FEEDLOT PERFORMANCE AND ESSENTIAL AMINO ACID GROWTH REQUIREMENTS OF DORPER LAMBS

by

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Study leader: Dr A V Ferreira

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DECLARATION

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

Date : 28/11/2002

Abstract

Title: Feedlot performance and essential amino acid growth
                   requirements of Dorper lambs

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The Dorper is numerically the second most abundent of all the sheep breeds in South Africa. It is the most numerous sheep breed in the dry arid areas of South Africa which make out a very big portion of the natural grazing in South Africa. In this study the feedlot performance was specifically investigated since so little research has been done in this regard. In the first study (Chapter 1), the production efficiency, body components and commercial yield of 13 Dorper and 12 Merino lambs were investigated. A pelleted diet was fed *ad lib* and the water intake per day was measured. Lambs were slaughtered at 30kg and at 40kg live weight and cut up according to the South African commercial cuts. The weights of the organs, head, feet, skin and carcass were also recorded. Results from the first study showed that Dorpers had a lower ($P<0.05$) water efficiency (285.97 mℓ/kg$^{0.75}$/day) than the Merinos (240.07 mℓ/kg$^{0.75}$/day), but had a higher ($P<0.05$) nitrogen retention. The head, feet, skin, heart, lungs, kidneys and diaphragm of Merino lambs were heavier ($P<0.05$). Merinos had heavier ($P<0.05$) breast and shank and thick rib (only at 40kg live weight) cuts. But the Dorper had a significantly heavier hindquarter (buttock and loin) which is the high-priced cut of any carcass. It seems that the Dorper will do well under feedlot conditions, and would possibly make a better commercial meat producer than the Merino under all circumstances.

In the second study (Chapter 2), the free-ranging Dorper on natural grazing were compared with 7 Dorper lambs in the feedlot study. The essential amino acids in the duodenal contents were compared. The free-ranging Dorpers were randomly

slaughtered at 40 kg live weight and a duodenal sample was collected. The feedlot Dorpers were also slaughtered at 40 kg live weight and a duodenal sample was taken. The second study indicated no significant differences between the EAA composition of the duodenal samples, whether protein quantity was taken into account (gAA/100g crude protein (CP)) or not (expressed as % of lysine). The chemical scores indicated that the two most limiting amino acids in the duodenal digesta for whole empty body growth were: arginine and histidine. Excess levels of amino acids tend to be present in all three duodenal digesta samples (isoleucine, leucine, lusine, methionine, phenylalaline, threonine and valine). The whole empty body EAA composition (g AA/100 g crude protein) was as follows: 7.10 arginine; 2.40 histidine; 3.31 isoleucine; 7.22 leucine; 6.61 lysine; 1.62 methionine; 3.91 phenylalanine; 3.77 threonine and 4.85 valine. The composition can serve as an example of the ideal EAA requirements for whole empty body growth between 30 and 40 kg live weight of Dorper ram lambs. The duodenal amino acid concentrations of the free-ranging Dorper compared well with those of the feedlot Dorpers which suggests that the microbial organisms have a big influence on the amino acid concentration which reaches the intestines.

Samevatting

Titel:	Die voerkraal prestasie en essentiële aminosuur behoeftes van groeiende Dorper lammers
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The Dorper is getalgewys die tweede mees talryke skaapras in Suid-Afrika. Dit is die mees talryke skaapras wat in die droë woestynagtige gebiede van Suid-Afrika aangetref word. Dié gebiede beslaan die grootste oppervlakte van Suid-Afrika se natuurlike weiveld. In die studie is voerkraal prestasie van die Dorper nagevors, spesifiek omdat daar so min navorsing op hierdie gebied gedoen is. In die eerste studie (Hoofstuk 1) is die produksie doeltreffendheid, liggaams komponente en kommersiële produksie van 13 Dorper- en 12 Merino lammers ondersoek. 'n Verpilde rantsoen is *ad lib* gevoer en die water inname per dag is ook gekontroleer. Die lammers is geslag op 30 en 40 kg lewende gewig en die karkasse is daarna opgesny volgens die Suid-Afrikaanse kommersiële karkassnitte. Die resultate van die eerste studie het getoon dat Dorpers 'n laer water potentiaal ($P<0.05$) (285.97 $m\ell/kg^{0.75}/dag$) as die Merinos (240.07 $m\ell/kg^{0.75}/dag$) het. Dorper lammers het ook 'n hoër ($P<0.05$) stikstof retensie. Die kop, vel, pote, hart, longe, niere en diafragma van Merino lammers was swaarder ($P<0.05$). Merinos se brisket en dikrib snitte weeg ook swaarder ($P<0.05$). Die Dorper het 'n beduidende swaarder agterkwart (lende en boud) gehad, wat die duurste snit is van enige karkas. Die Dorper het baie goed gedoen in die voerkraal toestande en sal waarskynlik onder alle omstandighede 'n hoër vleisproduksie op die Merino lewer.

In die tweede studie (Hoofstuk 2), is die vryweiende Dopers op natuurlike weiding vergelyk met die Dorpers in 'n voerkraal. Die twee groepe Dorpers se essensiële aminosuur samestelling in hul dunderms is bepaal en vergelyk om te bepaal of daar enige tekorte teenwoordig is. Die Dorpers in die veld en in die voerkraal is op 40 kg lewende gewig geslag en monsters van die dunderm inhoud is gekollekteer. Die monsters is ontleed om te bepaal of daar enige betekenisvolle verskille in die essensiële aminosure van die dunderm inhoud tussen die veld Dorpers en voerkraal Dorpers was. Die tweede studie het geen betekenisvolle verskille getoon tussen die dunderm monsters se essensiële aminosure, of die hoeveelheid proteïen (gAA/100g) in aanmerking geneem is of nie (uitgedruk as % lisien). Die chemiese telling dui aan dat die twee mees beperkende aminosure in die dunderm inhoud vir leë liggaam groei arginien en histidien was. Oormaat vlakke van aminosure kom voor in al drie dunderm inhoud monsters (isoleusien, leusien, lisien, metionien, femielalanien, treonien en valien). Die totale leë liggaam essensiële aminosuursamestelling (g aminosuur/100g ruprotein) was soos volg: 7.10 arginien; 2.40 histidien; 3.31 isoleusien; 7.22 leusien; 6.61 lisien; 1.62 metionien; 3.91 fenielalanien; 3.77 treonien en 4.85 valien. Hierdie aminosuursamestelling kan as 'n aanduiding dien vir die ideale aminosuurbehoeftes van Dorper ram lammers vir totale leë liggaamsgroei vanaf 30 tot 40 kg lewende massa. Die dunderm aminosuur konsentrasie van die Dorper in die veld stem goed ooreen met die van die voerkraal Dorper. Dit toon waarskynlik dat die mikrobe organismes in die rumen 'n groot invloed het op die aminosuur samestelling wat die dunderm bereik.

List of abbreviations

AA	Amino acids
NRC	National Research Council
ARC	Agricultural Research Council
EAA	Essential amino acids
WEB	Whole empty body
RDP	Rumen degradable protein
UDP	Undegradable protein
ME	Metabolizable energy
MJ	Mega joule
EUN	Endogenous urinary nitrogen
N	Nitrogen
MFN	Metabolic faecal nitrogen
DM	Dry matter
g	Gram
kg	Kilogram
W	Weight
GIT	Gastro intestinal tract
CP	Crude protein
NDF	Neutral detergent fibre
EE	Ether extract
ADF	Acid detergent fibre
GE	Gross energy
GLM	General linear model
ADG	Average daily gain
FCE	Feed conversion efficiency

Preface

The dissertation is presented in the form of two articles, augmented by a general introduction and general conclusion in an effort to eventually create a single unit. The materials and methods for each article have been discussed in detail for examination purposes, since technical execution is of importance in a masters study. The important task of publishing results from an academic study is often neglected and hence it was decided to address this problem.

The author hereby wishes to express sincere thanks to the following establishments and persons who contributed to this study :

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A H Jurgens
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General Introduction

The nutritional value of individual dietary protein sources for ruminants and non-ruminants differs markedly because of differences in anatomy and digestive processes. Thus the significant synthesis of amino acids in the microbial fermentation processes in the rumen may reduce the importance of dietary protein quality for ruminants significantly (Boisen et al., 1999). Ruminants utilise protein for growth most efficiently when provided with a supply of amino acids that matches tissue requirements (Mäntysaari et al., 1989 and Hussein et al., 1991). Robert et al. (1974) also said that protein quality is dependent upon the available amino acids (AA) leaving the rumen, rather than those in the ingested diet. Apart from feeding high producing animals, the quality of dietary protein is also very important when feeding a slow degraded protein in the diet (NRC, 1985). Sometimes rumen-produced microbial protein may not meet the amino acid requirement of the animal under these conditions and production may be less than optimal unless amino acids from non-microbial origin are supplied.

