

**THE EFFECT OF DIETARY PROTEIN DEGRADABILITY ON THE
PERFORMANCE OF SAANEN DAIRY GOATS**

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my original work and that I have not previously in the entirety or in part submitted it at any university for a degree.

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ABSTRACT

Title: The effect of dietary protein degradability on the performance of Saanen dairy goats
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The goat is a significant domestic animal throughout the world today. With an estimated world goat population of 590 million goats in 1991 (FAO, 1991 as cited by Haenlein, 1996) it is impossible to consider the goat as insignificant. The need for milk, and it seems particularly goat's milk, is obvious if one considers the increase in dairy goat populations over the past 20 years. Across the globe the dairy goat population has increased by 52% while in developing and developed countries, there has been an increase of 56% and 17%, respectively (Haenlein, 2000).

The goat dairy industry in South Africa is still very underdeveloped, yet it holds tremendous potential for the entrepreneur willing to take the risk and do the job correctly. With the present South African financial situation the opportunities that exist for exporting value added products to countries with stronger currencies is a market with extraordinary potential. In New Zealand, the national herd consists of approximately 16000 dairy goats and 90% of the milk produced is turned to powdered milk and then exported to the East, a valuable source of foreign currency. In South Africa, the same potential exists and with some vision and hard work the dairy goat industry can make a valuable contribution to generating foreign currency.

Research into the protein requirements and particularly protein degradability requirements of dairy goats is scarce, yet in recent years there has been an increased interest in the effect of protein supplementation to lactating animals (Mishra & Rai, 1996). In the work of Mishra & Rai (1996) there were benefits obtained from the use of different rumen degradable proteins for lactating dairy goat does. The does on the highly degradable protein diet had a better feed intake while the does on the low degradable protein diet gave a higher milk production. Other research on this field of study has also delivered positive results with more than one species of lactating animal that had increased levels of UDP in the diet (Robinson *et al.*, 1991 and Christensen *et al.*, 1993).

Loerch *et al.* (1995) suggested that improved production by making use of rumen undegradable proteins would have no effect if crude protein were not a limiting factor in production. Pailan & Kaur (1995) and Mishra & Rai (1996) did research on lowered CP levels with increased UDP levels in lactating dairy does. They used of three diets, with the one having a 20% lower CP value but an

increased level of UDP (40-45% of total CP). From this work it was concluded that a decreased CP level and an increased level of UDP is able to sustain production when compared with diets with a higher CP value.

The current study consists of two trials. In the first trial the effect of weaning age and dietary protein degradability on the growth of Saanen kids was investigated. In the second trial the effect of dietary protein degradability on the production of lactating Saanen does was investigated.

Fifty-eight Saanen kids were divided into groups to determine the effect of weaning age (42 vs. 70 days) on animal performance. Within the weaning day treatments, the kids were again divided into two dietary treatments. One group received a low UDP creep diet (LC) and the other a high UDP creep diet (HC). The two creep diets were formulated with rumen degradable: undegradable protein (RDP : UDP) ratios of 70:30 and 60: 40, referred to as LC and HC, respectively. However, the results from the degradability trial indicated no difference in RDP: UDP ratios for the low and high creep (72:28 and 73:27 respectively) diets. At 15.66 ± 3.09 kg the kids were taken off the creep diet and put on the growth diet. At this transition, the kids in each of the 4 established treatments were again randomly divided into two dietary treatments, a high or a low UDP growth diet, resulting in a total of eight treatments for the trial. The two growth diets were formulated with RDP: UDP ratios of 70:30 and 60:40, referred to as low growth (LG) and high growth (HG) respectively. Results from the degradability trial indicated RDP: UDP ratios for the LG and HG of 73:27 and 68:32 respectively. The growth trial was conducted over 140 days and feed intake, bodyweight change and feed conversion efficiency were compared for each of the 8 treatments.

From the trial with the Saanen kids it was concluded that weaning dairy goat kids at 42 days of age when feed intake was 240 g/day resulted in similar growth rates when compared with weaning at 70 days. The two creep diets did not differ in RDP: UDP ratios and thus no conclusion can be made regarding the influence of the creep diets on the growth of Saanen kids from 20 to 80 days of age. The two growth diets did in fact differ from one another, in terms of RDP: UDP however, protein degradability had no influence on the performance of the Saanen kids from 80 to 140 days of age.

Twenty-one lactating Saanen does were randomly assigned to one of three experimental diets. The treatments had two RDP: UDP ratios and two crude protein (CP) levels. Treatments were formulated to be 1) RDP: UDP = 70:30, CP = 20 % 2) RDP: UDP = 62:38, CP = 20% and 3) RDP: UDP = 62:38, CP = 18.3%. In the production trial the does were milked for 120 days, during which milk yield, milk composition, bodyweight change, feed intake and feed conversion efficiency were compared between the treatments. In the digestibility and nitrogen metabolism trial, 18 does varying from 84 to 110 days

in lactation, were used to compare the experimental diets. Furthermore, the experimental diets were compared in a degradability and rate of passage trial using cannulated Dohne merino wethers.

Results from the degradability trial indicated that the low UDP, low protein high UDP and high UDP diets had RDP: UDP ratios of 82:18, 78:22 and 79:21 respectively, and that the dietary protein degradability did not differ significantly between diets. Results from the production trial indicated that there was a significant difference in feed intake, dry matter (DM) intake and bodyweight. The does on the low UDP diet had significantly higher feed intakes and DM intakes and were significantly heavier at the end of the trial period. As the diets didn't differ in protein degradability other factors must have influenced the intakes between diets. Palatability may have influenced feed and DM intake, as the low protein high UDP and high UDP diets both contained higher levels of fishmeal. No significant differences in milk production, milk composition or milk production efficiency were observed. Besides the fact that the diets did not differ in effective protein degradability, large variations in milk production between animals and low numbers of animals per treatment limited the ability to measure a difference between the treatments. Results from the digestibility trial varied between diets with the low UDP diet having a significantly lower digestibility overall than the other two diets. Reasons for the difference in digestibility could be due to the difference in rate of passage (low UDP = 0.064/hour versus the 0.044-0.045/hour of the low protein and high UDP diets respectively) and the high ADF value of the low UDP diet. Because no difference in effective protein degradability existed between the diets it is not possible to make an accurate conclusion on whether or not the dietary protein degradability had an influence on production parameters tested in this trial.

OPSOMMING

Titel: Die effek van dieet proteïen degradeerbaarheid op die prestasie van Saanen melkbokke.
Kandidaat: John Thornton
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Huidiglik is die bok 'n belangrike gedomestikeerde dier dwarsoor die wêreld. Aangesien die wêreldwye bokpopulasie in 1991 op 590 miljoen geraam is (FAO, soos aangehaal deur Haenlein, 1996), is dit onmoontlik om die bok as onbelangrik te beskou. Die behoefte aan melk, en dan veral bokmelk, is duidelik as mens die toename in bokpopulasies oor die afgelope 20 jaar in ag neem. Wêreldwyd het die melkbokpopulasie met 52% toegeneem, terwyl dit in ontwikkelende en ontwikkelde lande met 56% en 17% onderskeidelik, toegeneem het (Haenlein, 2000).

Ten spyte van die feit dat die bokmelk-industrie in Suid-Afrika nog baie onderontwikkel is, is daar geweldige potensiaal vir die entrepreneur wat bereid is om 'n risiko te loop en die taak korrek aan te pak. Binne die huidige Suid-Afrikaanse finansiële situasie bestaan daar veral geleenthede om waardetoegevoegde produkte na lande waarvan die wisselkoers sterker is, uit te voer. In Nieu Zeeland is die nasionale kudde ongeveer 16000 melkbokke en 90% van die geproduseerde melk word verwerk na poeiermelk en uitgevoer na die Ooste. In Suid-Afrika bestaan dieselfde potensiaal en met die korrekte visie en harde werk kan die melkbok-industrie 'n belangrike bydra lewer om buitelandse valuta te verdien.

Alhoewel navorsing aangaande die proteïen-degradeerbaarheidsbehoefte van melkbokke skaars is, bestaan daar die afgelope paar jaar 'n toenemende belangstelling in die effek van proteïen supplementering aan lakterende diere (Mishra & Rai, 1996). In die werk van Mishra & Rai (1996) is die voordele om verskillende rumen degraderende proteïenvlakke in lakterende melkbokke te gebruik, aangetoon. Ooie op 'n hoogs degradeerbare proteïen-dieet het beter voerinnames getoon, terwyl die ooie op 'n laag degradeerbare proteïen-dieet hoër melkproduksies gelewer het. Navorsing van hierdie aard op ander lakterende spesies het ook positiewe resultate met 'n toename in verbyvloei-proteïen in die dieet gelewer (Robinson *et al.*, 1991 en Christensen *et al.*, 1993).

Loerch *et al.* (1995) het voorgestel dat 'n verbeterde produksie, deur gebruik te maak van verbyvloei-proteïen, geen effek sal hê as ruproteïen (RP) nie 'n beperkende faktor i.t.v produksie is nie. Beide Pailan & Kaur (1995) & Mishra en Rai (1996) het navorsing gedoen op die invloed van

verlaagde RP-vlakke en verhoogde nie-degradeerbare proteïen (NDP) vlakke in die diëte van lakterende melkooie. Daar is gebruik gemaak van drie diëte, waarvan die een dieet 'n 20% laer RP-inhoud, maar 'n verhoogde NDP-vlak (40-45% van totale RP) gehad het. Vanuit hierdie werk is die gevolgtrekking gemaak dat 'n verlaging in RP-vlak en 'n verhoging in NDP-vlak dieselfde produksie kan onderhou, soos met 'n hoër RP-inhoud.

Die huidige navorsing bestaan uit twee proewe. In die eerste proef is die effek van speenouderdom en dieet-proteïen-degradeerbaarheid op die groei van Saanen-lammers ondersoek. In die tweede proef is die effek van dieet-proteïen-degradeerbaarheid op die produksie van lakterende Saanen melkbokke ondersoek.

Agt-en-vyftig Saanen-lammers is verdeel in twee speenouderdom-behandelings, nl. 'n 42 dae (42) en 'n 70 dae (70) speenouderdom. Binne hierdie speenouderdom-behandelings is die lammers verder verdeel in twee dieet-behandelings. Die een groep het 'n lae NDP kruiprantsoen (LK) en die ander 'n hoë NDP kruiprantsoen (HK) ontvang. Die twee kruiprantsoene was geformuleer om rumen degradeerbare proteïen (RDP): NDP verhoudings van 70:30 (LK) en 60:40 (HK) te bevat, maar die resultate van die degradeerbaarheidsproef het aangetoon RDP: NDP verhoudings van 77:23 (LK) en 78:22 (HK). Die lammers is vanaf die kruipdieet oorgeplaas op 'n groeidieet by 'n gemiddelde lewende massa van 15.99 ± 3.09 kg. Tydens hierdie oorplasing is die lammers van die vier bestaande handelings verdeel in 'n verdere twee dieetbehandelings, nl. 'n hoë of 'n lae NDP groei-dieet (LG en HG onderskeidelik), met die gevolg dat 'n totaal van agt handelings in hierdie proef bestaan het. Die twee groeidiëte is geformuleer met RDP: NDP verhoudings van 70: 30 (LG) en 60: 40 (HG) onderskeidelik, maar die resultate van die degradeerbaarheidsproef het aangetoon RDP: NDP verhoudings van 78:22 (LG) en 72:28 (HG). Die groeioproef is uitgevoer oor 140 dae en voerinnome, verandering in liggaamsgewig en voeromsettingsdoeltreffendheid (VOD) is vergelyk tussen die agt handelings.

Uit die lammerproef is die gevolgtrekking gemaak dat boklammers wat op 42 dae gespeen is, wanneer voerinnome 240g/dag is, soortgelyke resultate i.t.v. groeitempo lewer as lammers wat op 70 dae gespeen is. Die twee kruiprantsoene het nie van mekaar in RDP: NDP verskil nie en dus kan geen gevolgtrekking gemaak word omtrent die invloed van dieet-proteïen-degradeerbaarheid op die groei van Saanen boklammers van 20 tot 80 dae ouderdom. Die twee groei diëte het van mekaar verskil in RDP: NDP maar dieet-proteïen-degradeerbaarheid het geen invloed op die groei van die Saanen boklammers van 80 tot 140 dae ouderdom gehad nie.

Een-en-twintig lakterende Saanen-ooie is ewekansig in drie groepe. Die handelings het twee RDP: NDP-verhoudings en twee ruproteïen (RP) –peile ingesluit. Behandelings was 1) RDP: NDP = 70:30,

RP = 20% 2) RDP: NDP = 62:38, RP = 20% en 3) RDP: NDP = 62:38, RP = 18.3%. Tydens hierdie produksieproef is die ooie vir 120 dae gemelk en die melkopbrengs, melksamestelling, verandering in liggaamsgewig, voerinnome en VOD bepaal en vergelyk tussen behandelings. In die verterings- en stikstofmetabolismeproef is 18 ooie gebruik om die diëte te vergelyk. Verder is die diëte ook vergelyk in 'n degraerings- en deurvloeitempoproef met gekannuleerde Dohne merino hamels.

Dieet-proteïen-degradeerbaarheid waardes verkry uit die degradeerbaarheidsproef het aangedui dat die bepaalde RDP: NDP verhoudings was 82:18, 78:22 en 79:21 vir die lae NDP, lae proteïen hoë NDP en hoë NDP diete, en dat daar geen verskil in dieet-proteïen-degradeerbaarheid was tussen die drie rantsoene. Resultate van die produksieproef dui daarop dat daar verskille in voerinnome, droëmaterialinnome, en liggaamsgewig tussen die drie rantsoene was. Die ooie op die laer NDP rantsoen het 'n hoë voer en DM innome gehad en was swaarder na 120 dae in die proef as die ooie in die ander twee behandelings. Redes vir hierdie verskille is nie as gevolg van dieet-proteïen-degradeerbaarheid nie. Die smaaklikheid kon dalk 'n rol gespeel het omdat dat die twee hoë NDP rantsoene hoër vlakke van vismeel gehad het. Daar was geen verskil in melkproduksie, melksamestelling en melkproduksiedoeltreffendheid tussen die drie behandelings. Resultate van die verteringsproef het tussen die laer NDP-rantsoen en die ander twee rantsoene gevarieer. Die rede vir die verskil in verteerbaarheid mag wees a.g.v. verskillende deurvloeitempo's (laer NDP = 0.064/uur teenoor 0.044 – 0.045/uur vir die lae proteïen en hoë proteïenrantsoene) en die ADF waarde wat van die lae NDP rantsoen verskil het van die ander twee rantsoene. Omdat die resultate van die degradeerbaarheidsproef aangedui het dat daar geen verskil in dieet-proteïen-degradeerbaarheid was nie is dit nie moontlik om 'n gevolgtrekking te maak rondom die invloed van dieet-proteïen-degradeerbaarheid op die produksie van lakterende Saanen melkbokke nie.

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CHAPTER 1

GENERAL INTRODUCTION

1.1. Dairy Goat Production

1.1.1. Across the Globe

The goat is a significant domestic animal throughout the world today. With an estimated world goat population of 590 million goats in 1991 (FAO, 1991 as cited by Haenlein, 1996) it is impossible to consider the goat as insignificant. Goats serve a number of needs and the three major areas of importance are meat, fibre and milk. An important characteristic of the goat is its ability to survive under the most extreme conditions, in other words its ability to adapt. Goats are found all over the world, whether it is mountainous, flat, hot, cold, wet or dry. They not only survive but also manage to generate products in the form of meat, fibre and milk. Besides these major areas of importance, the goat is starting to find importance in niche areas. These niche areas include bush control in traditional grassland environments, milk for lactose intolerant people and health conscious consumers and of course cheese for food connoisseurs. The need for milk, and it seems particularly goats milk, is obvious if one considers the increase in dairy goat populations over the past 20 years. Across the globe the dairy goat population has increased by 52% while in developing and developed countries there has been an increase of 56% and 17% respectively (Haenlein, 2000).

