differences in animals don't appear to have been studied extensively in the past. In this study body area differences were significant ($P < 0.05$) during hundred days to parturition and mohair growth was low at mid-lactation but increased by 34% at weaning and 66% at fifty days post weaning.

Pregnancy suppressed mohair production in Angora goats (Torien, *et al.*, 2000). Ivey *et al.* (2000) found that the effects on pregnancy and lactation on fiber growth are due to physiological changes associated with pregnancy and lactation rather than via nutrient competition. Fiber production was at its highest during pregnancy in the crossbred animals in this experiment. Newman *et al.* (1994) also found that fleece weights of the crossbred between New Zealand Angora and the South African Angora were intermediate between parental breeds at all shearing times.

Fiber protein content of the sample from the shoulder was low during pregnancy (83 ± 1.43) as compared to (87 ± 0.73) at peak lactation.

Nutritional treatment effects only yielded a slight difference in fiber protein content. The highest protein content for a high nutritional plane was 88.83 ± 0.86 while it was 87.33 ± 0.86 for the lower plane of nutrition. These higher protein percentages were recorded only after weaning. Protein percentages of the two body areas under investigation also increased from the period of pregnancy to weaning, although these differences were not significant. This can suggest that the crossbred animals diverted more protein to fetal

growth during pregnancy and milk production during lactation. After these physiological stages, more protein was found in the fiber. Other areas that will need further research are the fiber characteristics of crossbred animals. Compared with the purebred, the crossbred produced more coarse fiber.

4.3 Conclusions

The present results show that midrib patches from all animals had a lower greasy weight than the shoulder patches.

Physiological stages, pregnancy and lactation, had an adverse effect on fiber production, this is evident by the fact that there was a substantial increment in fiber production after the kids were weaned.

Nutritional levels affected mohair production of the crossbred animals. High plane of nutrition always resulted in increased production of fiber while restricted feeding lowered fiber production. Protein content of the fiber was also decreased the time the animals were weaned, further showing that preference was directed to the mammary gland during the period of lactation. This resulted in 90% kid survival among these animals. This is an important aspect and gives them advantage over the purebred Angora that are known for kid mortalities of up to 12%.

The results support the hypothesis that the F² crossbred had reduced fiber growth during gestation and lactation, partitioning nutrients to these physiological functions other than directing it to fiber production. However, in overall the F² crossbred produced less fiber than the purebred Angora goat.

Chapter 5. References

Adams, N. R., Briegel, J. R. and Ritchie, J. M. (1997). Wool and liveweight responses to nutrition by Merino sheep genetically selected for high or low staple strength. *Aus. J. Agr. Res.* **48**: 1129.

Allden, W. G. 1969. The summer nutrition of weaner sheep: Voluntary feed intake, body weight change, and wool production of sheep grazing the mature herbage of sown pasture in relation to the intake of dietary energy under supplementary feeding regime. *Aust. J. Agric. Res.* **20**: 499.

Allden, W. G. (1968b). Undernutrition of the Merino sheep and its sequelae. III. The effect on lifetime productivity of growth restrictions imposed at two stages of early postnatal life in a Mediterranean environment. *Aust. J. Agrc. Res.* **19**: 981

Allden, W.G. (1979). In *Physiological and Environmental limitations to wool growth*, p.61, Eds. J. L. Black and P. J. Reis. (University of New England Publishing Unit: Armidale).

Anderson, S. L. (1954). The air-flow method of measuring wool fiber fineness. *J. Text. Inst.* **45**: 312.

Black, J. L., Robards, G. E. & Thomas, R. (1973). Effects of protein and energy intake on wool growth of Merino wethers. *Aust. J. Agric. Res.* **24**: 399.

Blaxter, K. L. (1964). Utilization of the metabolizable energy of grass. *Proc. Nutr. Soc.* **23**: 62.

Bennet, J. W., Hutchinson. J. C. D. & Manika Wodzicka-Tomaszewska. (1962). Annual rhythm of wool growth. *Nature*. **194**: 651.

Bosman, V. (1935). The influence of pregnancy and lactation on Merino wool production. *Onderstepoort. J. Vet. Sci and Ani. Ind.* **4**:551

Brown, G.H., Turner, H.N., Young, S. S. Y., and Dolling, C. H. S (1966). Vital statistics for an experimental flock of sheep. 3. Factors affecting wool and body characteristics, including the effects of age of ewe and its possible interaction with method of selection. *Aus. J. Agric. Res.* **17**: 557.