Not long ago protein requirements of ruminants were expressed solely in terms of crude protein. Subsequently diets were balanced for ruminal undegradable and degradable protein. Now, we are moving towards the goal of balancing diets to fulfill the amino acid requirements of the ruminant. The most recent development of diet protein for the growing pig is based on the concept of an ideal protein. Baker & Han (1994) shows that the concept of an ideal protein or ideal amino acid ratios can be an accurate and successful method of assessing dietary protein for monogastric species. According to Chen & Ørskov (1994) the concept of an ideal protein has been used to refer to the protein that provides absorbed amino acids in the proportion that gives maximum efficiency or utilisation. As amino acid requirements at tissue level are an important consideration (Schingoethe, 1996), various attempts have been directed towards defining an ideal pattern of absorbed amino acids that is believed to exist for maintenance and growth (NRC, 2000). Furthermore, it is recognized that the pattern of amino acids required for body protein accretion, is closley correlated to the amino acid composition of the whole body protein itself (Fuller, 1996). Therefore, in terms of growth, the essential amino acid composition of the whole empty body could serve as an ideal example of the amino acids required for body protein accretion (Fuller, 1996).

It has been suggested that the most important single factor affecting the efficiency of protein utilisation for production of meat or eggs is the dietary balance of amino acids. According to Liebzig's Law of Minimums the undersupply of a single essential amino acid will inhibit the responses to those in adequate supply (Cole & Van Lunen, 1994). Rumen microbes are the primary source of protein and are responsable for modifying the amino acid pattern of the diet. When microbial protein production is limited, or when amino acid requirements are high, microbial protein may not meet the amino acid requirements for maintenance and production (growth, lactation) (Merchen & Titgemeyer, 1992). Thus it is very important to determine which essential amino acid is limiting in the animal's diet. Nitrogen balance studies are the basis for assessment of animals protein or amino acid requirements (Chen & Ørskov, 1994). According to Storm & Ørskov (1984) the duodenal protein may be deficient in certain amino acids such as methionine, lysine, histidine and arginine for growing lambs because the microbial protein is deficient in these amino acids. Richardson & Hatfield (1978) found that methionine, lysine and threonine are first limiting in the diet of growing steers when rumen synthesised microbial protein is essentially the sole source of protein. In studies where sheep were fed urea as the sole nitrogen source, the first limiting amino acids were methionine, lysine and threonine (Nimrick *et al.*, 1970). Amino acid requirements can vary for maintenance, growth, reproduction, lactation and wool growth (Chalupa, 1975 and Macrae *et al.*, 1993).

Williams *et al.* (1954) determined the amino acid requirements of the pig, rat and chicken by assessing the carcasses of these animals for amino acids during growth. Chen & Ørskov (1994), Smith (1980) and Cole & Van Lunen (1994) also determined the EAA profiles of growing lambs by using carcass analysis. Ferreira (1998), however, stated that if the EAA profile of the absorbed protein is not in balance with the needs of the animal, both the productivity and protein efficiency will decrease leading to poor results (e.g. growth). Therefore the "ideal" protein can be theoretically defined as one in which the composition of the EAA's absorbed from the small intestine matches exactly the amino acid requirement of the animal for productive purposes. The amino acid composition required for tissue maintenance is not known, but since the turnover of protein is mainly in tissue, it is possibly similar to that needed for tissue growth.

In South Africa , the Dorper breed is only outnumbered by the Merino in the national sheep flock. It is a synthetic, non-woolled, mutton breed. It originated from a cross between the Dorset Horn and Blackhead Persian. It was developed in the early

1940's for slaughter lamb production in the extensive, arid regions of South Africa. It is well-known for its adaptability in harsh environments. Some studies were done on the reproduction performance of Dorpers under extensive conditions, but there is no information on the nutrient requirement (EAA) of these animals, thus research is of utmost importance (De Waal & Combrinck, 2000; Snyman & Olivier, 2002).

Therefore the objectives of the study were to: (a) determine the retail yields of the carcass offal and joints, as well as the growth parameters of growing Dorper lambs under feedlot conditions (Chapter 1); (b) to determine the essential amino acid (EAA) requirements of Dorper lambs through evaluation of the whole empty body (WEB) EAA composition in order to derive the ideal protein requirement for growth under intensive and extensive feeding conditions (Chapter 2).

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CHAPTER 1

Production efficiency, body components and commercial yield of Dorper and Merino lambs receiving a feedlot finishing diet

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Abstract

Production efficiency, body components and commercial yield of 13 Dorper ram lambs and 12 Merino ram lambs were investigated. A pelleted diet was fed *ad lib.* Dorper lambs had a lower (P<0.05) water efficiency (285.97 mℓ/kg$^{0.75}$/day) than the Merinos (240.07 mℓ/kg$^{0.75}$/day). Dorper lambs on the other hand had a higher (P<0.05) nitrogen retention. The weight of the head, feet, skin, heart, lungs, kidneys and diaphragm were heavier (P<0.05) in Merino lambs. Dorper lambs had a heavier (P<0.05) liver, spleen, testis, empty stomach and intestines. Both kidney fat and gastro intestinal fat increased with age. Merinos had heavier (P<0.05) breast and shank and thick rib cuts (only at 40kg live weight). But the Dorper had a significantly heavier hindquarter (buttock and loin) which is the high-priced cut of any carcass. That makes the Dorper lamb a possibly better commercial meat producer than the Merino lamb.

Keywords: water consumption, water efficiency, feed conversion, slaughter weight, carcass, commercial cuts.

Introduction

In the past there has been considerable interest in differences in feeding behaviour, requirements and efficiencies between species and breeds. It is, however, well known that desert-adapted ruminants are more likely to utilise their water reservoir more efficiently and consequently this enables them to maintain their appetite and production potential more effectively under heat stress conditions (Silanikove, 1989).

Therefore differences among ruminants in energy requirements, digestive efficiency and water efficiency are very important criteria for the selection of the most appropiate type of animal to be kept in any particular circumstance, to achieve optimum production potential. Other criteria includes factors such as yield, chemical composition and meat quality (Hoffman, 2000). According to Von la Chevallerie (1970), carcass weights can give a good indication of the meat production potential of an animal, when sufficient data on carcass conformation and composition is available. Carcasses of meat producing animals are composed primarily of varying proportions of muscle, fat and bone. In developed countries where overabundance of calories is a major nutrional problem, the most important carcass tissue is muscle. Certain muscles, such as those of the hindleg and loin, contribute to the high-priced cuts of the carcass, because there is less associated fat and connective tissue. For this reason differences in species, degree of maturity and the distribution of muscles are commercially important carcass traits. (Ferreira & Hoffman, 2001).

Despite its large numbers in South Africa, little research have been published on the nutrition of Dorpers under harsh, arid grazing conditions. This is especially anomalous as Dorpers were created and developed for these conditions. The relative ease of conducting trails under controlled feeding conditions, compared to the more complex situation of grazing ruminants on natural pasture, probably played a major role in this regard.

The South African Merino was selected as standard to compare with the Dorper in this investigation. The Dorper is numerically second only to the Merino in the national sheep flock of South Africa. It has been bred out of the Dorset Horn and Blackhead Persian sheep breeds, to create a meat producer adapted to harsh and arid grazing conditions De Waal & Combrinck, (2000). After its development and recognition (Nel, 1998) it replaced the Merino in areas with predominantly hot, dry climatic conditions.

The objective of this study was to determine the production efficiency, body components and commercial yield of Dorper (mutton breed) and Merino (wool breed) lambs receiving a feedlot finishing diet.

Materials and Methods

Thirteen weaned Dorper and twelve weaned Merino ram lambs were used in this investigation. The average initial body weight of the Dorper and Merino lambs were 28.5 ± 1.80 kg and 28.7 ± 1.04 kg, respectively. Five Dorper and five Merino lambs were randomly selected to be slaughtered immediately, while the other animals were slaughtered when the groups reached the desired average live weight (Dorper ± 40kg; Merino ± 43kg) used in practice under feedlot conditions. Condition score was used as the criterion to determine when to slaughter each of the genotypes. Both genotypes had an average condition score of 2.9 on the day before slaughter, suggesting that both groups of lambs equally finished at slaughter. The eight Dorper and seven Merino lambs were housed individually in an enclosed but adequately ventilated shed with a slatted floor.

A standard feedlot diet was formulated (Table 1), pelleted (22 mm die) and fed *ad libitum,* to provide in the nutrient requirements of growing lambs (NRC, 1985). The feeds used to formulate the standard feedlot diet were those that are reasonably available and usually used in the feedlot. The lambs also received water *ad lib.* They were fed twice daily and orts were collected daily, pooled and the pooled weight determined weekly. The lambs were given 8 ℓ of water each morning. Weekly water intake, corrected for evaporation losses by measuring losses from a trough similar to those provided for the animals, was monitored. The animals were weight weekly.

During the last week of the feeding trial, the Dorper and Merino lambs were used to evaluate the digestibility of the diet. Total collection of faeces and urine were conducted twice daily. Twenty mℓ of urine preservative (80 g potassium dichromate and 20 g mercuric chloride dissolved in 1 ℓ distilled water) was added each morning to the urine collection jugs to prevent volatilization of ammonia from the urine. Faeces and urine were sub-sampled daily (10%) and composited over the whole period, prior to chemical analysis.

Methane gas production (MJ day^{-1}) was calculated as 8% of gross energy intake (McDonald *et al.*, 1988). Nitrogen (N) retention was corrected both for endogenous urinary N (EUN) and metabolic faecal N (MFN) according to McDonald *et al.* (1988) as follows:

EUN (g) = 0.18g N kg$^{-0.75}$ /day

MFN (g) = 5g N kg^{-1} DM intake

and

N-retention (gN W$^{-0.75}$/day) = {N_{in} – (N_{faeces} – MFN) – (N_{urine} – EUN)}/(W$^{-0.75}$)/days.