Milk production from goats varies from country to country (Table 1), with at least 10 countries depending on goats and sheep for 30 – 76% of total milk supply (Haenlein, 2000). Countries in Europe and around the Mediterranean region have the best-developed dairy goat industries as well as dairy goat focused research (Haenlein, 1996). In Europe, interest in goat production has increased and particularly so in France, in recent years. In Britain, it was estimated that the national herd had reached 90 000 animals by 1990 (Table 2). Although most farms have small numbers of animals, more farms with larger numbers of animals per farm are becoming popular. The average yield on these larger farms is now approaching 1000 kg per animal per lactation (AFRC, 1998).

Table 1 World leaders in goat milk production (1.000 t)¹⁾

Country	Production	Country	Production
India	2000	Brazil	135
Iran	897	Italy	125
Pakistan	666	Mexico	125
Somalia	640	Kenya	101
Sudan	528	Ethiopia	99
France	520	Bulgaria	62
Bangladesh	499	Iraq	62
Greece	465	Portugal	43
Spain	410	Germany	35
Turkey	389	Norway	29
Russia	350	Cyprus	23
Algeria	210	Czechoslovakia	19
Indonesia	180	Switzerland	18
Yemen	156	Israel	15
China	155	Tunisia	12
Mali	140	Austria	11

¹⁾ Estimates; no figures for United States (FAO, 1991).

Table 2 Britain's estimated dairy herd composition in 1985¹⁾

Breed	Percentage (%)
British Saanen	21
British Toggenburg	14
Anglo-Nubian	12
Saanen	7
British Alpine	5
Toggenburg	4

¹⁾ Islay and Jura Goat Society (1985) as cited by AFRC (1998).

In India, the goat is considered an economically important animal, with a national income of Rs. 15 210 million. In 1992 goat's milk comprised 3.2% of the total milk produced (Deoghara & Ram, 1992 as cited by Mishra & Rai, 1996). In Jordan, the Black or Baladi goat contributes about 12% of the total milk produced and in Spain the Murciano-Granadina dairy goat's primary role is to yield milk and almost all milk is destined for cheese production. In America, there are an estimated 1.5 million dairy goats, of which the Nubian is the most prominent (Haenlein, 1996). Estimated goat's milk production in the

USA is 24 000 tons (Haenlein, 1996). Of this, approximately 12 000 tons of goat's milk is commercially processed annually as fluid, evaporated, UHT or powdered milk. A further 12 000 tons of goat's milk is processed into cheese, predominantly of the French soft-type chevre (Stern, 1992 as cited by Haenlein, 1996). In Canada, Ontario has the largest concentration of goats, where 34% of Canada's 9000 goat farms and 43% of the national 76 000 goats are located. The large number of goats per farm is indicative of the serious nature of this agricultural enterprise. In Ontario there are approximately 140 commercial goat milk producers. Herds vary in size from 600 head of "A" grade dairy farms to small producers. Approximately 6 million litres of goat's milk is marketed in the province every year, which is processed at one of nine processing plants.

1.1.2. In South Africa

In South Africa, the dairy goat industry is a far cry from previously mentioned countries. Currently we have 28 registered breeders with close to 500 registered animals. The majority of the dairy goat farmers only farm on a small scale, however a few farms of 100 animals plus do exist. In Table 3 is the average production per lactation for first and all lactations of registered dairy goats.

Table 3 Average production per lactation (240-300 days) for registered first lactations and all lactations of dairy goats in South Africa¹⁾

No. of lactations	Registered No.	Ave. Milk (kg)	Fat %	Protein %
1 st lactation	79	946	2.85	2.74
All lactations	227	1014	2.85	2.76

¹⁾ National Dairy Cattle Performance Testing Scheme.

Dairy goats were first reported in South Africa (SA) in 1896, where dairy goats were kept at Groot Constantia, in the Cape . The history of dairy goats in South Africa is well documented by the SA Milch Goat Association and the history of the three main breeds is discussed. In SA the Saanen, Toggenburg and Alpine are all farmed and preference to one breed is normally personal. Although there appears to be no real growth in the dairy goat numbers, the seriousness of farming with dairy goats is starting to increase. The SA Milch Goat Association now takes part in the National Dairy Cattle Performance Testing Scheme and there is interest in making use of "Basic Linear Unbiased Predictions" or "BLUP" to improve the genetics of the national herd. However, as the majority of the farms are small it is not economically viable to take part in these schemes. Today most farmers are involved in semi-intensive to intensive units of small (10–30) to large (300–600) herds. Quality control is a major problem and possibly the biggest reason for the negative

consumer connotations to goat's milk. No commercial milk buyer exists and producers are responsible for their own milk processing (pasteurizing, yoghurt, cream, cheese, etc.) and marketing. Few consultants or advisors are available for practical and scientific advice and thus management and quality control vary to a large degree. The marketing of goat's milk is limited to producers doing their own promotion to their suppliers and markets. The development of a commercial milk buyer could be the start of a very lucrative industry with immense export potential, in a product such as milk powder.

1.1.3. Research

In recent years there has been an increased amount of dairy goat research projects and publications in the United States (Haenlein, 1996). This is not only common to the United States but also other countries around the world, which include India, Iraq and Nigeria (Haenlein, 1996). However, in the latter countries the dairy goat industries are not well organized. In the United States this increased research work has taken place in Oklahoma, Texas, California, Georgia, Alabama, Florida, Louisiana, New York, Connecticut, Delaware and Massachusetts. National support for research into goat husbandry and technology has resulted in new research facilities that have complimented the old research facilities. The Langston University in Oklahoma has been especially productive in new research and has attracted many students. The American Dairy Goat Association (ADGA) has also organized a Research Foundation that has attracted private money to fund the USDA buck proofs as well as a few selected research projects (Haenlein, 1996).

1.1.4. The Future

The goat industry, and in specific the dairy goat industry, has massive growth potential, because the market demand for fresh milk and processed milk products (especially cheese) far exceeds supply (Haenlein, 1996). People showing allergic reactions to cow's milk or who have other digestive afflictions can benefit from goat's milk products (Nestle, 1987 as cited by Haenlein, 1996). With the increasing awareness of consumers for healthier food to maintain a healthy lifestyle, the dairy goat has a prosperous future.

However, a few factors must be dealt with so as to boost the sales of fresh milk and processed milk products. Firstly, more research into the medicinal and health values of goat's milk must be conducted so that scientific facts become available on the benefits of goat's milk. Limited scientific information is available on the medicinal and health values of goat's milk, however the scarcity of scientific results on the unique qualities of goat's milk needs to be addressed (Haenlein, 2000). Secondly, the marketing of goat's milk with its medicinal and health values needs to be implemented. At present, consumers tend to have

a negative connotation to goat's milk, this is due to poor farming practices that causes milk to have poor sensory characteristics.

1.2. Protein sources

To fully grasp the concept of utilizing different raw materials, protein sources in this instance, so as to manipulate the gut environment and thus influence production, animal nutritionists must have a complete understanding of the chemical aspects of raw materials. It is the aim of this section to provide some information on the chemical aspects of protein sources that allow animal nutritionist to manipulate animal production through feed formulation.

Protein sources may be grouped into categories based on their chemical entities and reactivities (Cronjé, 1983). The following categories may be formed:

- Dried forages (C₃ and C₄ plants)
- Conserved forage (silage)
- Processed protein sources (plant and animal sources)
- Grains (cereal and oilseeds)

Each of these categories are made up of similar protein fractions, yet they differ in the availability or degradability of each fraction. Because of this difference in protein fractions, animal feed specialists are able to manipulate animal nutrition and improve production under different conditions, whether it is environmental or managerial.

1.2.1. Fractions

1.2.1.1. Forages

1.2.1.1.1. Fresh

Forages are not only a source of fibre and carbohydrates, but also protein. Forages are presented to the animals in different forms, namely fresh, dried (hay) or conserved (silage). The form in which forage is presented is largely dependent on the farmer and the environment or climate where the farm is situated. In terms of protein fractions all forages may have the following (Cronje, 1983):

- Fraction 1 leaf protein
- Fraction 2 leaf protein
- Chloroplast membrane protein
- Other fractions

Fraction 1 leaf protein constitutes about 38% of the total leaf protein and consists mainly of chloroplastic proteins. These chloroplastic proteins are mainly in the form of an enzyme called ribulose -1,5 biphosphate carboxylase. This enzyme is common in C₃ plants such as lucerne. In contrast, in C₄ plants (maize) the fraction 1 leaf proteins are absent from normal chloroplasts, but are found in the bundle sheath chloroplasts. The fraction 1 leaf proteins are highly soluble in water and degrade rapidly in the rumen (Van Straalen & Tamminga, 1990).

The fraction 2 leaf proteins constitute about 25% of the leaf protein and are made up of both chloroplasts and cytoplasm. Although the biological composition is known and it is water soluble, there is little known about the potential degradability in the rumen (Cronjé, 1983).

The chloroplast membrane fraction is made up of the lamellar membranes of the chloroplast. These lamellar membranes consist of various fractions:

- 1 Chlorophyll protein complex I - 28%
- 1 Chlorophyll protein complex II - 49 %
- 5 minor Chlorophyll protein complex - 20 %

Work by Mangan (1982), described the chlorophyll protein complex behaviour in the rumen. The chlorophyll protein complex I is insoluble in water. The behaviour of chlorophyll protein complex II in the rumen is unknown, however it is a component of the same membrane system as chlorophyll protein complex I and thus its behaviour may be closely related.

The other fractions of proteins include the cell walls, nucleus and mitochondrion. The nucleus and mitochondrial proteins are few in forages and make up no significant part of the forage protein content (Cronjé, 1983). The protein found in the cell walls is predominantly, extensin. The cell wall proteins are predominantly insoluble, because of the bonds that exist

between cellulose and extensin. Thus the cell wall proteins have a slow rate of degradation.

1.2.1.1.2. Dried and conserved

In dried and conserved forages the fractions that exist are the same, however, the behaviour of these fractions varies. This variation that exists has to do with the changes that occur when the forages are dried or conserved (ensiled).

In hay making, the drying or wilting may cause changes. Drying or any heating permanently precipitates the chloroplastic and cytoplasmic proteins and the end result is that none or little of the protein in the hay is water-soluble (Van Soest, 1982 as cited by Cronjé, 1983). Furthermore during field drying, the forage proteins are broken down by the action of plant protease. This means that the amino acid composition of the dry forage and the fresh forage may vary.

In silage making many factors can alter the nitrogen fractions of this forage, these factors include:

- Temperature
- pH
- Type of forage being ensiled
- Inoculants

The temperature of well-made silage should have little or no effect on the proteins in the forage. However, this is not the case in poorly made silage where clostridial fermentation occurs. Under such conditions the temperature and pH increase to high levels and deamination/ decarboxylation of the forage proteins to non-protein nitrogen (NPN) takes place. The type of forage that is being ensiled is also important. For instance grass contains a large proportion of soluble protein and in the silo this is extensively degraded to NPN compounds (Thomas & Thomas, 1988). Numerous inoculants are available today and the aim of these inoculants is to reduce the pH approximately to 4.0 as quickly as possible. Products range from acids (formic acid) to bacterial and enzyme products. The end result of using inoculants is a rapid reduction in proteolysis and thus more nitrogen in the form of whole protein is available.

1.2.1.2 Processed proteins

Processed proteins are some of the most important protein sources in South Africa for ruminant nutrition. The majority are industrial byproducts and processing methods vary considerably (Cronjé, 1983). The processed protein sources include both the plant and animal type.

1.2.1.2.1. Plant

Plant protein byproducts include oilcakes of sunflowers, soybeans and cottonseeds and processing involves the treatment of the sources with heat or chemicals. These processes are not well controlled and often the products have induced changes that affect the protein structure (Cronjé, 1983). The processes are often extreme and may even render the plant protein source indigestible to the animal (Cronjé, 1983). The most popular reason for carrying out these processes is to render the protein source partially or totally undegradable in the rumen.

1.2.1.2.2. Animal

Processed animal protein sources include fishmeal, carcass and bone meal, to name a few. The animal proteins are derived from sources such as enzymes, membranes, transport proteins (albumins) and/or muscle (myoglobin). The degradation properties between animal proteins vary to a large degree (Van Straalen & Tamminga, 1990), and the reason for this possibly lies in the induced changes that occur during processing. In the case of heat, coagulation or denaturation merely reduces protein solubility or accessibility (Van Soest, 1982 as cited by Cronjé, 1983). A more detrimental reaction is the Maillard reaction. The Maillard reaction may occur in fishmeal, but also in other feed sources, and can occur at mild or hot temperatures. The reaction involves proteins and other constituents especially carbohydrates found in a feed. Lysine is often affected when the ϵ -amino group and the sugar aldehyde group of glucose react. The end result is that the amino acid is absorbed by the animal but is unavailable in the body and is eventually excreted in the urine. In animal proteins the objective of heat or chemical treatment is to slow the rate of degradation in the rumen and thus increase the chance that the protein is carried to the small intestine.

1.2.1.3 Grains

In grains the majority of the protein is in the form of true protein and 80-90 % is stored in the aleuron and endosperm. A small amount is stored in the husk and pericarp (Ensminger & Olentine, 1978).

1.2.2. Solubility.

The solubility of protein sources may be one of the major factors affecting the protein utilization in the rumen and gut. Late in the 19th century cereal proteins were fractionated on the basis of their solubility in solvents:

- Albumins: soluble in H₂O
- Globulins: soluble in 0.5 N NaCl
- Prolamins: soluble in 70% ethanol
- Soluble glutelins: soluble in NaOH
- Insoluble glutelins: residues

From the above fractions it can be deduced that feeds whose major protein fractions are made-up of albumins and globulins have a higher solubility than those made-up of prolamins and glutelins, in the rumen environment (Church & Fontenot, 1979).

Protein sources with a high solubility in the rumen will result in high levels of ammonia being released, into the rumen. These ammonia levels could easily exceed the micro-organisms requirements for ammonia, resulting in a waste of ammonia. The solubility of protein sources appears to have a definite effect on production and diets with lower solubility appear to be retained better by the body than those with a high solubility (Church & Fontenot, 1979).

1.2.2.1. Factors influencing solubility

The solubility of protein sources varies and can be influenced by numerous factors. The pH has a definite effect on protein solubility, as does the chemical nature of the protein. Proteins are ampholytic (able to act as an acid or base), and electrostatic bonding between ions of opposite charge play an important role in maintaining stability (Cronjé, 1983). The solubility of proteins is less at the pH of 5.5 than at pH 6.5 or pH 7.5 and no difference exist at a higher pH. The ionic strength is also a factor that effects the protein solubility. As a result of interactions between charged groups of the protein molecule and ions of dissolved salts, many proteins which are insoluble in pure H₂O dissolve in the presence of small amounts

of neutral salts (Taylor, 1953 as cited by Cronjé, 1983). Thus in the presence of ionic fluids in the rumen, the protein solubility may increase. The effect of temperature on protein solubility is variable, and there exists no general rule. Some proteins decrease in solubility with a change in temperature, while others increase (Taylor, 1953 as cited by Cronjé, 1983).

1.2.3. Characterization

In the feed industry today, a range of protein sources are available to choose from for use in animal feeds. The important decision is which source to use. This decision becomes complex and a good understanding of the conditions on the farm will help in making an informed decision. For example, are the animals on green fertilized pastures or is dry land grazing utilized? Once the conditions on farm have been determined the decision is made that much easier. The protein sources in concentrate diets are to complement the on-farm conditions to optimize production, and in the end increase profitability. Important information needed on protein sources include (Santos *et al.*, 1998):

- Processing methods
- Amino acid profiles
- Potential to complement microbial protein in the small intestine.

Numerous rumen undegradable protein (UDP) sources are available on the market. These sources are commonly used to replace RDP sources in an attempt to increase animal production. A list of the most common UDP sources, in the United States, together with their amino acid profiles relative to milk protein, is given in Table 4. The importance of these protein sources as UDP lies in both the amount and balance of essential amino acids (EAA) in duodenal digesta.