Cameron, M., Luo, J. Sahlu, T., Hart, S and Coleman, S. (2000). Postweaning growth performance in Spanish, Boer x Spanish, and Boer x Angora goat kids. Goat Research. Langston University.

Clark, N. T. & Kohn, D. G. (1964). The measurement of seasonal wool production-a comparison between midside sampling and a dye-banding technique. *Aust. J. Exp. Agric. Anim. Husb.* **4**: 90.

Corbett, J. L. (1964). Effects of lactation on wool growth of Merino sheep. *Proc. Aust. Soc. Anim. Prod.* **5**: 138.

Corbett, J. L., (1966). Effects of pregnancy, length of lactation and stocking rate on the performance of Merino sheep. Proceedings of the Tenth International grasslands Congress, P: 491.

Corbett, J. L. (1979). In *Physiology and Environmental Limitations to Wool Growth*, p. 79, Eds. J. L. Black and P. J. Reis. (University of New England Publishing Unit: Armidale).

Corbett, J. L. and Furnival, E. P. (1976). Performance of ewes. *Aust. J. Exp. Agric. Anim. Hus.* **16**: 156.

Daly, R. A. and Carter, H. B. (1955). Fleece growth of young Lincoln, Corriedale, Polwarth, and fine Merino maiden ewes under housed conditions and unrestricted and progressively restricted feeding on a standard diet. *Aust. J. Agric. Res.* **6**: 476.

Doney, J. M. (1964). The fleece of Scottish Blackface sheep. Iv. The effects of pregnancy, lactation and nutrition on seasonal wool production. *J. Agric. Sci.* **62**: 59.

Edwards Hocking, J. E., and Hynd, P. I (1992). Cellular characteristics of wool follicles and fibres in fine wool and strong wool Merinos. *Aus. J. Agric. Res.* **43**: 355.

Ferguson, K. A. (1972). The relation between the responses of wool growth and body weight to changes in feed intake. *Aust. J. Biol. Sci.* **15**: 720.

Ferguson, K. A. (1972). The nutritional value of diets for wool growth. *Proc. Aust. Soc. Anim. Prod.* **14**: 636.

Ferguson, K. A., Carter, H. B. and Hardy, M. H. (1949). Studies of comparative fleece growth in sheep. 1. The quantitative nature of inherent differences in wool growth rate. *Aust. J. Sci. Res B.* **2**: 42.

Forbes, J. M. (1977). Interrelationship between physical and metabolic control of voluntary food intake in fattening, pregnant and lactating mature sheep: a model. *Animal Production.* **24**: 91.

Hansford, K. A. and Kennedy, J. P. (1988). Relationship between the rate of change in fibre diameter and staple strength. *Proceedings of the Australian Society for Animal Production.* **17**: 415.

Herselman, M. J., Olivier, J. J. and Snyman, M. A. (1998). Studies on small ruminant breeds with inherent differences in fibre production and ewe productivity. 1. Relationship between ewe productivity and wool production. *S. Afr. J. Anim. Sci.* **28**: 1.

Hogan, J. P. (1970). Protein limits to production in ruminants. *Proc. Aust. Soc. Anim. Prod.* **8** : 1.

Hogan, J. P., Elliot, N. M. & Hughes, A. D. (1979). Maximum wool growth rates expected from Australian Merino genotypes. In *Physiological and Environmental Limitations to Wool Growth*. University of England Publishing unit, Armidale, N. S. W., Australia. Pp 43.

Ivey, D. S., Owens, F. N., Sahlu, T., Th, T. H., Dawson, L. G., Campbell, G. A and Goetsch, A. L. (2000). Influences of the number of fetuses and levels of CP and ME in gestation and lactation supplements on performance of Spanish Does and kids during suckling and post-weaning. *Small. Rum. Res.* **35**: 123.

Johnson, J. U. (1998). Herd health program-General Management Practices. Animal Health Watch: Angora Goats **vol.2**.

Kenny, P. A. and Davis, I. F., (1975). Effect of time of joining and rate of stocking on the production of Corriedale ewes in Southern Victoria. 3. Wool growth and the composition and availability of pasture. *Aus. J. Exp. Agri. Anim. Hus.* **15**: 159.