The lambs were electrically stunned before being exsanguinated. The head, feet, skin, heart, heart fat, (including pericardium), liver, lungs and trachea, kidneys, kidney fat, spleen, testes, GIT (gastro-intestinal tract) fat (consisting of the mesenteric and omentum fat), diaphragm, stomachs (rumen, reticulum, omasum and abomasum combined, including oesophagus), and intestines (small intestine, large intestine and caecum combined) were removed and weighed. The stomachs and intestines were emptied, washed and reweighed to obtain the weight of the empty stomachs and intestines and of the contents by difference.

The whole empty body (WEB) weight was calculated as the live weight minus the weight of thestomach and intestinal contents. Dressing percentage was calculated from the weight of the cold carcass expressed as a percentage of live weight. The weight of the organs was expressed as a percentage of WEB weight in order to prevent the effect of rumen fill differences. The weights of the head, feet and skin were also recorded. "Edible offal" (internal offal) was calculated as the sum of the heart, liver, lungs and trachea, spleen, stomach, intestines, kidneys, kidney fat and GIT–fat as a percentage of WEB. "Non-edible offal" (external offal) was defined as the sum of the skin, head and feet as a percentage of WEB.

Carcasses were split into left and righ halves, by cutting with a handsaw along the median, from anterior to porterior. The exsaguinated carcasses were hung in a cooler (4 °C) for 24 hours, before they were weighed to determine cold carcass weight. Both halves of each carcass were jointed into seven individual cuts, following the South African Meat Board's chart for retail mutton cuts (Hoffman, 2000). These cuts consisted of the neck, breast and shank, thick rib, rib, loin, flank and buttock and were all weighed seperately.

Six lambs of the same age and weight as in the feedlot study were fitted with rumen cannulaes which facilitated manual placement of bags in the ventricle portion of the rumen. These lambs were used to determine the degradability of the test diet. The *in situ* technique, described by Weakly *et al.* (1983), was used to determine dry matter and protein degradation of the feedlot diet. Dacron polyester bags measuring

170 x 90 mm with a pore size of 65 µm were used for *in situ* incubation. According to Weakly *et al.* (1983), the nitrogen content of dacron polyester is low (<0.5%) and correction for its nitrogen contribution is negligible. Bags were made with double seams and were closed by means of a draw string. Approximately 5 g of feed sample, which had been milled to pass through a 2 mm screen, was accurately weighed into each bag. Bags were attached to a clip mounted on the inside of the cannula stopper by means of a 250 mm length of nylon line. Each bag was anchored by a 80 g stainless steel weight (Stern & Satter, 1984) to ensure thorough suspension of the bag in the rumen contents. After soaking the bags in water for 5 minutes, they were incubated in the rumen for 0, 1, 2, 3, 5, 6, 12, 18, 24, 36 and 48 hours respectively (Mehrez & Ørskov,1977). After removal from the rumen, bags were washed in a washing machine on a gentle cycle for 45 minutes, until the fluids coming out of the bags were clear. Other bags containing samples that had not been placed in the rumen were also included in the wash cycle and the dry matter content was determined according to Harris (1970) and AOAC (1997).

The same lambs that were used in the degradation study were used to determine the flow rate of particulate matter from the rumen, using chrome-treated wheat straw as marker of particulate matter. Chrome mordanting was accomplished by treatment of the wheat straw with a chromium (Cr_2O_3) solution according to the process described by Udén *et al.* (1980).

A polyester bag containing approximately 5 g of the chrome-mordanted wheat straw was placed in the rumen of the lambs for 24 hours. The aim was to determine the dry matter degradation of the mordanted wheat straw. An average dry matter degradation of 2.69% provided evidence that preparation of the wheat straw was successful and it could thus be effectively used to determine the rate of passage of particulate matter from the rumen.

Six grams of mordanted wheat straw was hydrated and added to the rumen contents via the rumen cannula. Faecal samples were collected 6, 9, 12, 18, 24, 36, 48, 60, 84 and 108 hours after adding mordanted wheat straw to the rumen, and prepared for chromium analysis according to the process described by Williams *et al.* (1962). The chromium concentration was analysed using an Atomic Absorption Spectrophotometer (VARIAN SPECTR>AA 300/400) and rumen flow rates calculated according to the method of Hartnell & Satter (1979).

The method used to estimate the extent of ruminal dry matter and protein degradation was proposed by Miller *et al.* (1980) and quoted by Stern & Satter (1984), who mathematically combined results obtained *in situ* with *in vivo* rate of passage measurements. This method was used in preference to more complex methods (Ørskov & McDonald, 1979), since previous research has shown no clear advantages for either method (Cronjé, 1992).

The following equation was used to estimate effective degradation (Miller *et al.* 1980, cited by Stern & Satter, 1984).:

$$D = a + (100-a)(Kd) / (Kr + Kd)$$

where: D   =   Effective degradability

a   =   Proportion of dry matter or protein disappearance at t = 0

Kd   =   Rate constant for disappearance of dry matter or protein form the polyester bags. Kd is thus equal to the slope of the linear regression

Kr   =   Rate constant for passage of undegraded dry matter or protein from the rumen. The average chrome concentration in the faeces of consecutive sampling times was used to determine Kr (Hartnell & Satter, 1979)

Representative samples of the diet and faeces were dried in a force-draught oven for 96 h at 50 °C. Dry samples were then milled through a 1 mm screen, mixed and stored at −10 °C for proximate analyses (AOAC, 1997). The feed and faeces were analysed for dry matter (DM), ash, crude protein (CP), ether extract (EE) (AOAC, 1995), crude fibre, neutral detergent fibre (NDF) (Van Soest and Wine, 1967), acid detergent fibre (ADF) (Van Soest, 1963), calcium, phosphorus (Watson, 1994) and energy content (AOAC, 1995). The urine samples were analysed for nitrogen and energy content (AOAC, 1995). Gross energy (GE) was determined by adiabatic oxygen bomb calorimetry (CP500 calorimeter), while CP was determined with a Leco auto analyser (model FP428). Nitrogen analyses were also performed on the right side of each carcass and on internal and external offal.

The data were compared statistically. Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1989). The following model was fitted for main effects (breed, slaughter weight) as well as interactions:

$$Y_{ij} = \mu + G_i + S_j + GS_{ij} + e_{ij}$$

Where Y_{ij} is the dependent variable of the ith breed with j^{th} slaughter weight, μ = the overall mean, G_i = breed effect, S_j = the slaughter weight effect, GS_{ij} = the interaction between breed and slaughter weight and e_{ij} = the residual effects.

The difference between breed and slaughter weight were, where appropriate, tested separately by means of the null hypothesis (H_0), with $H_0 : \mu = \mu_0$ and the alternative hypothesis (H_a) being $H_a : \mu \neq \mu_0$. This was done by means of contrast analyses and estimated least square means ($\pm$ SD) as reported in the various tables. Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P < 0.05$) for breed and slaughter weight.

Results and Discussion

The feedlot diet was pelleted to prevent the selection of certain feedstuffs. The effective degradation value for crude protein (75%) in Table 1 confirms that the feedlot diet used during the present study was a combination of degradable and undegradable protein. The degradable fraction of a diet is used as a source of nitrogenous nutrients for the synthesis of rumen microbial protein (Erasmus, 1991). Therefore, the protein fraction of the duodenal digesta in this study can be expected to be a combination of microbial protein, supplemented with the undegradable protein available in especially the gluten 60, gluten 20 and soya oilcake.

Table 1   Physical and chemical composition of the feedlot diet

Items	Contents (%)
Physical composition[1]	
Maize meal	56.00
Gluten 60	1.92
Gluten 20	1.92
Soya oilcake	5.33
Lucerne	8.50
Wheat straw	14.17
Molasses	9.36
Limestone	1.04
Salt	0.52
Ammonium chloride	0.87
Vit/Min premix[2]	0.08
Chemical composition[3]	
Dry matter	92.00
Metabolizable energy [4] (MJ/kg)	12.10
Crude protein	14.40
Undegradable protein[5]	5.10
Fat	4.40
Crude fibre	13.00
Calcium	0.69
Phosphorus	0.28
Acid detergent fibre (ADF)	11.17
Neutral detergent fibre (NDF)	21.97
Effective rumen degradability	
Dry matter	
Crude protein	78.21
$Kd^{[6]}$ (dry matter)	74.67
$Kd^{[6]}$ (crude protein)	0.0451
$Kr^{[7]}$	0.0418
	0.0214

[1] On an as is basis

[2] A standard mineral (macro and micro) and vitamin supplement formulated by Saldanha Feedmills according to the NRC (1985)

[3] On a dry matter basis

[4] Metabolizable energy (ME) = Digestible energy (DE) x 0.82 (NRC, 1985)

[5] Based on laboratory values determined by Saldanha feedmills

[6] Kd = Rate constant for disappearence of dry matter and protein from the rumen incubated polyester bag

[7] Kr = Rate constant for passage of undegraded particulate matter from the rumen

The body weight, weight gain, ADG, feed and water efficiencies and water consumption of Dorper and Merino ram lambs are represented in Table 2. The average daily gain , water efficiency and water consumption of the Dorper and Merino lambs did not differ (P>0.05). Feed conversion ratio (FCR) of Dorper lambs

(5.50) was significantly higher than that of Merino lambs (4.87). These values are much lower than those obtained in other feedlot studies with different sheep breeds (South African Mutton Merino 6.5 – 10.2; Blackhead Persian 9.8; Dorper 10.5) (Schoeman & Visser, 1995 and Ferreira *et al.*, 2002). According to Thorney *et al.* (1987) the main differences between feed intake and body weight gain are related to body size and age.