Table 4 Extended chemical scores of protein sources in relationship to milk protein¹⁾

Protein source	His	Phe	Leu	Thr	Met	Arg	Val	Ile	Trp	Lys
Blood meal	100	100	93	86	45	33	70	10	76	80
Fishmeal	77	69	58	68	100	59	59	47	71	80
Feather meal	11	59	66	59	23	32	38	32	29	13
Meat meal	67	65	46	59	49	76	51	36	39	58
M&B meal ²⁾	64	64	46	59	49	76	48	36	32	55
Corn gluten meal	67	100	100	60	100	36	48	40	30	18
Distiller grains with solubles	74	84	72	63	81	42	53	38	45	24
Soybean meal	89	100	56	74	56	89	60	55	75	70
Microbes	90	97	54	100	97	79	66	61	99	100

¹⁾ Adapted from Chandler (1989) and calculated as follows: (percentage of EAA in feed protein/percentage of EAA in milk protein) x 100. A score of 100 is a maximum value.

²⁾ Meat and bone meal.

1.3. Protein metabolism

Protein metabolism in ruminants is unique in that it relies on micro-organisms to break down dietary protein, form microbial protein and then on enzymes to break down microbial protein. Besides this, ruminants are unique in that they are able to produce *de novo* proteins from non-protein nitrogen's and endogenous proteins due to the presence of the micro-organisms.

1.3.1. Young ruminants

In the young ruminant, the development of gastric digestion has four phases (Leek, 1993):

1. Newborn phase (0-24 hours)
2. Preruminant phase (1-3 weeks)
3. Transitional phase (3-8 weeks)
4. Preweaning and postweaning phase (8 weeks to adulthood)

At birth (newborn phase) the forestomach is small and nonfunctional and has no micro-organisms. The diet consists solely of colostrum, which is particularly rich in immunoglobulins. The passive immunity of young ruminants is very important and numerous digestive adaptations allow this process to take place. The abomasum secretes no acid or pepsinogen during the first day, this allows the ingested milk to travel to the small intestine without being degraded. Once in the small intestine an antitrypsin factor in the colostrum prevents the digestion of the milk proteins. In the small intestine the antibodies are absorbed intact through the intestinal mucosa by means of a phagocytic mechanism. In this way the young ruminant develops an immune system and builds immunity to all the diseases against which its dam was resistant. This facility to transport immunoglobulins is only active for the first 24 to 48 hours.

During the preruminant phase the principal food is milk. During the later parts of this phase the young ruminant may start to ingest small amounts of solid food. The suckling action promotes the secretion of saliva which contains an esterase enzyme and this starts the hydrolysis of milk lipids. The passage of the milk from the mouth to the abomasum is a complex and interrelated occurrence of events. In the pharynx the milk stimulates the chemoreceptors with afferent pathways to the glossopharyngeal nerve. These chemoreceptors are more specifically stimulated by Na^+ in calves and Cl^- in lambs, it is uncertain which receptors are stimulated in goat kids. The end result is the contraction of the spiral lips of the reticular groove and the creation of a temporary tube connecting the cardiac and reticulo-omasal orifices. The milk thus bypasses the rumino-reticulum and quickly flows through the relaxed rudimentary omasum, ending up in the abomasum.

1.3.2. Rumen

In the rumen, dietary proteins are subject to fermentation by micro-organisms. These micro-organisms consist of bacteria and protozoa, of which the latter plays a very small role in the degradation of dietary protein (Baldwin & Allison, 1983). The bacteria that play an important role in the digestion of dietary nutrients can be categorized, based on the substrate they ferment:

- Proteolytic bacteria: protein fermentors
- Amylotic bacteria: starch fermentors
- Cellulytic bacteria: cellulose fermentors

Proteolytic bacteria represent only 12-38% of the total rumen bacteria population and normally only half of the dietary protein is degraded in the rumen (Leek, 1993).

Anaerobic protein degradation in the rumen occurs in two steps, namely hydrolysis and decarboxylation and/or deamination (Van Straalen & Tamminga, 1990). The first step, hydrolysis, involves extracellular bacterial proteolysis, where the peptide bond is hydrolyzed by protease or peptidase enzymes and the end product is peptides. Further hydrolysis occurs when the peptides are phagocytized into the bacterial cells and amino acids are formed. The second step is the decarboxylation and/or deamination of the amino acids. The amino acids, which are the product of the first step, are taken up by other microbes or deaminated to produce CO₂, ammonia, and various metabolic acids (Leek, 1993). The metabolic acids are the volatile fatty acids (VFA) and these VFA's include small amounts of branched chain VFA (isoacids: isobutyrate and isovalerate), which are derived from leucine, isoleucine and valine.

Non-protein nitrogen's (NPN) are an important nitrogen source for ruminants, which via micro-organisms are able to produce amino acids and thus proteins from this nitrogen source. Ammonia is the major product of degradation of dietary proteins and NPN sources as well as endogenous nitrogen sources. The two later compounds include plant amides, nitrites, nitrates and endogenous urea. Endogenous urea enters with saliva and/ or diffuses across the rumen wall into the ruminal fluid (Leek, 1993). The urease enzyme is responsible for the degradation of urea to ammonia and this action is concentrated at the ruminal wall: fluid boundary and in the fibrous raft of the dorsal ruminal sac. Ammonia is an important substrate for microbial protein synthesis. Microbial protein synthesis is subject to the amount of available alpha-ketoglutarate and suitable VFA's, which provides the carbon skeleton onto which the amino group can be added by transamination.

1.3.3. Omasum

The omasum is the spherical stomach following on from the reticulo-rumen. Most of the particles of digesta in the omasum are less than 1 mm in length, similar to those found in the reticulo-omasal orifice. The physiochemical conditions in the omasum are similar to those in the cranial and ventral regions of the rumino-reticulum, so that fermentation and absorption are similar. One of the functional significances of the omasum is that it is a site of fermentation with an importance related to its cubic capacity.

1.3.4. Abomasum

The abomasum is a pepsinogen and hydrochloric acid secreting organ, which is embryonically and functionally very similar to the stomach of monogastrics (Leek, 1993). The abomasum functions as both a site of acidic enzymic digestion and an inflow stabilizer for the duodenum. The fundic region of the abomasum has a pH of close to 1.0 and here the pepsinogen concentrations are relatively constant. The pepsinogen output in the fundic region varies in step with gastric juice volume. In comparison, the pyloric region is slightly alkaline and has little peptic activity. The average pH of the abomasum contents is 3.0.

1.3.5. Small intestine

In the small intestine dietary protein, microbial protein, and endogenous protein enter the duodenum from the abomasum. Here the digestion is very similar to the digestion that takes place in the small intestine of monogastrics. Enzymes are responsible for all of the digestion and are secreted from the pancreas and intestinal wall. The following enzymes, trypsin, chymotrypsin, carboxypeptidase, ribonuclease, deoxyribonuclease, peptidase and elastase are all secreted from the pancreas. From the pancreas the secretions enter the pancreatic duct (*duct of Wirsung*), this duct then unites with the common bile duct called the hepatopancreatic ampulla that enters the duodenum of the small intestine. The mode of action of these enzymes is given in Table 5 (Tortora & Anagnostakos, 1990)

Table 5 Mode of action of pancreatic enzymes¹⁾

Enzyme	Substrate	Product
Trypsin	proteins	peptides
Chymotrypsin	proteins	peptides
Carboxypeptidase	terminal a/a at carboxyl end of peptide	peptides and a/a
Ribonuclease	ribonucleic acid nucleotides	pentoses and nitrogenous bases
Deoxyribonuclease	deoxyribonucleic acid nucleotides	pentoses and nitrogenous bases
Peptidase	dipeptides	amino acids
Elastase	elastin	polypeptides

¹⁾ Tortora & Anagnostakos (1990)

Abomasal secretions are proportional to the number of sucks, therefore teat feeding may be more effective than bucket feeding. The abomasal secretion consists of:

- Rennin
- Chymosin
- Hydrochloric acid

Rennin is one of the first enzymes to have an effect and acts on milk at pH 6.5, within 3-4 minutes curd is formed. This curd is made-up of butterfat and curd casein proteins. The remaining fraction of the milk is whey, which consists of whey proteins (albumins and globulins) and the milk sugar, lactose. The hard curd remains in the abomasum for 12-18 hours where slow degradation occurs. The hydrolysis of the butterfat to fatty acids and glycerol occurs by two means:

1. Lipase of mammary gland origin in the milk
2. Pregastric esterase of the saliva

The curd proteins undergo further proteolysis by the rennin at a pH of 3.5. The end products of the curd slowly flow into the small intestine.

In the intestine the digestion is similar to that in the grown animal and the curd and whey proteins are completely hydrolyzed.

During the transitional phase, peak volumes of milk are ingested and handled as described in the previous phase. Important in this stage is the increased ingestion of solid food. This intake stimulates both saliva secretion and rumino-recticular developments. The ingestion of microbes also increases and a change away from the lactobacilli (found in the milk) occurs. Most of the microbes are acquired from the ingestion of feed and water. The eructate, cud and faeces from older ruminants in the same environment contaminate both the feed and water. The development of the rumen occurs through two actions, the volatile fatty acids (VFA) and the bulk factor of the roughage (Leek, 1993). The VFA's especially butyric acid, cause the development of the rumino-reticular papillae and of the omasal leaves, while the bulk factor of roughage is responsible for the size and muscular development of the rumino-reticulum. The roughage is also responsible for the onset of cyclic motility and effective rumination.

In the preweaning and postweaning phase there is a decrease in the amount of milk taken in and solid feed intake increases. The secretion of rennin in the abomasum stops and is replaced by pepsinogen. The rumen starts to increase progressively in size and assumes a greater proportion of the gastrointestinal mass.

The epithelial enzymes hydrolyze the final peptide bonds of the dipeptides and small polypeptides by the action of surface hydrolysis. The most common epithelial enzymes are amino polypeptidase and dipeptidases, which hydrolyze polypeptides and small peptides to amino acids.

1.3.6. Absorption and transport

The absorption of whole proteins from the intestines is limited to very young mammals that are able to absorb these whole proteins from the colostrum. For all older animals nitrogen absorption in the small intestine is limited to the amino acids and small peptides. According to Ganong (1997) absorption occurs in the duodenum and jejunum and takes place by means of a sodium dependent active transport system, which is very similar to the transport system used to transport glucose over the intestinal epithelium (Figure 1).

There are seven different systems to transport amino acids into the enterocytes, each system accommodates a different chemical group of the amino acids. Five of these require Na^+ , and co-transport of Na^+ and amino acids occurs in a fashion similar to the co-transport of Na^+ and glucose (Figure 1). Two of these four also require Cl^- and another two systems are independent of Na^+ for transport. The epithelial cells, via active transport utilizing H^+ instead of Na^+ , can also take in the dipeptides and tripeptides. The dipeptides and tripeptides can actually be absorbed faster than the amino acids, because of the low concentration gradient that exists for these peptides. As quickly as the dipeptides and tripeptides are absorbed into the epithelial cells they are hydrolyzed by the intracellular peptidases to amino acids, this explains the low concentration gradient. From the epithelial cells, the amino acids leave via the baso-lateral cell area by one of 5 facilitated transport systems.

Once the amino acids have left the epithelial cells they enter the capillaries of the villi and are transported in the blood. Collectively, the amino acids are present in the blood at concentrations of about 5 mg N/ 100 ml (Egan, 1976).

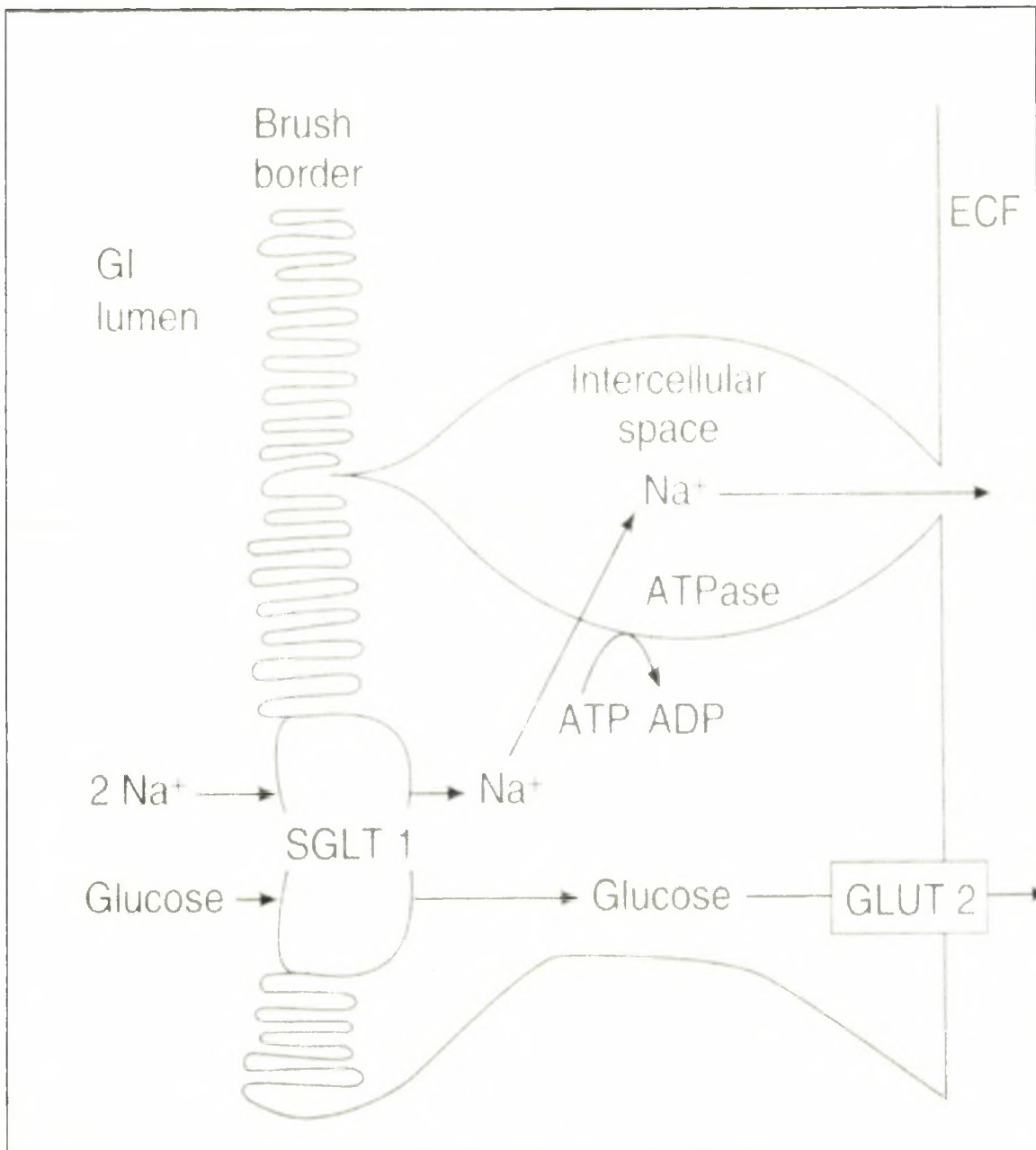


Figure 1 Mechanism for glucose transport across the intestinal epithelium, the same mechanism applies for amino acids (Ganong, 1997)

1.3.7. Liver

The amino acids are transported via the hepatic portal system to the liver, where a large proportion may be removed. In the liver the accumulated amino acids are disposed of over 1-3 hours in 3 different ways. The first method is to release amino acids to the extracellular fluid, the blood. The second method is the synthesis of proteins and the third method is by catabolism through pathways, which in the liver are not easily saturated (Egan, 1976).