Kempton, T. J. (1979). In *Physiological and Environmental Limitations to Wool Growth*, p. 209, Eds. J. L. Black and P. J. Reis. (University of New England Publishing Unit : Armidale)

Langlands, J. P. (1977). The intake and production of lactating Merino ewes and their lambs grazed at different stocking rates. *Aust. J. Agric. Res.* **28**: 133.

Langlands, J. P. and Donald, G. E. (1977). Forage intake and its relationship to wool production. *Aust. J. Exp. Agric. Anim. Hus.* **17**: 247.

Leng, R. A. & Leonard, G. J. (1965). Measurement of rates of production of acetic, propionic and butyric acids in the rumen of sheep. *Br. J. Nutr.* **19**: 469.

Lyne A. G. (1964). Effects of adverse nutrition on the skin and wool follicles in Merino ewes. *Aust. J. Agric. Res.* **15**: 788.

Marston, H. R. (1948). Nutritional factors involved in wool production by Merino sheep. *Aust. J. Sci. Res* **B**. 1: 362.

Masters, L. C., Mata, G., Liu, S. M., Peterson, A. D. (1998). Influence of liveweight, liveweight change and diet in wool growth, staple strength, and fiber diameter in young sheep. *Aust. J. Agric. Res.* **49**: 269.

McCloghry, C. E. (1997). Alternative dyebanding method for measuring the length growth rate of wool in sheep. *New Zealand. J. Agric. Res.* **40**: 569.

McDonald, P., Edwards, R. A. and Greenlough, J. F. D. 1991. *Animal Nutrition*. Fourth edition. Longman Singapore Publishers.

McGuirk, B. J., Paynter, J. R. and Dun R. B. (1966). The effects of frequency and time of shearing on the production and wool growth of Bungaree South Australian Merino ewes. *Aust. J. Exp. Agric. Anim. Hus.* **6**: 305.

Morley, F. H. W., Lockart, L. W., Davis, E. C. (1955). The value of production from a clipped measured area as an index of fleece weight. *Aust. J. Agric. Res.* **6**: 91.

- Mullaney, P. D., Brown, G. H., Young, S. S. Y., and Hyland. P. G. (1969). Genetic and phenotypic parameters for wool characteristics in fine wool merino, Corriedale, and Polwarth sheep. 1. Influence of various factors on production. *Aus. J. Agric. Res.* **20**: 1161.
- Nagorcka, B. N. (1977). The description and analysis of wool growth. *Aust. J. Agric. Res.* **28**: 737.
- Neutze, S. A. (1990). Use of wool growth response to estimate escape of protein supplement from the rumen. *Aust. J. Agric. Res.* **41**: 761.
- Newman, S-A. N., Paterson, D. J and Power M. T. Liveweight and fleece production from New Zealand, South African and first cross Angora goats. *Proc. New. Zea. Soc. Anim. Prod.* **54**: 151.
- NRC. 1981. Nutrients requirements of goats. National Academy Press. Washington, DC.
- Oddy, V. H. (1985). Wool growth of pregnant and lactating Merino ewes. *J. Agric. Sci. Cambridge.* **105**: 613.
- Oddy, V. H. and Annison, E. F (1979). In *Physiological and environmental Limitations to Wool Growth*, p. 295, Eds. J. L Black and P. J. Reis. (University of New England Publishing Unit: Armidale).
- Ray, E. E. and Sidwell, G. M. (1964). Effects of pregnancy, parturition, and lactation upon wool production of range ewes. *J. Anim. Sci.* **23**: 989.
- Reid, N. R. D. (1978). The effects of pregnancy and lactation on wool production and liveweight in Polwarth ewes. *Aust. J. Exp. Agric. Anim. Hus.* **18**: 58.
- Reis, P. J. (1992). Variation in the strength of fibres: a review. *Aust. J. Agric. Res.* **43**: 1337.