The water intake (ℓ/day) was significantly higher (P<0.05) in Dorpers, which contributed to the lower (P<0.05) water efficiency (mℓ/kg$^{0.75}$/day) in Dorper compared to Merino lambs. Since the Dorper was developed from the Blackhead Persian, which is adapted to desert-like conditions, one would have expected that the Dorper (285.97 ± 37.64) would be more efficient than the Merino (240.07 ± 11.63) (P<0.05). Studies by Schoeman & Visser (1995) show that the Dorper has a water efficiency of 246.1 ± 29.8, the Blackhead Persian 163.4 ± 19.6 and the Mutton Merino 301.5 ± 28.9. There is normally a close relationship between the water intake and the amount of food consumed by herbivores (Siebert, 1971; Macfarlane *et al,.* 1971; More *et al.*, 1983; Hamilton & Webster, 1987). Increased feed intake stimulates water intake. A 22% difference in water intake per kg feed intake between wool and hair sheep was also obtained by Quick & Dehority (1986), who reported values which varied from 2.3 to 2.8 litre/kg feed intake.

Table 2 : Initial and final weights, cumulative feed and water intake, feed and water efficiency and water consumption, average daily gain and body weight gain in Dorper and Merino lambs (Means ±SD) fed a feedlot diet.

Variable	Dorper	Merino
n	8	7
Initial body weight (kg)	32.60 ± 2.50	28.70 ± 1.50
Final body weight (kg)	40.90 ± 2.18	43.60 ± 1.10
Body weight gain (kg)	8.40 ± 1.13	14.90 ± 1.60
Average daily gain (g) (ADG)	300.63 ± 65.04	297.69 ± 35.62
Feed conversion ratio (kg feed/kg weight gain) (FCR)	5.50[a] ± 1.04	4.87[b] ± 0.33
Water intake : weight gain ratio (litre water/kg weight gain)	16.39 ± 4.82	14.51 ± 1.60
Water intake (litre/day)	4.67[a] ± 0.61	4.08[b] ± 0.24
Water consumption (litre water/kg feed intake)	2.76 ± 0.38	3.01 ± 0.34
Water efficiency (mℓ/kg$^{0.75}$/day)	285.97[a] ± 37.64	240.07[b] ± 11.63

[a,b] Values in rows bearing different superscript letters are significantly different (P<0.05)

Energy intake (MJ/day), excretion (MJ/day), retention (MJ/day) and diet metabolizable energy content (ME, MJ/kg) of Dorper and Merino lambs are presented in Table 3. No significantly differences between the Dorper and Merino lambs on energy excretion and energy retention (P>0.05) occured. Results from Sheridan (2001) also show no significant difference between Boer goat and Mutton Merino lambs fed a similar high energy feedlot diet (P>0.05). Results of studies from McDonald (1988) shows that sheep fed on barley with a gross energy of 18.5% MJ/day and with faecal and urinary losses of 3.0 and 0.6% MJ/day, are similar to the results of the present study.

Table 3 :   Energy metabolism of Dorper and Merino lambs fed a feedlot diet (Means±SD)

Variable	Dorper[1]	Merino[1]
n	8	7
Dry matter intake (g/day)	1174.74 ± 152.78	1153.57 ± 194.36
Gross energy (MJ/kg)	18.12 ± 0.00	18.12 ± 0.00
Energy intake(MJ/day)	21.28 ± 2.77	20.90 ± 3.52
Faecal energy (MJ/day)	5.08 ± 1.66	5.66 ± 1.66
Urinary energy (MJ/day)	0.63 ± 0.14	0.56 ± 0.16
Methane gas production (MJ/day)	1.70 ± 0.22	1.67 ± 0.28
Total energy excreted (MJ/day)	7.41 ± 1.75	7.89 ± 1.94
Faecal energy (% of energy intake)	23.65 ± 5.82	26.91 ± 5.11
Urinary energy (% of energy intake)	3.00 ± 0.79	2.64 ± 0.61
Total energy excreted (% of energy intake)	34.66 ± 5.38	37.55 ± 4.88
Energy retention (MJ/day)	13.87 ± 1.88	13.02 ± 2.15
Energy retention (% of energy intake)	65.34 ± 5.38	62.45 ± 4.88
Metabolizable energy of diet DM (MJ/kg)	11.84 ± 0.98	11.31 ± 0.88

[a,b] Values in rows bearing different superscript letters are significantly different (P<0.05)

Nitrogen metabolism and retention of Dorper and Merino lambs are presented in Table 4. Only nitrogen retention (gN/kgW$^{0.75}$/day) was significantly higher in Dorper than in Merino lambs. In this study faecal nitrogen (% of nitrogen intake) and urinary nitrogen (% of nitrogen intake) were very similar, with no significant difference (P>0.05) between breeds. Compared with the studies done by Sahoo et al., (2002), on chemically treated wheat straw, the faecal losses in the present study were low

(23-25%) compared to that of the literature (62-68%). The urinary nitrogen reported in the literature differs considerably (10-28%) to that of the present study (22-24%). It is probably to the percentage undegradable protein in the feedlot diet, which were absorb in the intestine and later disregarded as surplus nitrogen in the urine, where as the literature diets were all urea treated wheat which is highly degradable. It could be derived that sheep breeds will not have much influence on the faecal and urinary nitrogen losses when fed the same diet.

Table 4 :   Nitrogen metabolism of Dorper and Merino ram lambs fed a feedlot diet (Means±SD)

Variable	Dorper	Merino
n	8	7
Dry matter intake (g/day)	1174.74 ± 152.78	1153.57 ± 194.36
Nitrogen intake (g/day)	33.88 ± 8.49	32.53 ± 10.34
Faecal nitrogen (g/day)	7.56 ± 2.27	7.70 ± 1.92
Urinary nitrogen (g/day)	7.71 ± 1.76	6.64 ± 2.04
Total nitrogen excreted (g/day)	15.28 ± 2.14	14.35 ± 3.01
Faecal nitrogen (% of nitrogen intake)	22.89 ± 6.88	24.59 ± 5.85
Urinary nitrogen (% of nitrogen intake)	23.99 ± 7.82	21.57 ± 7.22
Total nitrogen excreted (% of nitrogen intake)	46.89 ± 9.56	46.15 ± 10.21
Nitrogen retention (gN/kgW$^{0.75}$/day)	4.39[a] ± 1.91	2.03[b] ± 0.88

[a,b] Means in the same row with different subscripts differ (P<0.05)

The body, whole empty body and carcass weight, dressing percentage and proportional distribution of tissue components relative to whole empty body weight of Dorper and Merino lambs are presented in Table 5. The body weight and WEB of Dorper and Merino lambs differ significantly (P<0.05) at 40 kg live weight, but not at the 30 kg live weight (P>0.05). The Dorpers' carcasses weight were significantly higher than those of the Merino at 30 and 40 kg live weight. Dressing percentages (P<0.05) follow the same tendency. It is probably because the Dorper produces only meat, while the Merino produces meat and wool. Sheridan (2001) has shown that South African Mutton Merino lambs and Boer goat kids have dressing percentages (calculated as % of empty body weight) of 59.1% and 57.4%, respectively. These percentages are much higher than those calculated in the present study for Dorpers (55.9%) and Merinos (48.2%).

Table 5 : Body, whole empty body and carcass weights (kg), dressing percentage and proportional distribution (Means ± SD) of tissue components of Dorper and Merino lambs.