1.3.8. Tissue level

Once the amino acids are released in the extracellular fluid from the liver, the other tissues rapidly remove them. Absorption into the tissue is mainly by active transport that is controlled by hormones. The hormones have specific effects on the uptake by different tissues. For example, growth hormone, insulin and testosterone stimulate the uptake of amino acids by the skeletal muscles, this is important for maintenance and growth. Uptake in the liver is stimulated by adrenaline and adrenocorticoid, while various trophic hormones have a specific stimulatory effect on amino acid absorption by their target organs. Absorption by the mammary gland is dependent on three factors: Arterial concentrations of amino acids and rate of mammary blood flow. The two above-mentioned factors determine the quantity of amino acids reaching the gland per unit of time. The third factor is the extraction process by which the carrier systems effect transfer of blood amino acids across the basal membranes of the secretory cells (Mephram, 1982).

At tissue level the amino acids are the building blocks of proteins. The amino acids can be grouped into two categories based on their importance, namely the essential and non-essential amino acids. These two groups are distinguished from one another based on the rate at which the amino acids are produced, making the animal either dependent or independent of a dietary supply (Egan, 1976). However, it is not as clear-cut as this and a grey area does exist between the two groups. Under some conditions certain amino acids will be limiting while under different conditions the same amino acids will not be limiting. Specie differences play a role in the variation of the rate of synthesis of amino acids, or in the amount of amino acid required for protein synthesis. For example, glycine that is readily formed from serine, appears to be produced at rates adequate for protein synthesis in man, rat and dogs at all ages, but not in growing chickens (Egan, 1976). The stage of physiological development (growing versus non-growing) or condition (pregnant versus non-pregnant) is another factor and variations in rate of synthesis or requirement from stage to stage and condition to condition do exist.

1.3.8.1. Growth

During growth the proportional utilization of amino acids is biased towards the synthesis of proteins of muscle and viscera (Egan, 1976). In general amino acids of importance for growth include glycine, histidine and arginine (Egan, 1976). These vary from the recommendations of Ferreira *et al.* (1999b) and Ferreira & Van der Merwe (2001) who stated that the four most limiting essential amino acids for optimal whole body protein synthesis are histidine, methionine, threonine and valine. For these amino acids a dietary

supplement is necessary so as to prevent these amino acids from being the limiting nutrients.

1.3.8.2. Lactation

Results from research on the amino acid requirements for lactation are inconsistent, and available literature is contradictory (Ahrar & Schingoethe, 1979; Sahlu *et al.*, 1984 and Schingoethe *et al.*, 1988). Limiting nutrients vary from condition to condition and may easily vary from one farm to another, based on what the feed ingredients are on those farms. A condition under which one amino acid may well be deficient is when cows are fed silage based diets. Under such conditions there will be a predictable methionine deficiency, resulting in a relatively inefficient microbial protein synthesis (Thomas *et al.*, 1980). Also, as reported by Schingoethe *et al.* (1987) who worked on ruminally protected methionine added to various types of soybean ingredients. These soybean ingredients included both heat-treated and extruded types. Under such conditions where heat treatment is used to lower rumen degradability, the heat may destroy or irreversibly bind lysine to sugars, the so-called Maillard reaction. Thus the lysine may become more limiting than the methionine.

The body of research done on amino acid requirements for lactation suggests that both lysine and methionine are the first limiting amino acids (Santos *et al.*, 1998).

1.4. Protein requirements

Protein is second in demand in quantitative terms only to energy (Church & Fontenot, 1979) and makes up 20 % of the wet tissue (Egan, 1978). Methods of determining protein requirements are very important and numerous systems have been developed through the years.

1.4.1. Protein evaluation systems

Methods used to determine the protein requirements of ruminants vary from the older crude protein (CP) and digestible crude protein (DCP) system to the more modern and accurate protein systems. Some of these include the Cornell Net Carbohydrate and Protein System (CNCPS), the absorbed protein (AP) and the metabolizable protein system (MP). The older CP system has its limitations (Mishra & Rai, 1996) and can only be used as a rough guide to the protein content of feed. More importantly, information is needed on the

numerous protein fractions and their possible chemical reactions (Cronjé, 1983). The MP system proposed by the AFRC, is one of the most recent protein systems and is defined as the total digestible true protein (amino acids) available to the animal for metabolism after digestion and absorption of the feed in the animal's digestive tract (AFRC, 1993). The MP system comprises two parts, the *digestible microbial true protein* (DMTP) content and the *digestible undegraded feed protein* (DUP). The DMTP is the protein produced by the activity of the rumen microbes, while the DUP is the fraction of the feed which has not been degraded during its passage through the rumen. The MP system also makes use of a value known as the efficiency of utilization. This value represents the amount of nitrogen that is used for maintenance or production from already digested nitrogen. This efficiency of utilization is the multiple of K_{aai} and the relative value of the amino acid supply. Where K_{aai} is the efficiency with which a mixture of absorbed amino acids in ideal proportion are used for tissue protein or milk protein.

The determination of protein requirements for ruminants is more accurate using the MP system, compared to the CP or DCP system, yet the implementation of this system is complex.

1.4.2. Requirements

The protein requirements of ruminants can be divided into two main sections: maintenance and production requirements. All these requirements occur simultaneously (Ørskov, 1992), however for simplicity these requirements will be discussed separately.

1.4.2.1. Maintenance

Determining the protein requirements for the maintenance of ruminants is complex and involves the determination of endogenous urinary nitrogen (EUN), metabolic faecal nitrogen (MFN) and dermal losses. The EUN represents the loss of nitrogen from the body, associated with the maintenance of body functions, particularly the breakdown and synthesis of protein (AFRC, 1998). The mean EUN values calculated for goats are limited to non-lactating goats ($0.12 \text{ g N/Kg } W^{0.75}$), for lactating goats no satisfactory results are yet available (AFRC, 1998). The MFN represents the nitrogen in the faeces of animals given nitrogen free diets. The literature available on this subject is limited and so far it is estimated that MFN losses of $0.35 \text{ g N/Kg } W^{0.75}$ occur per day. Determinations of dermal losses of nitrogen from goats have not yet been carried out and available values are those adapted from cattle, 0.018 and $0.02 \text{ g N/Kg } W^{0.75}$. The utilization

efficiency of amino acids for maintenance (k_{nm}) is set as 1.0 according to the AFRC (1998). In summary, all that has been discussed under maintenance requirements is termed as the "Total endogenous nitrogen" (TEN) losses and is estimated as $2.19 \text{ g MP}_m/\text{Kg W}^{0.75}$ for lactating goats.

1.4.2.2. Growth

The growth of all animals is natural, and requirements for nitrogen vary due to normal physiological changes in the animal. The need for protein by the young lamb is high and in general higher for lambs than for calves, this will apply to kids as well. The reason for this is that the growth rate of lambs, when related to metabolic body weight, is higher for lambs than for calves (Ørskov, 1992). The protein requirements for growing goat kids are given in Table 6 (AFRC, 1998).

Table 6 Requirements for metabolizable protein (MP_f) for the growth of goat kids¹⁾

Bodyweight growth interval	MP_f requirements (g/d)		
	15-20 kg	20-25 kg	25-30 kg
Growth rate			
100 g/d	24.6	24.0	23.4
200 g/d	49.2	48.0	46.8
300 g/d	73.8	72.0	70.2

¹⁾ AFRC (1998).

Growth is, however, not only limited to young animals. Goat ewes are ideally mated at 7 months at a target weight of 40-45 kg (Saaneis) (AFRC, 1998). Considering that an average Saanen ewe weighs 60 kg, it becomes obvious that a young ewe still has lots of growing to do. Thus, from mating weight to mature body weight an ewe must gain 15 kg and at the same time support the growth of single, double or even triplet kids. When determining the requirements for the growth of ewes this factor must be considered

1.4.2.3. Pregnancy

The reproductive status of any dairy herd is very important if the herd is to maintain milk production over any amount of time. Meeting the protein requirements of pregnant ruminant animals is based on the protein deposition in the gravid fetus of the dairy goat (AFRC, 1998). To determine

this value, the protein gains of the gravid fetus are given in Table 7 (AFRC, 1998).

Table 7 Estimated gains in protein in the gravid uterus in dairy goats with 1, 2 or 3 fetuses¹⁾

	Number of Foetuses	Days Pregnant (weeks before parturition)						
		63 (12)	77 (10)	91 (8)	105 (6)	119 (4)	133 (2)	147 (0)
Total gain of protein (g):	1	93	137	200	299	445	646	902
	2	121	192	297	465	714	1053	1482
	3	149	247	395	624	963	1420	1991

¹⁾ Adapted from AFRC (1998).

The utilization efficiency of truly absorbed nitrogen (k_{nc}) of 0.85 for pregnancy was accepted by the AFRC (1998). Thus the nitrogen requirements for pregnancy range from 4.4 g MP/day during the 9 to 13th week of pregnancy to 43.2 g MP/day in the 17th term week of pregnancy (Table 8).

Table 8 Additional requirements of dairy goats for metabolizable protein during the last three months of pregnancy¹⁾

Weeks pregnant	MP _c requirements (g/d) ²⁾		
	Singles	Twins	Triplets
9-13	4.4	7.2	10.0
13-17	10.1	17.2	23.5
17-term	19.2	32.2	43.2

¹⁾ Adapted from AFRC (1998).

²⁾ MP_c values are (1/0.85) times protein deposition in Table 7.

1.4.2.4. Lactation

Lactation is the most important characteristic of dairy goats and the accurate determination of protein requirements for lactation will be economically beneficial. The requirements for protein vary over the 10-month lactation period, and physiological changes in the body due to the demands of lactation are the cause of this. The requirements for protein in MP terms are given in Table 9 (AFRC, 1998).

Table 9 Metabolizable protein requirements (MP g/d) of lactating, multiparous, 65 kg Saanen/Toggenburg dairy goats¹⁾

Daily milk yield (kg/d)	Month 1 ²⁾	Month 2-3	Month 4-9 ³⁾
1	61	91	95
2	99	129	133
3	138	168	172
4	176	206	210
5	215	245	249
6	253	283	287

¹⁾ Adapted from AFRC (1998).

²⁾ A deficit of 30g MP/d is accepted in month 1 of lactation

³⁾ Assuming live-weight gain of 1.2 kg/month, equivalent to 4 g MP/d. For primiparous goats, a further 9 g/d should be added for a growth rate of 2.2 kg/month

Very often the protein requirements of high producing lactating animals exceeds the amount provided by the microbial protein, therefore these animals should benefit from the addition of rumen undegradable protein (UDP) in their diet. (Sanz Sampelayo *et al.*, 1998). Waldo & Glenn (1984) reported that the amount of microbial protein synthesized in the rumen is between 120 and 135 g/kg⁻¹ digestible organic matter (DOM). Thus the protein requirement for rumen degradable protein is given at 135 g/kg⁻¹ DOM (NRC, 1981), with the efficiency of microbial protein production from rumen degradable protein being 80-100 %.

The results from using UDP sources in the diets of lactating animals vary and improved results have been reported numerous times with lactating cows (Schingoethe *et al.*, 1988; Broderick *et al.*, 1990 and McCruffey *et al.*, 1990), ewes (Robinson *et al.*, 1979) and goats (Mishra & Rai, 1996). However, some trials done with cows and goats yielded no effect (Broderick & Lane, 1978; Kaim *et al.*, 1987 and Brun-Bellut *et al.*, 1990).

The effects of different RDP: UDP ratios on milk production in lactating dairy goats are not well documented (Mishra & Rai, 1996). The work done by Mishra & Rai (1996) on the effect of different RDP and UDP ratios found that a 55:45 ratio of RDP to UDP in diets for lactating goats may result in higher milk production as compared with a ratio of 75:25. They further reported that

by increasing the UDP (40-45% of total CP) level it may enable formulators to decrease CP (%) by 15-20% and still be able to sustain production.

The need to accurately determine the optimum RDP: UDP requirement is important (Pailan & Kaur, 1996), if maximum benefits are to be achieved from the use of cheaper RDP sources. The use of expensive UDP sources can then be optimized to increase milk production in the cheapest possible way.

1.4.2.5. Bodyweight changes during lactation

Bodyweight gain and loss during lactation is inevitable and can be considered dynamic. During early lactation the animals will mobilize body reserves to maintain or achieve peak milk production, this at the expense of bodyweight. Because of this mobilization of body reserves it is recommended that nitrogen allowances for early lactating goats be reduced during the first month of lactation (Table 9), a reduction of 30 g MP/day (AFRC, 1998). This decrease in nitrogen allowance should allow for no more than 1 kg live weight loss per week. Once the animal has reached the lactation peak and milk production starts to decrease the protein supply can be increased. The recommended daily allowance for protein, depending on the number of kids, should be increased by 4 g MP/day for multiparous and 13 g MP/day for primiparous goats from the fourth month of lactation (Table 9). This should ensure daily gains of 40g and 73 g, or 1.2 and 2.2 kg/month, respectively (AFRC, 1998).

1.5. Associative effects

The concept of associative effects refers to the interactions among ingredients in mixed diets (Erasmus, 2000). In one way or another all nutrients are interrelated on a metabolic level and no nutrient can be considered as more necessary than another. With a deficiency of one nutrient the nutritional value of all other nutrients will be affected.

1.5.1 Energy

The associative effect between energy and protein has been known for a long time, and has been reviewed in literature as early as 1962 by Blaxter. The effect is complex and the relationship between the two nutrients appears to be very close. However, many studies on protein-energy interactions have been confounded by various rumen and metabolic

factors. It is not possible to partition out the effects strictly due to alteration of energy or nitrogen. The source of energy also varies and includes carbohydrates, fats and proteins.

1.5.1.1. Carbohydrates

In the rumen, microbial yields are related primarily to the growth rate that carbohydrates permit and studies on early lactation indicates that dry matter intake and milk yields are highly correlated with carbohydrate digestion rates (Nocek & Russel, 1988). Carbohydrates make up 70-80% of the dry matter intake in a typical dairy cow ration and the rumen is the primary site of carbohydrate digestion.

The ratio of energy to protein (TDN: CP) may be a more accurate method of describing protein requirements than percentage protein (Van Horn *et al.*, 1985). The optimal ratio of digestible nitrogen to metabolizable energy (ME), as reported by Paquay *et al.* (1973), varies with stage of lactation. Requirements as digestible nitrogen intake per megajoules (MJ) ME are given in Table 10 (Paquay *et al.*, 1973).

Table 10 Digestible nitrogen intake/ MJ ME requirements for dairy cows¹⁾

Stage of lactation (months)	Digestible nitrogen intake/ MJ ME
0-3 ²⁾	1.55
6-7	1.30
10 >	1.1

¹⁾ Adapted from Paquay *et al.* (1973).

²⁾ No value available from 4 to 6 months or 8 to 10 months.

Other conclusions from the work of Paquay *et al.* (1973) indicate that a higher proportion of fermentable carbohydrates are likely to stimulate the utilization of digestible nitrogen for milk production, regardless of total energy intake. These results were further strengthened by the work of MacGregor *et al.* (1983) who formulated diets with similar soluble nitrogen (36.3 and 35.5% of CP), but with different starch contents. The diet with the higher starch content had better ruminal protein digestibility (79.6% versus 59.8%) and also lower rumen NH₃ concentrations (15.9 versus 19.3 mg NH₃/litre).

The synchronization of the release of protein and energy in the rumen is well documented (Hoover & Stokes, 1991; Sinclair *et al.*, 1995 and Schmidely *et*

al., 1996) but the results from research are inconsistent. The aim of synchronizing protein and energy release is to maximise microbial growth. Micro-organisms utilize dietary nitrogen to build microbial protein, however this cannot be done without available energy. This energy is supplied via three forms namely carbohydrates, fats and proteins. As previously mentioned, the major source of energy in the rumen is carbohydrates. Carbohydrates like proteins can be degraded at different rates and this allows animal nutritionists to control the rate of release of energy in the rumen. Thus it is believed that releasing energy and proteins at the same time in the rumen may increase dietary protein utilization by the micro-organisms. Research by Herrera-Saldana *et al.* (1986) and Sinclair *et al.* (1995) found that the synchronization of energy and protein release leads to an increased efficiency of microbial protein synthesis, 11 to 20 % in the work done by the first author. In comparison, recent work by Schmidely *et al.* (1996) found that in dry pregnant goats, synchronizing the release of rapidly degrading carbohydrates and proteins in the rumen resulted in an undesirable effect. The diets that were synchronized, inefficiently used nitrogen in the rumen and/or there was a spillage of nitrogen, reflected in the plasma urea. Deductions from the above mentioned trial may be that the period of time plays a role in the effect of synchronization of release. In the first trial mentioned the experimental period was over 16 hours and 4 feedings were given. In the second mentioned trial the experimental time was 3 hours and only one feeding. Therefore, the aim when synchronizing the release of carbohydrates and proteins in diets should be to have a consistent release over a period of time and not peaks in release, as was the case in the second mentioned trial.