- Reis, P. J & Sahl, T. 1994. The nutritional control of the growth and properties of mohair and wool fibers: A comparative review. *J. Anim. Sci.* **72**: 1899.
- Reis, P. J. & Schinkel, P. G. (1963). Some effects of sulphur-containing amino acids on the growth and composition of wool. *Aust. J. Biol. Sci.* **16**: 218.
- Reis, P. J. & Tunks, D. A. (1976). The influence of abomasal supplements of some amino acids on wool growth rate and plasma amino acids. *J. Agric. Sci. Cambridge.* **86**: 475.
- Ryder, M. L. & Stephenson, S. K. (1968). *Wool Growth*. Academic Press, London and New York.
- Sahl, T., Hart, S. P and Goetsch, A. L. (1999). Effects of level of feed intake on body weight, body components, and mohair growth in Angora goats during realimentation. *Small. Rum. Res.* **33**: 251.
- Sahl, T., Fernandez, J. M., Carneiro, H. and Flasher, H. M. (1992). In *Recent Advances in Goat Nutrition*: Proceeding of, and papers presented, Conference on Goats 5th, 1992 (New Delhi, New York).
- Sanderson, I. D., McFarlane, J. D. and Pratley. J. E. (1976). Production and quality of wool from wet ewes, dry ewes and wethers grazing irrigated Lucerne. *Proc. Aust. Soc. Anim. Prod.* **11**: 169.
- Saville, D. G. and Roberts, D. E. (1972). The efficiency of conversion of food to wool in selected and unselected Merino types. *Aust. J. Agric. Res.* **23**: 117.
- Sharkey, M. J., Davis, I. F., Kenny, P. A. (1962). The effect of previous and current nutrition on wool production in Southern Victoria. *Aust. J. Exp. Agric. Anim. Hus.* **2**: 160.

Sleng, S. B. & Whiting, F. (1956). Wool growth in mature range ewes as affected by stage and type of pregnancy and type of rearing. *Can. J. Agric Sci.* **36**: 8.

Steynberg, A. 1996. South African Mohair Growers Association. *The Ang. Goat. Moh. J.* **38 no 1**, 53.

Torien, C. A., Sahl, T and Wong, W. W. 2000. Energy expenditure of Angora goat does during the late trimester using the doubly - labelled water technique. Goat Research. Langston University.

Turner, H. N., Brown, G. H. and Ford, G. H (1968). The influence of age structure on total productivity in breeding flocks of Merino sheep. 1. Flock with a fixed number of breeding ewes, producing their own replacement. *Aust. J. Agric. Res.* **19**: 443.

Van der Westhuizen, J. M., 1981. Angora goat and mohair production in South Africa. Cawood Street. Port Elizabeth.

Waldron, D. F., Willingham, T. D., Thompson, P. V. (1996). A comparison of Angora and Spanish does for producing crossbred goats for slaughter: Effects on growth rate and feed efficiency. Combined Research Reports: Sheep and Goats, Wool and Mohair.

Wentzel, D., Viljoen, K. J. and Botha, L. J. J. (1979). Physiological and endocrinological reactions to cold stress in the Angora goat. *Agroanimalia*. **11**: 9

Werston, R. H. (1979). Digestion during pregnancy and lactation in sheep. *Annales de Recherches Veterinaires*. **10**: 442.

Williams, A. J. (1966). The efficiency of conversion of feed to wool during limited and unlimited feeding of flocks selected on clean fleece weight. *Aust J. Exp. Agric. Anim. Hus.* **6**: 90.

Williams, A. J., Tyrell, R. N. and Gilmour, A. R. (1978). Effects on wool production during pregnancy and lactation of twice daily abomasal supplementation with casein or methionine and cystine. *Aust. J. Exp. Agric. Anim. Hus.* **18**: 52.

Williams, A. J. and Winston, R. J. (1965). Relative efficiencies of conversion of feed to wool at three levels of nutrition in flocks genetically different in wool production. *Aust. J. Exp. Agric. Anim. Hus.* **5**: 390.

Williams, O. B., and Chapman, R. E., 1966. Additional information on the dye-banding technique of wool growth measurement. *J. Aust. Ins. Agric. Scie.* **32**: 298

Williams, O. B. and Suijdendorp, H. (1968). Wool growth of wethers grazing *Acacia aneura* Triodia pungens Savanna and ewes grazing Triodia pungens hummock grass steppe in the Pilbara. *Aus. J. Exp. Agric. Anim. Hus.* **8**: 653.

Wilson, L. T. (1951). Physical analysis of the fleece of sheep for biological purposes. I. The actual and apparent cross sectional areas of a staple of fleece wool under lateral compression. *Aust. J. Agric. Res.* **2**: 181.