	Dorper		Merino	
Variable	30 kg	40 kg	30 kg	40 kg
n	5	8	5	7
Final body weight (kg)	$28.50^{cd} \pm 1.80$	$40.90^{b} \pm 2.20$	$28.70^{cd} \pm 1.04$	$43.65^{a} \pm 1.06$
Whole empty body (kg)[1]	$23.90^{cd} \pm 2.20$	$35.50^{b} \pm 2.00$	$23.10^{cd} \pm 0.96$	$38.10^{a} \pm 0.80$
Cold carcass (kg)[2]	$13.20^{c} \pm 1.40$	$20.10^{a} \pm 1.50$	$11.50^{d} \pm 0.40$	$18.50^{b} \pm 0.70$
Dressing %[3]	$46.00^{cd} \pm 0.04$	$49.00^{a} \pm 0.02$	$40.10^{cd} \pm 1.70$	$48.70^{b} \pm 1.70$
Proportional distribution[4] (%)				
Whole empty body	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00
Body weight	$119.39^{a} \pm 5.08$	$115.44^{ab} \pm 2.93$	$120.35^{ab} \pm 5.66$	$113.23^{b} \pm 1.23$
Cold carcass	$54.97^{b} \pm 2.86$	$56.87^{a} \pm 2.16$	$48.28^{c} \pm 1.38$	$48.08^{d} \pm 1.62$
Head	$6.32^{c} \pm 0.28$	$5.61^{d} \pm 0.30$	$8.30^{a} \pm 0.44$	$7.34^{b} \pm 0.40$
Feet	$3.29^{b} \pm 0.19$	$2.77^{d} \pm 0.16$	$3.61^{a} \pm 0.29$	$2.91^{c} \pm 0.08$
Skin	$8.95^{b} \pm 0.92$	$8.42^{b} \pm 1.13$	$14.06^{a} \pm 1.74$	$16.10^{a} \pm 1.86$
Heart	$0.50^{c} \pm 0.04$	$0.47^{d} \pm 0.06$	$0.58^{a} \pm 0.06$	$0.51^{b} \pm 0.04$
Liver	2.43 ± 0.41	2.42 ± 0.28	2.75 ± 0.32	2.34 ± 0.21
Lungs	$1.63^{c} \pm 0.26$	$1.65^{c} \pm 0.26$	$1.80^{b} \pm 0.20$	$2.38^{a} \pm 0.20$
Kidneys	$0.41^{b} \pm 0.03$	$0.34^{d} \pm 0.04$	$0.48^{a} \pm 0.03$	$0.40^{c} \pm 0.04$
Kidney fat	0.67 ± 0.27	0.70 ± 0.15	0.48 ± 0.49	0.75 ± 0.21
Spleen	0.17 ± 0.01	0.23 ± 0.13	0.24 ± 0.11	0.21 ± 0.04
Testes	0.85 ± 0.35	1.14 ± 0.38	0.78 ± 0.24	0.91 ± 0.16
GIT fat	1.35 ± 0.28	1.50 ± 0.45	$0.75^{b} \pm 0.65$	$1.82^{a} \pm 0.23$
Diaphragm	0.48 ± 0.12	$0.44^{b} \pm 0.10$	0.38 ± 0.36	$0.73^{a} \pm 0.10$
Full stomach	$19.90^{a} \pm 4.85$	$16.07^{b} \pm 2.19$	$19.18^{a} \pm 4.55$	$13.30^{b} \pm 1.25$
Empty stomach	$4.27^{a} \pm 0.67$	$3.57^{c} \pm 0.27$	$3.68^{b} \pm 0.47$	$3.21^{d} \pm 0.21$
Contents stomach	$15.63^{a} \pm 4.53$	$12.50^{b} \pm 2.09$	$15.50^{a} \pm 4.22$	$10.09^{b} \pm 1.25$
Full intestines	$9.59^{a} \pm 1.76$	$8.60^{b} \pm 0.51$	$10.12^{a} \pm 1.79$	$8.14^{b} \pm 0.75$
Empty intestines	$5.83^{a} \pm 0.71$	$5.15^{b} \pm 0.16$	$5.27^{a} \pm 0.78$	$5.00^{b} \pm 0.44$
Contents intestines	$3.75^{a} \pm 1.36$	$3.45^{b} \pm 0.52$	$4.85^{a} \pm 1.70$	$3.14^{b} \pm 0.42$
Blood	$6.79^{a} \pm 0.61$	$4.50^{b} \pm 1.22$	$4.16^{c} \pm 1.33$	$4.27^{c} \pm 0.47$
Internal offal	18.59 ± 2.17	18.00 ± 1.15	17.17 ± 0.51	18.53 ± 0.77
External offal	18.56 ± 1.20	17.01 ± 1.32	25.97 ± 1.80	26.34 ± 1.96

[1] WEB = live weight minus stomach and intestinal contents

[2] Including kidneys and kidney fat

[3] Expressed as a percemtage of empty body weight

[4] The percentage of the weight of an organ or tissue relative to that of the whole empty body weight

[5] Internal offal is defined as the sum of the heart, liver, lungs & trachea, spleen, stomach, intestine, kidneys, kidney fat and GIT-fat as a percentage of WEB

[6] External offal is defined as the sum of the skin, head and feet as a percentage of WEB

[a,b,c,d] Means in the same row with different superscripts differ (P<0.05).

At slaughter weights of 30 kg and 40 kg, the porportional weights of the head, feet, kidneys, stomach, intestines and blood at 30 kg were significantly higher than those of the 40 kg lambs (P<0.05). On the other hand, the lungs and GIT fat (P<0.05) were heavier at 40 kg slaughter weight. Shemeis, et al. (1994) found that as animals age, the proportional weights of the head, feet and skin decrease. The GIT fat (P<0.05) and kidney fat (P>0.05) were more in the 40 kg lambs, which gives the indication that the feedlot diet had energy in excess of the needs for growth and maintenance.

The skin (as a percentage of WEB) of the Merino was significantly heavier than that of the Dorper at 30 and 40 kg live weights (P<0.05), probably due to the fleece cover. The proportional contribution of the lungs and GIT fat was higher in 40 kg Merino lambs than in 30 kg lambs (P<0.05) and proportionally higher than that of the Dorper (P<0.05).   The proportional weight of the blood to the WEB was significantly higher at 30 kg than at 40 kg for Dorper lambs (P<0.05), but in the Merino lambs was similar at both slaughter weights. In the remaining organs there was no (P>0.05) significant interaction between breed and slaughter weight.

Comparison of the head, feet and skin, as well as the external offal, indicates that there were differences (P<0.05) between the two breeds, with the Merino lambs having higher percentages (P<0.05) than the Dorper lambs at both slaughter weights. With the exception of the heart, lungs, kidneys, empty stomach and blood there were no other differences (P<0.05) between Dorper and Merino lambs with respect to internal offal. The internal and external offal in Dorper lambs was higher at 30 kg than that at 40 kg (P<0.05). However in the Merino lambs internal offal (P>0.05) was similar at both slaughter weights, but the external offal (P<0.05) at 40 kg was much higher than at 30 kg. When comparing the external and internal offal, it seems that the proportional contribution of the Merinos' skin (16.1) and head (8.4) is a much higher percentage (P<0.05) of WEB than the skin (7.3) and head (5.6) of the

Dorper. The skin and head contribute therefore to the lower (P<0.05) dressing percentage in the Merino. The main factor for this big difference in dressing percentage between the two species is that the Merino is predominantly a wool sheep with a dense, long fleece, whereas the Dorper is a mutton sheep with a predominantly hairy coat.

In general the sheep breeds have a higher percentage of external offal (average 19.9%) than game (average 15.1%) and cattle (13.3%) species, mainly because the skin (including the wool) contributes a higher proportion in all the sheep breeds (Owen & Norman, 1977; Robelin et al., 1990; Ferreira et al., 1999; Ferreira & Hoffman, 2001; Sheridan, 2001; Van Zyl, 2001).

Riley et al. (1989) stated that internal offal is usable and can be considered to be included in the meat production potential of animals or to their total yield of usable products. Thus Dorper and Merino have a total usable product percentage of 77.8% and 69.6%, respectively, which is much lower than game (84.8%) (Van Zyl, 2001; Ferreira & Hoffman, 2001). It seems the game species have a higher meat production potential than the domesticated species, not only because of the higher dressing percentages (Van Zyl, 2001; Ferreira & Hoffman , 2001), but also because of the equal or higher internal offal production. Studies from Robelin et al. (1990) stated that cattle have proportionly a much lower internal offal than sheep (15.8 vs 21.4%).

Table 6 : Commercial cuts (Mean±SD) as a percentage of carcass weight of Dorper and Merino lambs

Variable	Dorper		Merino	
	30 kg	40 kg	30 kg	40 kg
Neck	5.48 ± 0.98	6.17 ± 1.24	6.82 ± 0.44	6.59 ± 0.89
Breast & Shank	15.67[b] ± 1.20	14.73[b] ± 1.31	16.36[a] ± 1.62	16.13[a] ± 0.51
Thick Rib	15.54[c] ± 1.01	13.59[d] ± 1.60	17.72[a] ± 1.30	15.98[b] ± 0.46
Rib	8.13[b] ± 1.06	8.72[a] ± 1.33	7.20[b] ± 0.92	8.39[a] ± 0.34
Loin	7.77[b] ± 0.89	8.14[a] ± 0.90	7.49[b] ± 1.08	9.33[a] ± 0.94
Flank	12.28[b] ± 0.36	13.21[b] ± 1.70	10.24[a] ± 0.75	10.58[a] ± 0.77
Buttock	34.89[a] ± 1.22	35.10[a] ± 1.75	33.45[b] ± 1.53	33.16[b] ± 1.18

[a,b,c,d] Values in rows bearing different superscript letters are significantly different (P<0.05).

Table 6 shows the weight of the commercial cuts as a percentage of carcass weight. Breed did not significantly influence the proportions of the neck, rib and loin, when expressed as a percentage of the carcass. However, the breast and shank, flank and buttock were more developed in Dorpers than in Merinos (P<0.05). The proportional contribution of the thick rib in Merino was greater than that of the Dorpers (P<0.05).

There was no significant influence of slaughter weights of the 30 or 40 kg on weights of the neck, breast and shank, flank and buttock, in both the Dorpers and Merinos (P>0.05). The thick rib as a percentage of the carcass weight in 30 kg lambs was significantly higher than that of the 40 kg lambs (P<0.05). The rib and loin as a percentage of the carcass weight in both breeds was higher and more developed in the 40 kg lambs than in the 30 kg lambs (P<0.05). There was, however, no significant interaction between the breed and slaughter weight. The buttock of Dorpers (35.10%) comprises a higher percentage of carcass weight than that of the Merino (33.16%) at 40 kg live weight (P<0.05). The combination of buttock and loin torms the hindquarter (which is a high-priced cut). The hindquarter of the Dorper (45.3%) is much heavier (P<0.05) than that of the Merino (42.5%). Therefore the Dorper has a better meat production potential than the Merino. Ledger *et al.* (1967), reported some hindquarter percentages for unimproved Boran cattle at 53.1% and goats 50.0%.