1.5.1.2. Lipids

Results from work on methionine have suggested that this amino acid may facilitate lipoprotein synthesis in the liver (Oldham, 1984). This in turn may cause an increased rate of lipid availability for milk synthesis as well as metabolic fuel. Part of the effect of feeding methionine results from changes in ruminal microbial metabolism (Oldham, 1984), yet intravenous infusion has also increased milk fat synthesis (Chamberlain & Thomas, 1982). It is believed that the mechanism is related to the needs for amino acids to synthesize the apo protein fraction of lipoproteins. It may also be that there

is a specific need for methionine as a methyl donor in phosphatidyl choline synthesis (Oldham, 1984).

Although results are inconsistent (Peel *et al.*, 1980 and Oldham, 1984) it has been suggested by Oldham (1984) that an increased supply of amino acids to the intestines may increase the concentration of growth hormone in the blood. This increased concentration of growth hormone has in turn been found to increase palmitate flux in ruminants, which is presumably evidence of lipolytic action (Bines & Hart, 1982).

1.6. Rumen undegradable protein requirements

Research on the effect of rumen undegradable protein sources on milk production is well documented. Recently, Santos *et al.* (1998) compiled a literature review based on trials done on the "Effects of rumen undegradable protein on dairy cow performance" over a 12 year period, 1985-1997. The review covered 108 studies, published primarily in the Journal of Dairy Science. This section will concentrate primarily on the findings and opinions of this review.

Results from the replacement of RDP sources with UDP are inconsistent. From the studies in the review, 76% of the UDP diets resulted in a decreased microbial protein synthesis. Microbial nitrogen flow to the small intestine was significantly decreased when UDP sources were used in 10 comparisons. The opposite was observed when soybean meal was used, and in 25 out of 27 trials microbial nitrogen flow to the small intestine was increased. From this it can be deduced that a shortage of RDP sources in the diet will reduce microbial nitrogen synthesis.

The total flow of nitrogen (sum of microbial nitrogen and non ammonia non microbial nitrogen) to the small intestine was not increased for diets high in UDP. The reason for this was the decreased microbial protein synthesis that balanced the increased non-ammonia non-microbial protein. The microbial protein appears to have a favourable amino acid profile for milk synthesis (Table 11). Schwab (1994), as cited by Santos *et al.* (1998) stated that the majority of UDP sources, however, are inferior to microbial protein in terms of essential amino acids (Table 11).

Table 11 The lysine and methionine contents (as a % of total essential amino acids) of microbial protein and protein sources compared with milk¹⁾

Item	Lysine	Methionine	EAA ²⁾ (% of CP)
Milk	16.4	5.1	38.4
Bacteria	15.9	5.2	33.1
<i>Protein sources</i>			
Blood meal	17.5	2.5	49.4
Brewers dried grain	6.7	4.5	46.3
Maize gluten meal	3.8	7.2	44.2
Maize DDG ³⁾ +solubles	5.9	5.9	37.7
DDG+solubles	6.5	3.7	43.3
Feather meal	3.9	2.1	31.4
Fish meal	16.9	6.5	44.8
M&B meal ⁴⁾ :			
45% CP	12.4	3.0	39.4
50% CP	14.2	3.7	36.6
Soybean meal (solvent)	13.8	2.9	49.6
Expeller soybean meal	13.0	2.9	49.6

¹⁾ Adapted from Schwab (1994), as cited by Santos *et al.* (1998)

²⁾ Essential amino acid

³⁾ Distillers dried grain

⁴⁾ Meat and bone meal

The flow of essential amino acids was not affected by the replacement of soybean meal with UDP sources, this is clear from the 5 out of 25 trials where increases were observed. The flow of lysine and methionine to the small intestine was not significantly increased by UDP sources.

Like all things the RDP-UDP system has its weaknesses. These weaknesses were also listed in the review. A summary of these weaknesses are given:

1. A decreased microbial protein production when diets rich in UDP are fed.
2. A lack of consideration of requirements for limiting amino acids for synthesis of milk protein, tissue protein, and other protein needs of the animal.

3. No consideration is given to the changes in the amino acid composition of protein existing in the rumen for absorption in the small intestine when various UDP sources are fed.
4. No consideration for the efficiency of absorption of essential amino acids in the small intestine.
5. No consideration for the use of amino acids by the gut and liver tissue prior to release for mammary uptake.
6. No consideration for the efficiency of mammary use of amino acids for milk protein synthesis.

Regarding the last three points, little data is available on these factors. At present only modeling of data in the literature and the use of recent post absorptive data is able to estimate the value of these last three points.

The advantages or benefits of the RDP-UDP system are not discussed in the review, yet mention must be made of some of its advantages or benefits. The system is well implemented in feed mills today and many animal nutritionists make use of it, it is user friendly and is useful on a practical level. The value of protein sources as RDP versus UDP is generally well known to animal nutritionists. However, it is important that animal nutritionists stay abreast with new data, especially information on the quality characteristics of the protein sources. No system is perfect and even a complex system such as the Cornell system has its weaknesses (Santos *et al.*, 1998). In all systems, however, an understanding of these weaknesses is crucial. With this understanding, the weakness in the system can be reduced and greater benefits be obtained from the system.

In conclusion, the review states that the replacement of soybean meal with protein sources high in UDP may result in a decreased microbial protein flow to the duodenum if the RDP is insufficient to meet the microbial needs. Thus, UDP sources should not replace RDP sources at the expense of the RDP sources. Certain UDP sources have proved to be more consistent in delivering positive results. Most of the UDP sources that are used commercially have an inferior amino acid profile when compared to microbial protein. In order, fish meal and then treated soybean meals are more often than not the UDP sources used in trials where positive results are seen. It is also these sources that ranked highest in their EAA index when compared to milk (Table 11). The use of UDP sources in diets can have positive effects. However, a knowledge of the findings of this review are necessary to achieve these benefits.

1.7. Conclusion

Information concerning the effects of RDP: UDP ratios on dairy goat production is included in the requirements given by the AFRC (1993), yet there is still a shortage of published data on this topic which is relevant to dairy goats. The purpose of this study was to determine the effect of dietary protein degradability on the performance of Saanen dairy goats. In Chapter 2, the study attempts to address two issues namely, the effect of weaning age and dietary protein degradability on the performance of Saanen kids. In Chapter 3, the study attempts to investigate the influence of dietary protein degradability on the performance of lactating Saanen does.

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CHAPTER 2

THE EFFECT OF WEANING AGE AND DIETARY PROTEIN DEGRADABILITY ON THE PERFORMANCE OF SAANEN KIDS

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ABSTRACT

The effect of weaning age (42 versus 70 days) and dietary protein degradability were investigated, using 58 male Saanen kids. The kids were randomly divided into two weaning day treatments, a 42 day (42) and a 70 day (70) weaning day treatment. Within the weaning day treatments, the kids were again divided into two dietary treatments. One group received a low rumen undegradable protein (UDP) creep diet (LC) and the other a high UDP creep (HC) diet. At 15.66 ± 3.09 kg the kids were taken off the creep diet and put on the growth diet. At this transition, the kids in each of the four established treatments were again divided into another two dietary treatments, a low (LG) or a high (HG) UDP growth diet, resulting in a total of eight treatments for the trial. Weaning age had a significant effect on performance. Kids weaned at 42 days of age versus those weaned at 70 days of age had a higher daily intake. The 42 day weaned kids were successfully weaned with no post-weaning shock when the kids were consuming an average of 240g/day of the diet. The creep diets used in this trial were formulated with different RDP: UDP ratios (LC = 73:30 and HC = 60:40), however the results from the degradability trial failed to show a difference in the RDP: UDP ratios (LC = 72:28 and HC = 73:27). For this reason it is not possible to make any conclusions regarding the effect of dietary protein degradability in the creep diets on growth performance. In the growth diets there was a significant difference in the dietary protein degradability between the low UDP and the high UDP diets (LG = 73:27 and HG = 68:32). The different dietary protein degradabilities in the two growth diets used in this trial had no effect on any of the growth parameters tested for when the Saanen kids were 80 to 140 days of age.

Key words: Dairy Goats, Protein Degradability, Nutrition, Weaning age, Saanen kids.

INTRODUCTION

The rearing of dairy goat kids is not well researched, and literature on the effects of weaning age and nutritional requirements of dairy goat kids is scarce when compared with dairy calves. The correct raising of replacement does for the milk herd is a long-term investment in the farmer's business. Good replacement does for the dairy herd could mean the difference between profitable and non-profitable dairy goat farming. A good kid rearing program, that has been scientifically

proven, needs to be developed and continually improved on, so as to maximize farm profitability both in the short and long term.

There are generally two weaning programs for the rearing of dairy goat kids, weaning at 42 days or 70 days of age (Mowlem, 1992). If kids are to be weaned at 42 days of age it is imperative that they are eating adequate solid food and drinking water. Well-grown kids on a weaning program where milk is decreased before weaning, should not undergo a post-weaning growth shock, provided their dry matter intake is sufficient (Mowlem, 1992).

Very little research has been done on the effect of dietary protein degradability on goat kid performance. In young, fast-growing ruminants the protein requirements may exceed the amount that can be provided by the microbial protein. Supplementation with low degradable proteins, to provide an optimum amino acid pattern in the lower digestive tract, may result in an increased performance of pre-weaned and post-weaned kids (Hadjipanayiotou *et al.*, 1995).

This study aims to address two of the above-mentioned issues, namely the effect of weaning age, as well as dietary protein degradability, on the performance of Saanen kids.

MATERIALS AND METHODS

Two creep and two growth diets were formulated, according to the NRC (1985) for lambs, mixed and pelleted at Meadow Feed Mills, Cape (Paarl, South Africa). The crude protein (CP) content of the creep and growth diets on a dry matter (DM) basis were iso-nitrogenous at 21.00% and 16.52%, respectively. All the diets were iso-caloric (11.58 MJ ME/kg) on a DM basis. The creep diets and growth diets were formulated with different protein degradabilities. The two creep diets were formulated to have rumen degradable protein (RDP): rumen undegradable protein (UDP) ratios of 70:30 and 60:40, referred to as low creep (LC) and high creep (HC) diets, respectively (Table 1). The two growth diets also were formulated with RDP: UDP ratios of 70:30 and 60:40, referred to as low growth (LG) and high growth (HG) diets, respectively (Table 1). Fishmeal was used as a natural source of rumen undegradable protein in the HC and HG diets (Table 2).

Table 1 Chemical¹⁾ composition of the creep and growth diets

	Creep low	Creep high	Growth low	Growth high
Dry matter (%)	89.81	89.45	88.10	90.66
Organic matter (%)	90.82	90.63	88.80	87.66
Crude protein (%)	21.21	20.82	16.85	16.18
UDP (%)	4.88	4.48	3.71	4.53
RDP:UDP	77:23	78:22	77:22	72:28
ME (MJ/kg)	11.55	11.60	11.73	11.45
Crude fibre (%)	11.37	8.93	9.71	7.59
ADF (%)	15.22	14.26	15.92	16.99
NDF (%)	30.63	20.14	29.81	19.31
Fat (%)	4.97	4.20	3.82	2.95
Ca (%)	0.77	0.77	0.77	0.77
P (%)	0.39	0.39	0.39	0.38
Na (%)	0.23	0.29	0.34	0.34

¹⁾ On a dry matter basis

Table 2 Physical¹⁾ composition (%) of the creep and growth diets.

	Creep low	Creep high	Growth low	Growth high
Maize meal	20.56	34.43	32.24	55.48
Wheat bran			13.75	
Fish meal		3.82		7.04
Groundnut oilcake	3.33		3.33	
Sunflower oilcake (37.5% CP)	10.79		1.62	
Soya oilcake (46.5% CP)	2.34	13.01		
Full fat soya	5.00	4.00		
Maize germ oil	10.00		10.00	
Lucerne meal	30.00	30.00	22.00	25.15
Molasses meal	9.00	9.00	9.00	9.00
Supermax premix	6.81	3.70	5.46	0.97
Vit A,D, E premix	0.10	0.10	0.10	0.10
Eco oxytet 20%	0.05	0.05	0.05	0.05
Salt	1.02	1.16	1.58	1.24
Sheep minerals	0.05	0.05	0.05	0.05
Ammonium chloride	0.50	0.50	0.75	0.75
Taurotec ²⁾	0.03	0.03	0.03	0.03
Limestone	0.38	0.16	0.16	0.16

¹⁾ On an as fed basis

²⁾ Growth promoter

Growth trial

Fifty-eight Saanen male kids (\pm 7 days of age) were used in a 140-day growth trial on the experimental diets presented in Table 1 and 2. Until 20 days of age the kids were grouped to prevent losses due to the cold. At 20 days of age the kids were individually penned and feed and

water were available *ad libitum*. The kids' average bodyweight at the beginning of the trial was 6.44 ± 0.93 kg (20 days of age).

The kids were randomly divided into two weaning age treatments, viz. 42 days and 70 days. Within the weaning day treatments, the kids were again divided into two dietary treatments. One group received a low UDP creep diet (LC) and the other a high UDP creep diet (HC). At 15.66 ± 3.09 kg (80 days of age) the kids were taken off the creep diet and put on the growth diet, a low UDP (LG) versus a high UDP (HG) growth diet. At this transition, the kids in each of the four established treatments were again divided into two dietary treatments, a high or a low UDP growth diet, resulting in a total of eight treatments for the trial. A summary of the treatments follows:



Throughout this paper, reference is made to the treatments as, for example 42 LL. This indicates weaning day treatment (42 or 70) and the creep UDP treatment (L or H) followed by the growth UDP treatment (L or H).

Milk intake was increased by 100 ml/day from 600 ml/day at 10 days of age until 1200 ml/day was reached. A week prior to the weaning date the milk volume per kid was halved, and milk was only offered once a day.

Feed intake was recorded weekly and kids were weighed weekly before the morning feeding.

Degradability trial

The experimental diets were also compared in a degradability trial, so as to determine the amount and type of protein supplied to the dairy goat kids. Six ruminally cannulated Dohne merino wethers were used as experimental animals. The average bodyweight was 65 kg. The wethers were individually penned and feed and water were available *ad libitum*.

The wethers were adapted to the diets over a period of 14 days. Three wethers per diet were tested at one time. After each period the diets were allocated to three different wethers and the animals adapted again to the new diet, resulting in six observations for each diet.

The procedure described in the AFRC (1993) Technical Committee on Responses to Nutrients, Report No. 9, "Estimation of protein degradability", were followed. In this trial the experimental diets presented in Table 1 were used. Attachment of the bags was described by Loëst (1995). The bags were inserted into the rumen using the reverse order, starting with the 48 hour incubation sample and then simultaneously removing all the bags at 0 hours (Brand, 1999). The following incubation times were used, 0, 1, 2, 4, 8, 12, 18, 24 and 48 hours.