Conclusions

The study provided useful information about the differences in growth and carcass characteristics between Dorper and Merino lambs when they are finished under identical conditions. In this investigation the Dorper and Merino had a similar ADG. In terms of FCR the Merino was more efficient (P>0.05) than the Dorper. The Dorper had a higher nitrogen retention (P<0.05) than the Merino. This is probably due to the Merinos wool growth requirement. Big differences were also seen in slaughter weight components and weights of the commercial cuts. The head and skin of the Merino were much heavier (P<0.05) as a proportion of the whole empty body than that of the Dorper. In comparison to this the carcass compared to the whole empty body of the Dorper was heavier (P<0.05) than that of the Merino. The main reason for this is the production of a thick wool coat in combination with carcass growth,

where as the Dorper has short hair and more nutrients can be available for muscle growth.

The high-priced commercial cuts like the loin and hindquarter were higher in the Dorper than in the Merino (P<0.05) which gives Dorper lambs a higher meat production potential than Merinos. This study suggests that both species would be suitable for feedlot finishing.

Acknowledgement

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CHAPTER 2

Estimating the essential Amino Acid requirements of growing Dorper lambs through evaluation of the essential amino acid composition of the whole empty body and duodenal digesta

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Abstract

The essential amino acid (EAA) profile of the duodenal digesta and whole empty body of 7 Dorper ram lambs managed under intensive and extensive feeding conditions, was investigated. Significant differences were found between the EAA composition of the duodenal samples, whether protein quantity was taken into account (gAA/100g crude protein (CP)) or not (expressed as % of lysine). The chemical scores indicated that the two most limiting amino acids in the duodenal digesta for whole empty body growth were: arginine and histidine. Excess levels of amino acids tended to be present in all three duodenal digesta samples (isoleucine, leucine, lusine, methionine, phenylalanine, threonine and valine). According to the EAA: Lysine ratios of the whole empty body of Dorpers and beef cattle it is remarkably similar. The whole empty body EAA composition (g AA/100 g crude protein) was as follows: 7.10 arginine; 2.40 histidine; 3.31 isoleucine; 7.22 leucine; 6.61 lysine; 1.62 methionine; 3.91 phenylalanine; 3.77 threonine and 4.85 valine. The composition can serve as an example of the ideal EAA requirements for whole empty body growth between 30 and 40 kg live weight of Dorper ram lambs.

Keywords: essential amino acids, whole empty body, duodenal digesta.

Introduction

Like all mammals, ruminants require an exogenous source of essential amino acids (EAA). However, because ruminal fermentation leads to production of microbial protein, ruminants are usually not perceived to have dietary requirements for EAA

(Merchen & Titgemeyer, 1992). Recently considerable attention has been devoted to the protein requirements of ruminants. The idea that the balance of the amino acids required for growth in mammals can be determined from the amino acid composition of body protein is now well established, according to Schingoethe (1996). Amino acid requirements at tissue level is an important consideration, as ruminants have metabolic requirements for amino acids rather than protein requirements *per se* for maintenance and production functions (Baker, 1989; Schwab, 1996). An ideal pattern of absorbed amino acids is believed to exist for various physiological functions, including maintenance and growth (NRC, 2000). In order to determine the desired supply of EAA to optimise utilisation by the host, some attempt must be made to appreciate the needs of the host (Merchen & Titgemeyer, 1990). A simple and effective approach is provided by the ideal protein concept when examining the pattern of dietary amino acids in monogastric animals (Fuller & Chamberlain, 1982). In terms of whole empty body growth, the amino acid composition of the whole empty body (WEB) has been defined as an ideal example for the amino acid composition of dietary protein, resulting in improved amino acid utilisation (Mäntysaari *et al.*, 1989; Hussein *et al.*, 1991; Ferreira *et al.*, 1999). The requirement of the whole body represents the summation of nutrient utilisation by each tissue. Each tissue bed or organ in the body has a specific function and these functions dictate the pattern of amino acid utilisation. A better knowledge of the specific need for and utilisation of nutrients by each tissue, will allow us to meet requirements of the whole body for optimal growth (McBribe *et al.*, 1998).

Tagari *et al.* (1995) stated that the evaluation of the amino acids reaching the duodenum forms a fundamental part in assessing the nutritional value of diets for ruminants. Therefore, Ferreira *et al.* (1999) concluded that the designated strategy to determine the ideal protein is to determine the duodenal amino acid profile (microbial and non-degradable protein) from a specific diet, which is then compared to the whole body on a qualitative and/or quantitative basis to detect the limiting amino acids.

The Dorper is the most numerous mutton breed in South Africa and thus plays a major role in the production of mutton under both feedlot and veld conditions. Since there is no information regarding the EAA requirements of the Dorper, extensive research is of utmost importance.

The objectives of this study were : (a) to determine the EAA growth requirements of Dorper lambs according to the whole empty body EAA profile, and (b) to detect imbalances in the duodenal digesta for optimal growth under both intensive and extensive feeding conditions.

Materials and Methods

Seven Dorper ram lambs with an fasted stomach weight of 30 kg were used for the study. A standard feedlot diet (Table 1) was formulated adn fed *ad libitum* to provide in the nutrient requirements of growing lambs (NRC, 1985). The feeds used to formulate the standard feedlot test diet were those that are reasonably available and usually used in the feedlot.

The lambs were individually weighed and slaughtered when the desired unfasted stomach weight of 40 kg was reached. At slaughter, blood samples were taken and the digesta content of the proximate 4 m of the small intestine (representing the EAA available for absorption) was recovered and stored at –20 °C for later analysis. Van der Walt & Meyer (1988) stated that the small intestine might be investigated by dividing the gut of slaughtered animals into segments and quantitatively recovering the digesta from each segment. According to Johns & Bergen (1973) and Phillips *et al.* (1979), the ileum is the dominant site of amino acid absorption. Therefore it was accepted that the digesta contents of the proximate 4 m contains the potential amino acids that could be absorbed by the lambs.

The carcasses were split medially through the vertebrae into isomorphous left and right halves. The right side of the carcass, external offal (head, feet and skin) and internal offal (heart, heart fat, liver, lungs and trachea, kidneys, kidney fat, gastro-intestinal fat, spleen, diaphragm, stomachs and intestines) were stored at –20 °C. All the body components were milled twice through a carcass mill while still in the frozen state.

Duodenal samples were also collected during the summer growing season (October – November) from Dorper lambs (n=7), with an average live weight of 40kg ± 1.5kg, in two different grazing areas of South Africa.

The first study area is located in the north western part of South Africa, being a part of the Kalahari Thornveld (Veld type 16a) (Acocks, 1988). The landscape is an alternating series of dunes and open savannas. The grasses are tufted and entirely

of the "white" type, mostly *Aristida spp.* (Thee-awn) and *Eragrostis spp.* (Hairy love grass), with the silvery *Stipagrostis uniplumis* (Silky Bushman grass) conspicuous. On the dunes and valleys *Centropodia glauca* (Gha grass), *Schmidtia kalahariensis* (Sour grass) and *Schmidtia pappophoroides* (Sand Quick), are important, with *Acacia erioloba* (Camel Thorn trees) growing close to the dry river beds. The mean annual rainfall is between 100 – 200 mm per year and occursmostly in the late summer months (Van Oudtshoorn, 1994). The temperature ranges from 0 °C (minimum) to 45 °C (maximum).

The second study area is located in Cymbopogon – Themeda veld in the Namakaroo (Veld type 48a) (Acocks, 1988). The vegetation consists of a mixture of shrubs and short summer-growing grasses. The shrubs include *Pentzia incana* (Ankerkaroo) and *Felicia muricata*, and the grasses include *Themeda triandra* (Rooigras) and *Digitaria eriantha* (Finger grass). It is a summer rainfall area with a mean annual rainfall of 450 – 550 mm a year (Acocks, 1988), and the temperature ranges from – 10 °C (minimum) to 35 °C (maximum).

Representative samples of all the body components were mixed, according to weight, to obtain a whole empty body sample. Representative samples of the whole empty body and duodenal digesta (feedlot and veld) were freeze-dried and stored at –10 °C. The dry samples, as well as the diet, were then milled through a 1 mm screen, thoroughly mixed and stored at –10 °C.

The diet was analysed for moisture, ash, crude protein, crude fibre, ether extract, calcium and phosphorus according to the methods of Harris (1970) and AOAC (1997). Duodenal samples were also analysed for their crude protein content. The acid detergent fibre and neutral detergent fibre were analysed according to the methods of Harris (1970) and AOAC (1997). The EAA composition of the whole empty body and duodenal digesta samples were determined with a BECKMAN SYSTEM 7300 high performance analyser after 22 h of acid hydrolysis (6N.HCl) at 110 °C (AOAC, 1997).

The data was compared statistically. Analyses of variance were performed, using the General Linear Model (GLM) procedure of SAS(1989).

Results and Discussion

The essential amino acid composition of the whole empty body of Dorper lambs is shown in Table 2 (woollen- and wool-free sheep and cattle). It is apparent that there are some differences. There are four amino acids that occur in the feedlot diet which are in higher concentrations than in the Dorper WEB (isoleucine, leucine, phenylanine and tryptophan), whereas the following occur in higher concentrations in the Dorper WEB (arginine, histidene, lysine, methionine, threonine and valine) compare to that of the feedlot diet.

Table 1   Physical and chemical composition of the feedlot diet

Items	Contents (%)
Physical composition[1]	
Maize meal	56.00
Gluten 60	1.92
Gluten 20	1.92
Soya oilcake	5.33
Lucerne	8.50
Wheat straw	14.17
Molasses	9.36
Limestone	1.04
Salt	0.52
Ammonium chloride	0.87
Vit/Min premix[2]	0.08
Chemical composition[3]	
Dry matter	92.00
Metabolizable energy [4] (MJ/kg)	12.10
Crude protein	14.40
Undegradable protein[5]	5.10
Fat	4.40
Crude fibre	13.00
Calcium	0.69
Phosphorus	0.28
Acid detergent fibre (ADF)	11.17
Neutral detergent fibre (NDF)	21.97
Effective rumen degradability	
Dry matter	78.21
Crude protein	74.67
Kd[6] (dry matter)	0.0451
Kd[6] (crude protein)	0.0418
Kr[7]	0.0214

[1] On an as is basis

[2] A standard mineral (macro and micro) and vitamin supplement formulated by Saldanha Feedmills according to the NRC (1985)

[3] On a dry matter basis

[4] Metabolizable energy (ME) = Digestible energy (DE) x 0.82 (NRC, 1985)

[5] Based on laboratory values determined by Saldanha feedmills

[6] Kd = Rate constant for disappearance of dry matter and protein from the rumen incubated polyester bag

[7] Kr = Rate constant for passage of undegraded particulate matterdry matter or protein from the rumen.

Dorpers have similar EAA concentrations to those of the wool-free sheep and cattle, whereas the wool sheep have a very high concentration of histidine, leucine, methionine, phenylalanine and lesser concentrations of threonine and valine. The main reason for this is the high wool content in the sample. Studies by Van Zyl (2001) show that game species have an overall higher EAA concentration than that of domestic species, with similar methionine and threonine concentration. The only EAA of which domestic species have a higher content than game species, is arginine.

Table 2 Essential amino acid (EAA) content (Mean ± SD) of the whole empty body of Dorper lambs (n=7), wool sheep and cattle (g AA/100 g crude protein) on a dry matter basis

EAA	Feedlot diet	Dorper	Sheep[1]	Sheep[2]	Cattle[3]
Arginine	4.62	7.10 ± 0.69	7.72 ± 0.58	8.40	6.6
Histidine	2.31	2.40 ± 0.09	4.54 ± 0.40	2.1	2.5
Isoleucine	3.60	3.31 ± 0.18	3.06 ± 0.33	3.2	2.8
Leucine	9.77	7.22 ± 0.21	8.53 ± 0.64	6.4	6.7
Lysine	3.48	6.61 ± 0.27	6.46 ± 0.46	6.3	6.4
Methionine	1.13	1.62 ± 0.09	3.56 ± 0.22	1.8	2.0
Phenylalanine	4.38	3.91 ± 0.11	5.22 ± 0.44	3.5	3.5
Threonine	2.95	3.77 ± 0.15	4.65 ± 0.48	3.8	3.9
Valine	4.16	4.85 ± 0.58	5.18 ± 0.41	4.1	4.0
Tryptophan	0.81	0.72 ± 0.14	-	-	0.79

[1] Sheep whole empty body including wool (Ferreira et al., 1999)

[2] Sheep whole wool-free empty body (Ørskov et al., 1986)

[3] Average for cattle whole empty body (Williams, 1978; Rohr & Lebzien, 1991; Ainslie et al., 1993)

The EAA content of the WEB and duodenal digesta (g AA/10g CP) of Dorper lambs for the feedlot diet, Kalahari and Namakaroo grazing areas are presented in Table 3. Comparing the three areas with each other the feedlot duodenal samples were significantly lower (P < 0.05) in arginine and threonine than that of the two grazing areas, which were remarkably similar. Leucine and lysine were substantially higher (P < 0.05) in the feedlot sample than in those of the grazing areas. The concentration of essential amino acids in the Kalahari and Namakaroo did not differ much which demonstrate us the big influence of the microbial protein in the rumen. The differences between the EAA composition of the feedlot diets' duodenal digesta and that of the grazing lambs duodenal digesta were expected to occur, since it has been reported (Merchen & Titgemeyer, 1992; Cole & Van Lunen, 1994) that in diets high in RDP, rumen micro-organisms are the primary source of protein flowing into the duodenum. Rumen microbes, through the process of rumen fermentation, rumen microbes, therefore modify the duodenal amino acid profile compared to that of the feedlot diet. To further complicate matters, the amino acid profile of the UDP fraction of feeds is often different from that of the ingested feeds (Hvelplund & Hesselholt (1987); Susmel et al., 1989; Erasmus et al., 1994).

Mean duodenal EAA values obtained from the literature (Rulquin & Vérité, 1996), tend to reflect higher concentrations of isoleucine, leucine (only Kalahari and Namakaroo), methionine, phenylalanine, threonine and valine than the values in the present study (Table 3). The EAA from the duodenal digesta fell within the boundaries of the minimum and maximum values reported in the literature, except for histidine and threonine from the feedlot diet. The examples in Table 3 illustrate the variation in duodenal amino acid composition from different feedstuffs. The intestinal amino acid profile was generally assumed to be constant due to the smoothing effects of microbial protein on the variation (Oldham & Tamminga, 1980). However, extensive literature studies based on 133 cattle diets (Rulquin & Vérité, 1996), indicated that the variation (CV) of individual EAA concentrations can rage from; 7-11% for lysine, arginine, phenylalanine, threonine and the branched-chain amino acids; 12% for histidine and 18% for methionine. According to Hvelplund & Madsen (1985) a variation of 5 to 11% in duodenal contents exists within diets due to changes in the relative contribution of microbial and by-pass protein as well as each fraction's variable amino acid profile. Furthermore, an additional source of variation between the three duodenal digesta EAA concentrations could be attributed to the fact that bacterial amino acid compositions can vary according to the composition of

the diet, feeding frequency, passage rates and substrate fermented (Clark *et al.*, 1992; Erasmus, 1992). The WEBs' arginine content and histidine was the only amino acid that was higher than all three the duodenal samples (P<0.05), whereas all the other EAA were lower (P<0.05) or did not differ (Table 3).

Table 3   Essential amino acid (EAA) composition (Mean ± SD) of the whole empty body(WEB) of Dorper lambs (n=7) and duodenal digesta (Dd) (n=5) of Dorper lambs collected in the feedlot and on natural grazing

EAA	Dd feedlot	Dd Kalahari	Dd Namakaroo	WEB	Rulquin and Vérité (1996)			
					Mean 1)	VC %	Min	Max
Arginine	2.70^{d} ± 0.64	5.87^{bc} ± 0.90	5.12^{bc} ± 0.28	7.10^{a} ± 0.69	4.96	10.6	3.76	7.07
Histidine	2.21^{ab} ± 0.20	2.21^{ab} ± 0.27	1.93^{b}± 0.11	2.40^{a} ± 0.09	2.21	11.9	1.34	2.89
Isoleucine	4.45^{bcd} ± 0.36	4.80^{bcd} ± 0.53	4.46^{bcd} ± 0.22	3.31^{a} ± 0.18	5.45	8.0	4.44	6.73
Leucine	9.45^{bcd} ± 0.84	8.84^{bcd} ± 0.46	8.53^{bcd} ± 0.72	7.22^{a} ± 0.21	8.87	10.5	6.77	11.9
Lysine	9.16^{b} ± 2.42	7.67^{ab} ± 0.72	7.26^{ab} ± 0.36	6.61^{a} ± 0.27	6.88	9.7	4.82	8.42
Methionine	1.84 ± 0.38	1.88 ± 0.23	1.66 ± 0.28	1.62 ± 0.09	1.97	17.6	1.27	2.99
Phenylalanine	4.43^{bcd} ± 0.43	4.99^{bcd} ± 0.57	4.52^{bcd} ± 0.18	3.91^{a} ± 0.11	5.12	7.1	4.13	6.06
Threonine	3.81^{d} ± 0.58	4.52^{bc} ± 0.38	4.40^{bcd} ± 0.28	3.77^{ad} ± 0.15	5.32	7.0	4.36	6.16
Valine	4.96^{ab} ± 0.51	5.90^{b} ± 0.69	5.33^{ab} ± 0.26	4.85^{a} ± 0.58	6.01	10.8	4.03	7.33
Tryptophan	1.64 ± 0.24	- -	- -	0.72 ± 0.14	-	-	-	-

[a,b,c,d] Values in rows bearing different superscripts are significantly (P < 0.05) different

[1] Mean, min and max values of duodenal amino acid concentrations calculated from Rulquin & Vérité (1996) based on cattle fed 133 diets

In order to identify a first- and second-limiting amino acid for the Dorpers on both the feedlot diet and natural grazing, the chemical score and resulting EAA index was calculated in Table 4. For any animal, ruminant or non-ruminant, the most important single factor affecting the efficiency of protein utilisation is the profile of digestible EAA entering the small intestine (Boisen *et al.*, 2000). These EAA arriving in the duodenum, originate from different sources of nitrogen, namely the microbial protein (60-85%), undegraded dietary protein (percentage depends on the rumen degradability of dietary protein) (Ørskov *et al.*, 1986) and endogenous protein (9-12 % of non-ammonia-N) (NRC, 2000). According to Ferreira *et al.* (1999b) the

chemical score (Table 4) provides a better evaluation of amino acids resulting in an EAA index.