The effective DM and CP degradability of the three diets was determined according to the model of Ørskov & McDonald (1970):

$$dg = a + b \{1 - e^{(ct)}\}$$

Chemical and statistical analyses

The diets were analysed for moisture, ash, CP and ether extract (EE) according to the methods of A.O.A.C. (1998). The acid detergent fibre (ADF) and neutral detergent fibre (NDF) were analysed using a Tecator Fibretec System (Van Soest, 1963 and Van Soest & Wine, 1967). For the degradability trial the incubated samples were analyzed for DM and nitrogen (N). The N content was determined with a Leco Auto Analyzer (Model FP-428). The effective DM and CP degradability of the four diets were determined according to the method of Ørskov & McDonald (1970). The rate of rumen turnover was set at two levels, 0.05 and 0.08 per hour (AFRC, 1993).

The treatment design for the growth trial was a 2 x 2 x 2 (Weaning age x Creep diet x Growth diet) factorial design. The degradability trial had four treatments (Creep high, Creep low, Growth high and Growth low). The experimental design of the trials was a completely randomised design with eight replicates for the growth trial and six replicates for the degradability trial. Data was tested for normality using the Shapiro-Wilk statistic (Shapiro & Wilk, 1965). An analysis of variance was performed and significant effects were further submitted to Student's t – LSD ($P < 0.05$) (SAS, 1996). Weaning age and dietary protein degradability interactions were also tested.

RESULTS AND DISCUSSION

Degradability Trial

The DM degradability results (Table 3) show no significant ($P < 0.05$) differences for any of the estimated fractions, nor were there significant differences in effective DM degradabilities at any of the solid outflow rates/hour (0.05 or 0.08).

Table 3 The non-linear dry matter degradability parameters *a*, *b* and *c* and effective degradability values of the creep and growth diets as obtained with ruminally cannulated Dohne Merino wethers (mean and standard error) (*n* = 6)

	Creep low	Creep high	Growth low	Growth high
<i>a</i> ¹⁾	0.479±0.015	0.441±0.015	0.421±0.015	0.458±0.015
<i>b</i> ¹⁾	0.373±0.015	0.406±0.015	0.402±0.015	0.384±0.015
<i>c</i> ¹⁾	0.220±0.030	0.198±0.030	0.178±0.030	0.151±0.030
Effective degradability (%) (<i>r</i> = 0.05/hour) ²⁾	77±1.4	76±1.4	73±1.4	75±1.4
Effective degradability (%) (<i>r</i> = 0.08/hour) ²⁾	74±1.6	73±1.6	70±1.6	71±1.6

^{a,b} Values in rows bearing different superscript letters differ significantly (*P* < 0.05)

1) Degradability parameters: *a* is the zero time intercept (fraction of the protein sample that is quickly solubilized or degraded in the rumen), *b* is the fraction that is potentially degradable in the rumen, *c* is the rate of degradation of fraction *b* (/h).

2) *r* is the rumen solid outflow rate/hour (0.05 and 0.08).

The results from the degradability trial (Table 4) indicate the two creep diets had 77% (0.05/hour) and 72% (0.08/hour) of rumen degradable protein, which were higher than the formulated values. According to the formulated values the two creep diets had RDP: UDP ratios of 70:30 and 60:40. The two creep diets did not differ significantly (*P* < 0.05) from one another in terms of RDP or UDP. Thus these creep diets could not be used to test the influence of dietary protein degradability on the growth of Saanen kids.

Significant differences in protein degradability between the growth diets were obtained for some of the estimated parameters that were tested and calculated (Table 2). At a passage rate of 0.05/hour the growth diets differed significantly (*P* < 0.05) in effective protein degradability. The growth low diet showed a significantly (*P* < 0.05) higher slowly degraded protein value. Accordingly the growth low diet provided the highest amount of effective rumen degradable protein at both the solid rumen outflow rates. From the results of this trial it is possible to test the effect of the dietary protein degradability, using these growth diets, on the growth of Saanen kids.

Table 4 Estimation of the amount and type of dietary protein (mean and standard error) supplied to the male Saanen kids in the creep and growth diets, using the metabolizable protein system (AFRC, 1993) (n = 6/treatment)

	Creep low	Creep high	Grow low	Grow high
Dietary CP (g/kg DM)	212	208	168	161
a ¹⁾	0.452±0.019	0.425±0.019	0.477±0.020	0.490±0.021
b ¹⁾	0.465±0.029	0.504±0.029	0.458±0.032	0.371±0.032
c ¹⁾	0.119±0.016	0.125±0.016	0.113±0.017	0.084±0.017
Effective degradability (%) (r = 0.05/hour) ²⁾	77±1.7	78±1.7	78±1.8 ^a	72±1.8 ^b
Effective degradability (%) (r = 0.08/hour) ²⁾	72±1.8	73±1.8	73±1.9	68±2.0
Quickly degraded protein (g/kg DM)	95.7±3.89	88.6±3.896	80.3±4.27	79.2±4.27
Slowly degraded protein, r = 0.05/hour (g/kg DM)	67.9±4.47	73.9±4.47	51.2±4.90 ^a	37.5±4.90 ^b
Slowly degraded protein, r = 0.08/hour (g/kg DM)	57.6±4.47	62.8±4.18	43.0±4.58 ^a	30.6±4.58 ^b
Rumen undegradable protein, r = 0.05/hour (g/kg DM)	48.4±3.36	45.8±3.36	36.9±3.68	45.0±3.68
Rumen undegradable protein, r = 0.08/hour (g/kg DM)	58.8±3.62	56.8±3.62	45.2±3.96	51.9±3.96
Effective rumen degradable protein, r = 0.05/hour (g/kg DM)	144.6±3.26	144.7±3.26	115.4±3.57 ^a	100.9±3.51 ^b
Effective rumen degradable protein, r = 0.08/hour (g/kg DM)	134.1±3.39	133.7±3.39	107.3±3.72 ^a	94.0±3.72 ^b

^{a,b} Values in rows bearing different superscript letters differ significantly (P < 0.05)

¹⁾ Degradability parameters: a is the zero time intercept (fraction of the protein sample that is quickly solubilized or degraded in the rumen), b is the fraction that is potentially degradable in the rumen, c is the rate of degradation of fraction b (/hour).

²⁾ r is the rumen solid outflow rate/hour (0.05 and 0.08).

Effect of weaning age

The effect of weaning age on performance of Saanen kids at 80 days of age is presented in Table 5. The feed intake of the 42 day treatment was 48% higher (P < 0.05) than the 70 day treatment. When considering the feed intake per day (Figure 1) it is clear that following weaning at 42 days of age, the daily feed intake increased dramatically, compared to the 70 day weaning treatment. In the 42 day weaning treatment the kids were consuming 240 g of creep diet per day at weaning. Dry matter intake (milk plus creep diet) was also significantly (P < 0.001) higher for the 42 day weaning treatment compared to the 70 day weaning treatment.

The data presented in Figure 1 and Table 5, would suggest that weaning at 42 days of age can be successfully achieved, provided that kids eat at least 240 g of the diet per day. On the other hand, Morand-Fehr (1976) reported that few problems with weaning were observed when Alpine kids were eating 30-50 g/day of dry feed. This reported result varies considerably from the results obtained in this trial.

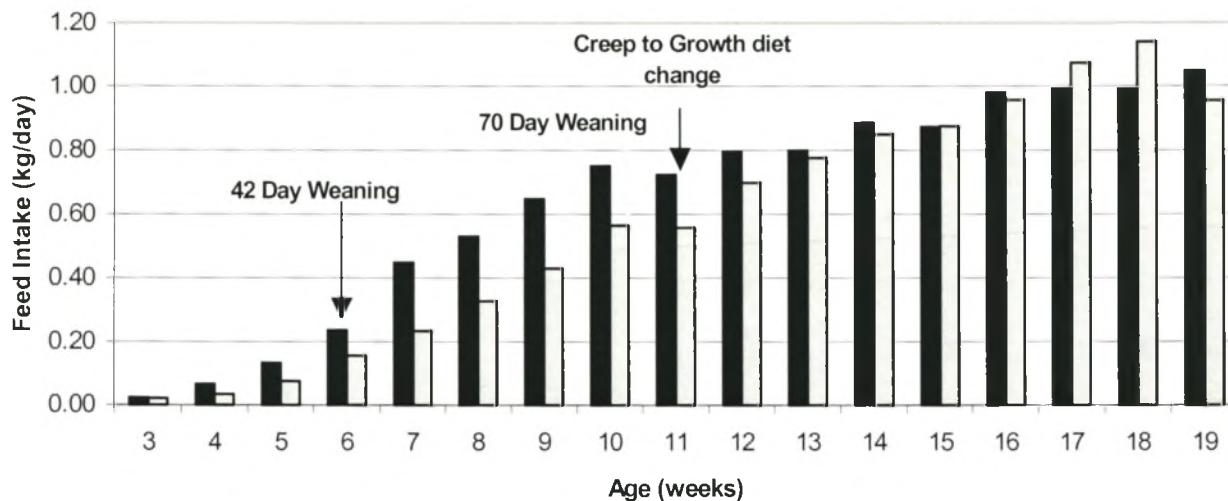


Figure 1 Feed intake (kg/day) of the 42 versus 70 day weaned kids over the total trial period of 140 days.

Table 5 The effect of weaning age on performance (mean and standard error) of male Saanen kids from 20 to 80 days of age

Weaning age (days)	42	70
Number of animals	30	28
Initial bodyweight (kg)	6.4 ± 0.17	6.4 ± 0.18
Final bodyweight (kg)	15.9 ± 0.57	15.4 ± 0.60
Cumulative feed intake (kg)	24.9 ± 1.32 ^a	16.8 ± 1.39 ^b
Feed intake (g/day)	395 ± 20.9 ^a	266 ± 22.0 ^b
Cumulative dry matter intake ¹⁾ (kg)	27.6 ± 1.18 ^a	22.7 ± 1.24 ^b
Dry matter intake ¹⁾ (g/day)	437 ± 18.7 ^a	361 ± 19.7 ^b
Average daily gain (g/day)	150 ± 8.1	142 ± 8.6
Feed conversion efficiency ¹⁾ (kg feed/kg weight gain)	3.0 ± 0.13	2.8 ± 0.14

^{a,b} Values in rows bearing different superscript letters differ significantly (P < 0.05)

¹⁾ Milk plus creep diet intake

Effect of dietary protein degradability on growth of Saanen kids

The effects of the creep diet protein degradability and weaning age on the performance of Saanen kids from 20 and 80 days of age are presented in Table 6. No significant differences ($P < 0.05$) occurred between any of the dietary treatments within a weaning age treatment.

As the results from the degradability trial indicated no significant difference in protein degradability existed between the two creep diets. Thus no conclusions can be drawn from this trial regarding the effect of dietary protein degradability on the growth of Saanen kids fed a creep diet.

Casey (1982) conducted a similar type of trial with boer goat kids which they separated from their dams at 24 hours and artificially raised (creep diet with 14% CP) and then weaned the kids at 42 days of age. The boer goats kids in the trial achieved an average daily gain (ADG) of 139 g/day from birth to 23 days of age. Compared with the data from ^{table 6} ~~this trial~~, in which the male Saanen kids grew at an average of 146 g/day, the Boer goat kids did not perform as well.

Table 6 The effect of the creep diet protein degradability and weaning age on the performance (mean and standard error) of male Saanen kids from 20 to 80 days of age

Weaning age (days)	42		70	
Creep diet	L ¹⁾	H ²⁾	L	H
Number of animals	16	14	13	15
Initial bodyweight (kg)	6.6±0.32	6.3±0.25	6.1±0.26	6.7±0.25
Final bodyweight (kg)	16.3±0.79	15.4±0.84	15.6±0.87	15.3±0.84
Cumulative feed intake (kg)	26.2±1.81 ^a	23.5±1.94 ^a	15.8±2.01 ^b	17.7±1.94 ^b
Feed intake (g/day)	415±28.7 ^a	373±30.7 ^a	250±31.8 ^b	281±30.7 ^b
Cumulative dry matter intake ³⁾ (kg)	28.7±1.62 ^a	26.3±1.73 ^{ab}	21.9±1.80 ^b	23.6±1.73 ^b
Dry matter intake ³⁾ (g/day)	455±25.8 ^a	416±27.5 ^{ab}	347±28.6 ^b	374±27.5 ^b
Average daily gain (g/day)	155±11.2	144±11.9	150±12.4	135±11.9
Feed conversion efficiency ³⁾ (kg feed/kg weight gain)	3.0±0.18	2.9±0.19	2.6±0.20	3.0±0.19

^{a,b,c} Values in rows bearing different superscript letters differ significantly ($P < 0.05$)

^{1,2)} Low (L) or high (H) creep dietary protein degradability

³⁾ Milk plus creep diet

The effects of the growth diet protein degradability and weaning age on the performance of Saanen kids from 80 and 140 days of age are presented in Table 7. No significant differences ($P < 0.05$) occurred between any of the dietary treatments within a weaning age treatment.

Results from the degradability trial (Table 4) show a significant difference ($P < 0.05$) in protein degradability between the two growth diets. The use of low degradable protein diets to increase protein supply to the small intestine and thus increase growth and improve production (Hadjipanayiotou *et al.*, 1996) has failed to demonstrate any benefits over this period of the trial.

In the trial of Casey (1982) the boer goat kids grew from 23 to 32 kg bodyweight at 182 g/day, this is not as good as the ADG of the male Saanen kids in this trial who grew from 15.65 to 29.91 kg at an average of 254 g/day.

Table 7 The effect of the growth diet protein degradability and weaning age on the performance (mean and standard error) of male Saanen kids from 80 to 140 days of age

Weaning age (days)	42				70			
Creep diet	L ¹⁾		H ²⁾		L		H	
Growth diet	L ³⁾	H ⁴⁾	L ³⁾	H ⁴⁾	L ³⁾	H ⁴⁾	L ³⁾	H ⁴⁾
Number of animals	8	8	7	7	7	6	7	8
Initial bodyweight (kg)	16.3±0.79		15.4±0.84		15.6±0.87		15.3±0.84	
Final bodyweight (kg)	29.6 ±1.88	30.7 ±1.88	29.6 ±2.01	29.6 ±2.01	30.9 ±2.01	28.8 ±2.17	29.7 ±2.01	30.4 ±2.01
Cumulative feed intake (kg)	50.7 ±3.10	48.1 ±3.10	54.1 ±3.31	49.3 ±3.31	55.6 ±3.31	49.3 ±3.58	53.8 ±3.31	49.1 ±3.31
Feed intake (g/day)	910± 55.3	858± 55.3	966± 59.1	880± 59.1	991± 59.1	881± 63.8	960± 59.1	877± 59.1
Cumulative dry matter intake (kg)	44.9 ±2.76	43.6 ±2.76	47.7 ±2.96	44.7 ±2.96	50.6 ±2.96	46.4 ±3.19	49.0 ±2.96	46.2 ±2.96
Dry matter intake (g/day)	801± 49.3	778± 49.3	851± 52.7	798± 52.7	903± 52.7	828± 57.0	875± 52.7	824± 52.7
Average daily gain (g/day)	244± 23.1	248± 23.1	262± 24.7	244± 24.7	276± 24.7	230± 26.7	262± 24.7	266± 24.7
Feed conversion efficiency (kg feed/kg weight gain)	3.3 ±0.24	3.3 ±0.24	3.3 ±0.25	3.4 ±0.25	3.5 ±0.25	3.3 ±0.24	3.3 ±0.25	3.4 ±0.25

a,b) Values in rows bearing different superscript letters differ significantly ($P < 0.05$).

1,2) Low (L) or high (H) creep dietary protein degradability

3,4) Low (L) or high (H) growth dietary protein degradability

The results from the growth trial from 20 to 140 days of age are presented in Table 8. No significant differences ($P < 0.05$) occurred between any of the parameters tested. Ferreira (1992) calculated the ADG of merino lambs kept under similar conditions at 16 weeks of age (112 days of age) to be 257 g per day. This is 60 g/day more than the ADG of the kids (140 days of age) used in this trial (ADG of 197g/day). Considering that Saanen goats are selected primarily for milk

production and not for meat production, the above ADG comparison between merino lambs and Saanen goat kids is favourable for Saanen goat. In the 1999 Oklahoma Meat Goat Association annual meat buck performance test, (Gipson, 2000) castrated boer goat kids achieved an average feed conversion efficiency (FCE) of 5.29. Compared with the 3.0 FCE of the male Saanen kids in this trial the boer goats did not perform as well.

Table 8 The effect of the dietary protein degradability and weaning age on the performance (mean and standard error) of male Saanen kids from 20 to 140 days of age

Weaning age (days)	42				70			
Creep diet	L ¹⁾		H ²⁾		L		H	
Growth diet	L	H	L	H	L	H	L	H
Number of animals	8	8	7	7	7	6	7	8
Initial bodyweight (kg)	6.6±0.32 ^a		6.3±0.25 ^a		6.1±0.26 ^a		6.7±0.25 ^a	
Final bodyweight (kg)	29.6 ±1.88	30.7 ±1.88	29.6 ±2.01	29.6 ±2.01	30.9 ±2.01	28.8 ±2.17	29.8 ±2.01	30.4 ±2.01
Cumulative feed intake (kg)	75.9 ±5.12 ^a	75.4 ±5.12	77.6 ±5.48	72.9 ±5.47	71.33 ±5.48	65.2 ±5.92	71.3 ±5.48	66.9 ±5.48
Feed intake (g/day)	638± 43.1	633± 43.1	651± 46.0	612± 46.0	599± 46.0	547± 49.7	599± 46.0	562± 46.0
Cumulative dry matter intake ³⁾ (kg)	72.5 ±4.57	73.3 ±4.57	73.9 ±4.89	71.0 ±4.89	72.4 ±4.89	68.3 ±5.28	72.5 ±4.89	69.8 ±4.89
Dry matter intake ³⁾ (g/day)	609± 38.4	616± 38.4	620± 41.1	596± 41.1	608± 41.1	573± 44.4	609± 41.1	586± 41.1
Average daily gain (g/day)	196± 15.1	199± 15.1	194± 16.1	197± 16.2	208± 16.2	190± 17.5	195± 16.2	197± 16.2
Feed conversion efficiency ³⁾ (kg feed/kg weight gain)	3.1 ±0.13	3.2 ±0.13	3.2 ±0.14	3.1 ±0.14	2.9 ±0.14	3.0 ±0.15	3.2 ±0.14	3.0 ±0.14

^{a,b} Values in rows bearing different superscript letters differ significantly (P < 0.05)

^{1,2)} Low (L) or high (H) dietary protein degradability

³⁾ Milk plus creep and growth diet intake

The results from the trial (80 to 140 days of age) agree with the results of Holtshausen & Cruywagen (2000), where the use of low rumen degradable protein failed to improve the production of veal calves under 100kg live weight. The lack of a physiologically developed rumen and rumen bacterial population appears to be the most obvious reason for the lack of response. Holtshausen & Cruywagen (2000) concluded that as long as the calves were consuming feed on an *ad lib.* basis, and the CP content met basic recommendations, they would be able to consume sufficient DM to supply their needs for rapid growth from a highly degradable protein source. Also, inconsistent improvements in animal growth performance with slow degradable proteins was reported by Loerch (1985), and it was suggested that improvements would only be achieved under certain conditions, such as when dietary protein was limiting for growth. In the present study, the growth diets were formulated with a 16.52% CP level, on a DM basis, this CP levels may have supplied all the necessary protein required.

CONCLUSION

In this trial weaning at 42 days of age has proven to be effective. After weaning at 42 days, with a feed intake of 240 g/day, the kids underwent no post-weaning shock. At 80 days of age the feed intake was higher for those kids weaned at an earlier age, approximately 48 % in this trial. At 80 days the kids weaned at 42 days weighed the same as those weaned at 70 days of age.

The results from the degradability trial conducted on the two creep diets indicated no significant difference ($P < 0.05$) in effective protein degradability existed between the diets, therefore no conclusion can be made from this trial regarding the influence of dietary protein degradability over the creep period (20 – 80 days of age) of this trial.

Significant differences ($P < 0.05$) in effective protein degradability between the growth diets fed over the period 80 – 140 days of age did exist. Growth parameters tested over the period 80 – 140 days of age did not differ significantly ($P < 0.05$). Adequate DM intake and supply of CP in the diet are possible reasons for the lack of response. In this trial dietary protein degradability had no effect on growth parameters.

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CHAPTER 3

THE EFFECT OF DIETARY PROTEIN DEGRADABILITY ON PRODUCTION CHARACTERISTICS OF LACTATING SAANEN DOES

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ABSTRACT

Three diets formulated with different dietary protein degradabilities were tested, using 21 lactating Saanen does. The three diets were formulated with rumen degradable protein (RDP): rumen undegradable protein (UDP) ratios of 70:30, 62:38 and 62:38, with one of the high UDP diets containing 20% less CP. Results from the degradability trial showed that the diets in fact had RDP: UDP ratios of 82:18, 78:22 and 79:21, and that the diets did not differ significantly from one another. Results from the production trial indicated that there was a significant difference in feed intake, dry matter (DM) intake and bodyweight. The does on the low UDP diet had significantly higher feed intakes and DM intakes and were significantly heavier at the end of the trial period. Palatability may have influenced feed and DM intake, as the low protein high UDP and high UDP diets both contained higher levels of fishmeal. No significant differences in milk production, milk composition or milk production efficiency were observed. Besides the fact that the diets did not differ in effective protein degradability, large variation in milk production between animals and low numbers of animals per treatment limited the ability to measure a difference between the treatments. Results from the digestibility trial varied between the diets with the low UDP diet having a significantly lower digestibility overall than the other two diets. The reasons for the difference in digestibility could be due to the difference in rate of passage (low UDP = 0.064/hour versus the 0.044-0.045/hour of the low protein and high UDP diets respectively) and the high ADF value of the low UDP diet. Because no difference in effective protein degradability existed between the diets it is not possible to make an accurate conclusion on whether or not the dietary protein degradability had an influence on production parameters in this trial.

Key words: Dairy Goats, Saanen Does, Protein Degradability, Nutrition.

INTRODUCTION

With an estimated world goat population of 590 million goats in 1991 (FAO, 1991 as cited by Haenlein, 1996), it is impossible to consider the goat as insignificant. The need for milk and, it seems, particularly goat's milk, is obvious if one considers the increase in dairy goat populations over the past 20 years. During the past twenty years the dairy goat population has increased by

52%, while in developing and developed countries there has been an increase of 56% and 17% respectively (Haenlein, 2000), across the globe.

Research into the protein requirements and particularly protein degradability requirements of dairy goats is scarce, yet in recent years there has been an increased interest in the effect of protein supplementation to lactating animals (Mishra & Rai, 1996). The work of Mishra & Rai (1996) showed the benefits obtained from the use of different rumen degradable protein supplements (RDP) for lactating dairy goat does. Does on highly degradable protein diets had higher feed intakes, while the does on low degradable protein diets gave higher milk production. Highly degradable protein diets stimulate the production of rumen flora, which in turn increases the rate of digestion and increases rate of passage, this increased rate of passage allows for a higher feed intake. Low degradable protein diets may allow the animal to overcome any limiting nutrients, in particular limiting amino acids, and this could explain the increase in milk production. Other research in this field of science has delivered positive results with more than one species of lactating animal with increased levels of UDP in the diet (Robinson *et al.*, 1979 and Christensen *et al.*, 1993).

Santos *et al.* (1998) reviewed 108 published studies from 1985 to 1995, it was strongly suggested that the use of rumen undegradable protein (UDP) in the diets of dairy cows often results in decreased RDP, and a change in absorbed amino acid profiles. This review concluded that increased UDP levels in the diet don't consistently improve lactation production.

Pailan & Kaur (1996) and Mishra & Rai (1996) did research on lowered crude protein (CP) levels with increased UDP levels in lactating dairy does. They made use of three protein supplements with the one containing a 20% lower CP value but an increased level of UDP (40-45% of total CP). The research concluded that a decreased CP level and an increased level of UDP still resulted in sustainable production, as compared to supplements with a higher CP value.

The aim of the present study was to determine whether an increased UDP and decreased RDP level would be able to increase production and also whether a decreased CP level and an increased UDP level would be able to sustain the production of lactating Saanen does.

MATERIALS AND METHODS

Three complete diets, each with different protein degradabilities, were formulated according to the NRC (1981), mixed and cubed at Meadow Feed Mills, Cape (Paarl, South Africa). The three diets were formulated with different RDP: UDP ratios of 70:30; 62:38 and 62:38, referred to as low UDP, low protein high UDP and high UDP diets respectively (Table 1). The low UDP and high UDP diets

were iso-nitrogenous (20.11% CP) while the low protein high UDP diet had an 18.30% CP content on a dry matter (DM) basis. All diets were iso-caloric (12 MJ ME/kg DM). Fishmeal was used as a natural source of UDP in all three diets, while cottonseed oilcake was used as an additional natural source of UDP in the high UDP diet (Table 2).

Table 1 Chemical composition¹⁾ of the three experimental diets

	Low UDP	Low protein, high UDP	High UDP
Dry matter (%)	85.58	84.97	86.98
Organic matter (%)	89.23	91.07	91.51
Crude protein (%)	20.73	18.30	19.48
UDP (%)	3.73	4.03	4.09
RDP:UDP (% of CP)	82:18	78:22	79:21
ME (MJ/kg)	12.13	12.18	11.98
Crude fibre (%)	14.34	13.40	13.52
ADF (%)	20.28	11.78	14.79
NDF (%)	24.43	36.50	29.12
Fat (%)	5.31	5.40	6.30
Ca (%)	0.57	0.73	0.84
P (%)	0.40	0.41	0.54
Na (%)	0.41	0.48	0.52

¹⁾ On a dry matter basis

Table 2 Physical composition¹⁾ (%) of the three experimental diets

	Low UDP	Low protein, high UDP	High UDP
Maize meal	23.86	42.82	34.43
Fish meal	2.72	7.06	11.23
Groundnut oilcake	3.33		
Soya oilcake (46.5% CP)	4.97		
Cotton oilcake (45% CP)			2.17
Limestone	3.31		
Maize germ	10.00		
NaOH wheat straw	5.00	5.00	5.00
Coarse Lucerne	32.00	32.00	32.00
Molasses cuber	5.00	5.00	5.00
Supermax premix	8.95	7.38	9.44
Vit A,D,E premix	0.16	0.16	0.16
Salt	0.50	0.50	0.50
Sheep mineral premix	0.05	0.05	0.05
Citrus ruminant flavour	0.02	0.02	0.02

¹⁾ On an as fed basis

Production trial

Twenty-one early lactating (± 1 week) Saanen does were used as experimental animals in a 120-day production trial. The does were stratified according to lactation number (two–five) and bodyweight (59 ± 2.6 kg). The does were randomly allocated to one of the three experimental diets and were individually penned and feed and water were available *ad libitum*.

Milking took place twice a day at 6:30 and 15:30, at intervals of nine and 15 hours. Milking was done with a milk machine adapted for goats (Porter, 1998) using hygienic practices. Does were milked in groups of six animals of mixed treatments, so as to avoid a milking effect.

Milk production was recorded at every milking. Feed intake and bodyweight were determined weekly while milk samples (during an afternoon milking) were taken once a week for analysis. As the milk samples were only taken during afternoon milking, the following equation, supplied by the South African National dairy cattle performance-testing scheme, was applied to determine butterfat values to correct daily variations in the percentage of butterfat:

$$\text{Corrected Butterfat (\%)} = \frac{1.71 \times \% \text{ butterfat} \times \text{afternoon milk yield (kg)}}{\text{Milk yield for the day (kg)}}$$

Digestibility and nitrogen metabolism trial

The three experimental diets were compared in a seven-day digestibility and nitrogen metabolism trial. Eighteen (six/diet) does were used (due to space limitation) and they varied from 84 to 110 days in lactation. Metabolic crates were used to ensure accurate collection of faeces and urine. Feed intake was restricted to a maximum of 2kg/day to minimize refusal (Barnes & Brown, 1990) and was offered in two equal portions after milking in the morning and evening. The does received water *ad libitum*. Does were hand-milked twice daily.

Feed intake, faeces and urine excretion and milk production were recorded daily. The urine was preserved using potassium dichromate, to prevent microbial growth and volatilization of ammonia (Barnes & Brown, 1990).

Degradability and rate of passage trial

The experimental diets were compared in a degradability and rate of passage trial. Nine Dohne merino wethers with an average bodyweight of 65 kg were used. The animals were individually penned and feed and water were available *ad libitum*. The wethers were adapted to the diets over a period of 14 days. Three wethers per diet were tested at a time. After the trial period, the diets were allocated to three different wethers and the animals adapted again on the new diet. This gave six observations for each diet.

The procedure described in the AFRC (1993) Technical Committee on Responses to Nutrients, Report No. 9, "Estimation of protein degradability", was followed with a few exceptions. The

following procedures used in this trial varied from the recommendation of the report. In this trial the experimental diets given in Table 1 were used. The method of bag attachment was adopted from Loëst (1995). The bags were inserted into the rumen using the reverse order, starting with the 48 hour incubation sample and then simultaneously removing all the bags at 0 hours (Brand, 1999). The following incubation times were used: 0, 1, 2, 4, 8, 12, 18, 24 and 48 hours. The effective CP degradability of the three diets was determined according to the model of Ørskov & McDonald (1970):

$$dg = a + b \{1 - e^{(ct)}\}$$

Nine Dohne merino wethers were used to determine the flow rate of particulate matter from the rumen. The same procedure as in the degradability trial was followed, in order to obtain six observations per experimental diet. The wethers were kept under the same conditions, and the same feeding regime was used as in the degradability trial. The preparation of the fibre and the chrome mordanting of the wheat straw was done according to the method described by Uden *et al.* (1980). Dacron bags were incubated in the rumen for 24 hours to determine the DM degradability of the chrome-treated wheat straw (Loëst, 1985). An average DM degradation of 6% was determined. To determine the rate of passage, each wether was dosed with 70g of hydrated chrome mordanted wheat straw, via the rumen fistula. Rectal grab samples were taken at the following times: 0, 6, 9, 12, 18, 24, 36, 48, 60, 84 and 108 hours (Uden *et al.*, 1980). The data from the analysis was used to calculate the rumen flow rates according to the model of Hartnell & Satter (1979):

$$\ln y = \ln A - k_1 T$$

Chemical and statistical analyses

The diet and faeces were analysed for moisture, ash, CP, and ether extract (EE) according to the methods of A.O.A.C. (1998). The crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) were analysed using a Tecator Fibretec System (Van Soest, 1963 and Van Soest & Wine, 1967). Gross energy (GE) was determined using an adiabatic bomb calorimeter. Urine samples were analyzed for N by standard A.O.A.C. (1998) methods. Samples from the degradability trial were analysed for DM and nitrogen (N). The N content was determined by the Leco Auto Analyser (Model FP-428). Milk samples were analysed with a Milk-O-Scan apparatus for butterfat, protein, lactose, urea and somatic cells. Butterfat, protein, lactose and urea were determined by means of an infrared analysis. Somatic cells were determined by Fossomatic analysis. All faecal samples from the rate of passage trial were analysed for Chrome (Cr) concentration. Samples were prepared according to A.O.A.C. standards (1998), and an Atomic Absorption Spectrophotometer (Varian Spectra. AA 300/400) was used to analyse the prepared samples.

The trial had three treatments (low UDP, low protein high UDP and high UDP) and the experimental design was a completely randomized block design; with eight replicates in the production trial and six replicates in the nitrogen balance, degradability and rate of passage trials. Data was tested for normality using the Shapiro-Wilk statistic (Shapiro & Wilk, 1965). A two-way analysis of variance was performed and significant effects were further submitted to Student's t-LSD ($P < 0.05$) (SAS, 1996).

RESULTS AND DISCUSSION

Degradability and rate of passage trial

The results of the degradability and rate of passage trial are presented in Table 3. The rapidly degradable fraction (a) of the low UDP diet was significantly different ($P < 0.05$) from the low protein high UDP diet. The rate of degradation of fraction b (c) also varied significantly ($P < 0.05$) between the diets, with the low UDP diet having the highest value, and the low protein high UDP diet having the lowest value. The rate of passage determined by means of the mordanted wheat straw varied significantly between the diets, with the low UDP diet having a significantly ($P < 0.05$) faster rate of passage than the other two diets. There were no significant differences ($P < 0.05$) in effective rumen degradability (%) between the diets. The slowly degradable protein (g/kg DM) component of the low protein high UDP diet was significantly lower ($P < 0.05$) than the low UDP diet. Effective rumen degradable protein (g/kg DM) differed significantly ($P < 0.05$) between the diets, with the low and high UDP diets containing the highest effective rumen degradable protein (g/kg DM). In terms of intake of the different protein fractions, the low UDP diet had the highest significant ($P < 0.05$) intake for all three diets.

The effective RDP in the low UDP diets was greater than in the low protein high UDP diet but was the same as the high UDP diet. Ideally the low UDP diet should have had the highest amount of effective RDP. The UDP fractions of the diets are inconsistent with the formulated values. All the diets contained the same levels of UDP. The reason for the difference between the formulated values and the determined values is unknown, as the diets in Table 1 do not reflect this.

Because there were no significant differences between the diets in terms of dietary protein degradability interpretations of the results from the other trials that were conducted are made difficult. Any significant differences ($P < 0.05$) that did occur can't be attributed to dietary protein degradability.

Table 3 Estimation of the amount and type of dietary protein (mean and standard error) supplied to the lactating Saanen does, using the metabolizable protein system (AFRC, 1993) (n=6/treatment)

	Low UDP	Low protein, high UDP	High UDP
Dietary CP (g/kg DM)	207	183	194
a^1	0.48±0.02 ^b	0.56±0.02 ^a	0.53±0.02 ^{ab}
b^1	0.44±0.03	0.34±0.04	0.40±0.03
c^1	0.30±0.07 ^a	0.14±0.07 ^b	0.11±0.07 ^b
Determined rate of passage (/hour)	0.064±0.05 ^a	0.044±0.05 ^b	0.045±0.05 ^b
Effective protein degradability (%)	82±2.0	78±2.0	79±2.0
Quickly degraded protein (g/kg DM)	100±4.1	101±4.5	103±4.1
Quickly degraded protein intake (g/day)	188±7.2 ^a	156±7.2 ^b	161±7.2 ^b
Slowly degraded protein (g/kg DM)	63±5.8 ^a	45±6.7 ^b	50±6.7 ^{ab}
Slowly degraded protein intake (g/day)	119±11.4 ^a	71±11.4 ^b	78±11.4 ^a
Rumen undegradable protein (g/kg DM)	44±4.9	37±4.9	41±4.9
Rumen undegradable protein intake (g/day)	83±8.3 ^a	58±8.3 ^b	64±8.3 ^b
Effective rumen degradable protein (g/kg DM)	142±4.2 ^a	125±4.6 ^b	133±4.2 ^{ab}
Effective rumen degradable protein intake (g/day)	270±8.5 ^a	196±8.5 ^b	207±8.5 ^b

^{a,b} Values in rows bearing different superscript letters differ significantly ($P < 0.05$)

¹⁾ Degradability parameters: a is the zero time intercept (fraction of the protein sample that is quickly solubilized or degraded in the rumen), b is the fraction that is potentially degradable in the rumen, c is the rate of degradation of fraction b (/hour).

Production trial

The results from the production trial are presented in Table 4. The feed and dry matter (DM) intake (Table 4) were significantly ($P < 0.05$) different between the groups, with the does on the low UDP diet having the highest feed and DM intake of the three diets. This difference in feed and DM intake would have had an effect on the intake of RDP and UDP (Table 3) with the low UDP diet having the highest intake of both these fractions. Even though there was no significant difference in effective protein degradability, between the diets, the does on the low UDP diet still took in more RDP but also more UDP. It is not possible to attribute this difference in intake to dietary protein degradability because there were no differences between the diets. Other factors may have played a role here, such as palatability of the diets (high fish meal levels in the other two diets, Table 2).

Body weight differed significantly ($P < 0.05$) at the end of the trial, with the does on the low UDP diet being significantly heavier than those on the low protein high UDP diet. This result appears consistent with the results of Mishra & Rai (1996), who reported that does on a low UDP diet had the highest bodyweight after a 120 day production trial. The reason for this difference would have to be attributed to the higher RDP and UDP intake of the does on the low UDP diet.

Milk production did not differ significantly ($P < 0.05$) between any of the groups over the trial period. Besides the fact that the diets did not differ in effective protein degradability, variation in milk production between animals was large and with only 6 animals per treatment, in this trial, caution is taken in stating that no difference in milk production was observed. The use of lactation curves to measure a response was investigated and applied to the data, however the variation between animals was so great no logical information could be drawn from this application. For similar trials that are conducted in future large animal numbers per treatment must be used to measure responses in milk production.

Table 4 The effect of different dietary protein degradabilities on the production (mean and standard error) of lactating Saanen does over a 120-day trial period

	Low UDP	Low protein, high UDP	High UDP
Number of animals	8	6	7
Initial bodyweight (kg)	61±2.4	55±2.6	61±2.8
Final bodyweight (kg)	65±2.1 ^a	56±2.3 ^b	58.6±2.8 ^{ab}
Feed intake (kg)	2.1±0.11 ^a	1.7±0.11 ^b	1.7±0.12 ^b
Dry matter intake (kg/day)	1.9±0.01 ^a	1.5±0.10 ^b	1.6±0.11 ^b
Feed conversion efficiency (kg feed/kg weight gain/loss)	1.5±0.08	1.6±0.01	1.7±0.11
Milk production (kg/day)	3.0±0.25	2.6±0.29	2.8±0.34
Fat corrected milk, 4% (kg/day)	2.8±0.22	2.5±0.26	2.4±0.31
Milk protein (%)	2.7±0.06	2.7±0.07	2.7±0.08
Milk lactose (%)	4.5±0.06	4.6±0.07	4.6±0.08
Corrected fat (%)	2.3±0.13	2.7±0.15	2.3±0.18
Total fat for 120 days (kg)	9.4±0.74	8.2±0.84	8.7±0.10
Total protein for 120 days (kg)	13.1±1.09	12.1±1.24	11.2±1.46
Urea (mg/dl)	34.5±1.65	31.5±1.87	34.8±2.21

^{a,b} Values in rows bearing different superscript letters differ significantly ($P < 0.05$)

The milk production efficiency is presented in Table 5. Only the CP intake showed a significant ($P < 0.05$) difference between diets for all the characteristics calculated. The low UDP diet had the highest CP intake of the three diets, because of the significantly ($P < 0.05$) higher feed intake of this group (Table 4).

According to Van der Merwe & Smith (1991) a 50 kg doe requires 150g of CP for the production of 1kg of milk per day. This differs considerably from the value stated in the NRC (1981) for goats, where the total protein requirement for the production of one liter of milk with three percent butterfat is given as 64g. In a similar study Mishra & Rai (1996) found a similar value to the one found in this present study. In both these studies the does on the low UDP diets had the highest CP intake per kilogram milk yield. In the present study the CP intake per kg milk yield was an average of 113 ± 0.01 g.

Table 5 The effects of different dietary protein degradabilities on the milk production efficiency (mean and standard error) in lactating Saanen does over a 120-day trial period

	Low UDP	Low protein, high UDP	High UDP
Number of animals	8	6	7
Milk yield per kg dry matter intake (kg)	1.6 ± 0.10	1.7 ± 0.11	1.8 ± 0.12
Fat corrected milk (4%) per kg dry matter intake (kg)	1.5 ± 0.11	1.7 ± 0.12	1.6 ± 0.13
ME intake (MJ/day)	18.1 ± 0.96	15.7 ± 1.03	16.0 ± 1.11
ME intake per kg milk yield (MJ)	6.1 ± 0.43	6.5 ± 0.45	5.8 ± 0.49
CP intake (g/day)	350 ± 0.02^a	260 ± 0.02^b	300 ± 0.02^b
CP intake per kg milk yield (g)	120 ± 0.01	110 ± 0.01	110 ± 0.01

Values in rows bearing different superscript letters differ significantly ($P < 0.05$)

The results of the nitrogen (N) balance trial are presented in Table 6. The does on the low UDP diet had a significantly higher intake of N than the low protein high UDP diet, due to their higher feed intake and higher dietary CP level. Regarding N loss through the faeces and urine, the same significant ($P < 0.05$) differences as in N intake were observed. No significant differences in N loss through the milk were observed for any of the diets. The total loss of N was significantly higher in the low UDP diet compared with the low protein high UDP diet. The high UDP diet did not differ significantly from either of the diets. Nitrogen secretion in the milk as a percentage of the total N intake was significantly higher in the low protein high UDP diet compared with the low UDP diet. The N secretion in the milk as a percentage of the total N intake, in the high UDP diet, did not differ significantly from either of the above two diets.

The significant differences in N balance observed in this trial were due to differences that existed in intake and dietary CP levels. Although the does on the low protein high UDP diet had a significantly ($P < 0.05$) lower N intake, they were still able to maintain a similar output of N in the milk when compared with the other diets.

Table 6 The effect of different dietary protein degradabilities on nitrogen balance (mean and standard error) in lactating Saanen does over a 120-day trial period (n=6)

	Low UDP	Low protein, high UDP	High UDP
Nitrogen _{in} (g/day)	57.2±3.42 ^a	44.2±3.42 ^b	51.1±3.42 ^{ab}
Nitrogen _{faeces} (g/day)	15.1±1.22 ^a	10.7±1.22 ^b	11.5±1.22 ^{ab}
Nitrogen _{urine} (g/day)	23.4±2.88 ^a	11.7±2.88 ^b	17.8±2.88 ^{ab}
Nitrogen _{milk} (g/day)	12.8±1.41	13.1±1.41	13.1±1.41
Nitrogen _{out total} (g/day)	51.4±4.38 ^a	35.4±4.38 ^b	42.4±4.38 ^{ab}
Nitrogen _{retention} (% of total nitrogen)	16.4±3.57	19.7±3.26	20.9±3.57
Nitrogen _{secretion in the milk} (% of total nitrogen)	22.4±1.94 ^b	29.3±1.94 ^a	25.6±1.94 ^{ab}

^{a,b} Values in rows bearing different superscript letters differ significantly (P < 0.05)

From the results of the digestibility trial (Table 7) the low UDP diet was significantly (P < 0.05) lower for DM, OM, N, NDF and fat digestibility. Crude fibre digestibility was significantly higher in the high UDP diet, as compared to the low protein UDP diet, and the low UDP diet did not differ from either of the diets. Fat digestibility was significantly (P < 0.05) better in the high UDP diet.

In the work of Ensminger & Parker (1986), ADF was defined as the best predictor of roughage digestible DM. As ADF is comprised of the least digestible parts of the plant, it relates negatively to digestibility. The results from the proximate analysis (Table 1) done to determine ADF, indicate that the low UDP diet had the highest ADF value, followed by the high UDP diet and then the low protein high UDP diet. The ADF digestibility was numerically similar for both the low UDP and high UDP diets. The high ADF value, of the low UDP diet, is one possible explanation for the lower overall digestibility of the low UDP diet.

Differences in digestibility between the diets could be attributed to differences in rate of passage (Table 3) and the ADF component of the diets.

Table 7 The effect of different dietary protein degradabilities on digestibility coefficients (mean and standard error) in lactating Saanen does (n=6)

	Low UDP	Low protein, high UDP	High UDP
DM Digestibility (%)	68.7±1.39 ^b	77.3±1.39 ^a	75.6±1.39 ^a
OM Digestibility (%)	71.7±1.68 ^b	76.6±1.68 ^a	78.3±1.57 ^a
N Digestibility (%)	33.4±4.42 ^b	48.9±4.42 ^a	42.7±4.42 ^{ab}
CF Digestibility (%)	48.8±4.10 ^{ab}	37.4±4.10 ^b	50.5±4.10 ^a
ADF Digestibility (%)	32.3±4.07	22.1±4.07	32.4±4.07
NDF Digestibility (%)	26.4±2.65 ^c	67.3±2.65 ^a	52.8±2.65 ^b
Fat Digestibility (%)	81.4±1.03 ^b	83.1±1.03 ^b	87.1±1.03 ^a

^{a,b} Values in rows bearing different superscript letters differ significantly (P < 0.05)

CONCLUSION

Findings from the degradability trial showed that no significant differences in effective protein degradability existed between the diets. Thus it is impossible to make a conclusion on whether or not increasing the UDP fraction of the diet or lowering CP level and increasing UDP levels had a positive effect on milk production and performance of Saanen does.

In future such trials must commence with the degradability trial to ensure that there are differences between the diets with regards to degradability. Regarding the production trial, it is advised that treatments consist of large numbers of animals so that the inherent large variation in milk production between animals can be overcome and a response can be measured.

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CHAPTER 4

GENERAL CONCLUSION

The dairy goat industry in South Africa is still very underdeveloped, yet it holds tremendous potential for the entrepreneur willing to take the risk and do the job correctly. With the present South African financial situation, the opportunities that exist for exporting value added products to countries with stronger currencies, is a market waiting to be tapped. Research on dairy goat production is relatively scarce, yet recently in more developed countries such as America, more money and time is being spent on developing a better knowledge of how to farm with these animals effectively and profitably.

In New Zealand the national herd consists of approximately 16000 dairy goats, and 90% of the milk produced is turned to powdered milk and exported to the East. This is a valuable source of foreign currency. In South Africa the same potential exists, and with some vision and hard work the dairy goat industry can make a valuable contribution to generating foreign currency.

Studies on the nitrogen requirements of dairy goats are scarce and in recent years there has been an increased interest in this field of research (Mishra & Rai, 1996). The use of rumen undegradable proteins has received much attention in dairy cows and the past 20 years of published papers has been reviewed and published in an article by Santos *et al.* (1998). The conclusion from this review paper, covering data from 108 trials, was that increasing UDP in the diets of cows often results in a decrease in RDP and a change in absorbed amino acid profiles, in turn resulting in inconsistent improvements in lactation performances.

The use of rumen undegradable proteins to increase production in dairy goats has received little interest and few published papers exist. From published papers, it has been found that the use of rumen undegradable proteins may increase milk production (Pailan & Kaur, 1995 and Mishra & Rai, 1996). From this literature it appears as though a RDP: UDP ratio of 55-60: 45-40 gives the best results. Besides the RDP: UDP ratio, these papers also investigated the effect of decreasing the CP (15-20% of total CP%) level and using high levels of UDP (40-45%). The results from this investigation suggested, that with lower CP levels and an increased UDP level, milk production could be maintained.

The results from the trial done with the Saanen kids (Chapter 2) indicate that weaning at 42 days of age is achievable if the DM intake of the kids is sufficient. In this trial the kids were consuming 240 g/day of the creep diet, and following weaning no post-weaning growth shock was observed. The results from the degradability trial showed that no significant difference ($P < 0.05$) in effective

protein degradability existed between the creep diets, therefore no conclusion can be made from this trial regarding the influence of dietary protein degradability over the creep period (20 – 80 days of age) of this trial. There were significant differences ($P < 0.05$) in effective protein degradability between the growth diets fed over the period 80 – 140 days of age. Growth parameters tested over the period 80 – 140 days of age did not differ significantly ($P < 0.05$). Adequate DM intake and supply of CP in the diet are possible reasons for the lack of response. In this trial dietary protein degradability had no effect on growth parameters.

In the trial conducted with the lactating Saanen does the findings of the degradability trial showed that no significant differences in effective protein degradability existed between the diets. Thus it is impossible to make a conclusion on whether or not increasing the UDP fraction of the diet or lowering CP level and increasing UDP levels had a positive effect on milk production and performance.

In future degradability trials must commence with the degradability trial to ensure that there are differences between the diets with regards to degradability. Regarding the milk production trials, it is advised that treatments consist of large numbers of animals so that the large variation in milk production between animals can be overcome and a response may be measured.

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