The chemical score presents the proportion of a specific amino acid in the duodenal digesta relative to that of the whole empty body, while the amino acid index represents the proportion of the ten EAA relative to that of the whole empty body protein (Loëst et al., 1999). The chemical score in Table 4 suggests that the first and second-limiting amino acid in the duodenal digesta of the three diets are similar. The first limiting is arginine and second histidine. It is interesting to note that the three duodenal samples are so similar, although they were collected at such different areas/conditions. The high SD-values in Table 4 could also influence the limiting amino acids to a certain extent. It should, however be mentioned that, according to Newbold (1988) the importance of arginine may be overestimated when comparing the amino acid composition of tissues with that of the duodenal digesta. Arginine tends to be only semi-essential for ruminants (Boisen et al., 2000) and it is not known if arginine is synthesised or released at adequate rates to meet arginine requirements (Zinn & Owens, 1993). Furthermore, histidine requirements may also be overestimated when using tissue chemical scores, since histidine is found in large endogenous reservoirs as non-protein dipeptides, carnosine and serine (Zinn et al., 2000). Research based on growing swine emphasised that tissue chemical scores overestimate histidine requirements by 25-50 % (Izquierdo et al., 1988; Chung & Baker, 1994). Erasmus (1999) also stated that methionine and lysine are the first and second limiting amino acids in ruminally synthesised microbial protein for nitrogen retention in growing cattle.

Studies done on sheep revealed that methionine was the first-limiting and lysine the second-limiting amino acid for growing lambs, while histidine, arginine and threonine also seem potentially limiting (Nimrick et al., 1970; Storm & Ørskov, 1984; Chen & Ørskov, 1994). Ferreira et al. (1999b), however, found that the duodenal digesta was first-limiting in histidine and second-limiting in methionine, followed by threonine and arginine for South African Mutton Merino lambs fed a feedlot diet with an effective degradation value of 75%, which indicates that the diet was well balanced with degradable and undegradable protein. Likewise for cattle, Richardson & Hatfield (1978) reported that methionine, lysine and threonine were the first three limiting amino acids in growing steers when rumen microbial protein is the sole source of protein. Thus, there is no good comparison between the results of the present study and that found in the literature on the amino acids that are limiting in growing

ruminants. The fact that methionine and lysine were first and second-limiting for wool sheep and cattle could, however, not be confirmed in the present study. The rest of the amino acids (Table 4) tended to be well balanced, illustrating the balancing effect of rumen bacteria on duodenal digesta. According to Newbold (1988) tryptophan is frequently not measured and its importance consequently overlooked. However in the present study, the concentration of tryptophan was abundant in the feedlot diet relative to requirements.

Table 4   Chemical score (Means ± SD) and essential amino acid (EAA) index for duodenal digesta of Dorper lambs collected in the feedlot and natural grazing (n=5)

EAA	Chemical score[1]: Feedlot (%)	Chemical score[1]: Kalahari (%)	Chemical score[1]: Namakaroo (%)
Arginine	38 ± 8.95	72 ± 3.90	83 ±12.67
Histidine	92 ± 8.35	81 ± 4.42	92 ± 11.38
Isoleucine	134 ± 11.02	135 ± 6.55	145 ± 15.98
Leucine	131 ± 11.62	118 ± 9.98	122 ± 6.34
Lysine	139 ± 36.65	110 ± 5.48	116 ± 10.95
Methionine	113 ± 23.56	102 ± 16.99	116 ± 14.06
Phenylalanine	113 ± 11.01	116 ± 4.60	128 ± 14.63
Threonine	101 ± 15.48	117 ± 7.41	120 ± 9.99
Valine	102 ± 10.49	110 ± 5.41	122 ± 14.32
Tryptophan	228 ± 33.45	- -	- -
EAA index[2] , %	93	94	97

[1] Chemical score presents the proportion of a specific EAA relative to that of whole empty body protein

[2] EAA (index) presents the proportion of all the EAA's studied relative to that of whole empty body protein

Based on the EAA index (Table 4), the duodenal digesta of the feedlot diet contains 93% of the total EAA needed for optimal growth. The Kalahari samples (94 %) and Namakaroo (97 %) have even higher indexes than the feedlot diet group, but these values are still below the optimum (100 %). Both the chemical score and the EAA index therefore indicate that the EEA patterns of the duodenal digesta are disproportionate to those of the whole empty body. Seven duodenal EAA from both Kalahari and Namakaroo samples, and eight duodenal EAA from the feedlot sample

tended to occur in excess of that required in the whole empty body (ideal amino acid balance), and that may have negative effects on animal production performance. According to Loëst et al.(1999) focus should not only be placed on limiting amino acids, but also on EAA that may occur in excess. D'Mello (1994) reported that adverse effects may arise from the intake of essential or non-essential amino acids absorbed in quantities and patterns that are disproportionate to those required for optimum tissue utilisation. In studies with rats and pigs, amino acid imbalances (limitations or excess) resulted in depressions in food intake and growth, and reduced the efficiency of utilisation of protein (Harper & Rodgers, 1965; Edmonds et al., 1987). On the other hand, D'Mello (1994) also mentioned that ruminants are less susceptible to the effects of amino acid imbalances because of the extensive microbial metabolism of amino acids in the rumen. The fact that some kind of amino acid imbalance does occur in ruminants is evident in the improved milk yield and protein synthesis in dairy cows (Schwab, 1996), wool growth in sheep (Reis & Tunks, 1976) and body weight gain in cattle (Titgemeyer et al., 1988; Veira et al., 1991) observed after the post-ruminal supplementation of amino acids (mainly lysine and methionine). In connection with the supplementation of amino acids, Merchen & Titgemeyer (1992) suggested that whole proteins should be provided post-ruminally rather than one or two critical amino acids, since several amino acids are often co-limiting.

In order to provide a direct comparison of the EAA composition of the WEB of different species (Table 5), regardless of protein, EAA's must be expressed as a percentage of lysine (Cole & Van Lunen, 1994; Loëst et al., 1999).

Table 5   Whole empty body essential amino acids expressed as a percentage of lysine (Means ± SD) for Dorper lambs (n=7).

EAA	EAA: Lysine[1] Dorper	EAA: Lysine[2] Sheep	EAA: Lysine[3] Cattle
Arginine	107 ± 12.22	120 ± 3.00	92 ±5.00
Histidine	36 ± 1.36	70 ± 2.00	36 ± 0.60
Isoleucine	50 ± 3.07	47 ± 4.00	54 ± 7.00
Leucine	109 ± 4.96	132 ± 3.00	94 ± 1.00
Lysine	100 ± 0.00	100 ± 0.00	100 ± 0.00
Methionine	24 ± 1.46	55 ± 2.00	27 ± 0.70
Phenylalanine	59 ± 2.46	81 ± 3.00	54 ± 1.00
Threonine	57 ± 3.16	72 ± 4.00	54 ± 1.00
Valine	73 ± 8.87	80 ± 5.00	71 ± 2.00
Tryptophan	11 ± 1.80	- -	11± 3.00

[1] EEA: Lysine expresses each essential amino acid as a percentage of lysine (lysine=100%)

[2] Values of SA Mutton Merino sheep (Ferreira, 1998)

[3] Values of beef cattle (Erasmus, 2001)

The ideal ratio to lysine remains largely unaffected by dietary – (protein level, energy level and feed intake), environmental – (disease and heat stress) and genetic (sex and capacity of lean vs fat growth) factors (Baker & Han, 1994). Tamminga & Verstegen (1996), stated that animals require EAA in a well-balanced and strictly defined ratio for protein deposition.   Once an ideal profile of amino acids is established, the quantitative needs of the remaining nine EAA can be estimated relative to lysine (Peisker, 1999; Mack et al., 1999). Detailed information regarding the protein quality of the duodenal digesta, and hence, the respective diet, can be obtained from calculations of the contributions of each individual amino acid to the ideal pattern (Boisen et al., 2000). The comparison of individual EAA: lysine ratios (Table 5) indicates that there are differences (P < 0.05) between the whole empty body of the Dorpers in the present study and that of the literature, irrespective of protein quantity. The EAA to lysine ratio (Table 5) gives leucine and arginine higher in concentration than lysine. When we compare the "wool-free" Dorper lamb with the ratio of cattle it is remarkably similar except for arginine and leucine. It is important to note that the Mutton Merino lamb values reported by Ferreira et al. (1999a) differ to a large extent from those of the Dorper, probably due to the wool content in the WEB.

Table 6   The duodenal digesta essential amino acids expressed as a percentage of lysine (Means ± SD) for Dorper lambs (n=7).

EAA	EAA: Lysine[1] Feedlot	EAA: Lysine[2] Kalahari	EAA: Lysine[3] Namakaroo	EAA: Lysine[3] WEB
Arginine	32 ± 10.76	77 ± 9.58	71 ± 2.02	107 ± 12.22
Histidine	25 ± 5.86	29 ± 2.77	27 ± 2.45	36 ± 1.36
Isoleucine	52 ± 13.91	63 ± 6.12	61 ± 2.06	50 ± 3.07
Leucine	108 ± 22.39	116 ± 7.27	117 ± 4.23	109 ± 4.96
Lysine	100 ± 0.00	100 ± 0.00	100 ± 0.00	100 ± 0.00
Methionine	21 ± 6.17	25 ± 2.76	22 ± 3.21	24 ± 1.46
Phenylalanine	51 ± 12.29	65 ± 7.59	62 ± 1.83	59 ± 2.46
Threonine	43 ± 6.62	59 ± 3.26	61 ± 1.38	57 ± 3.16
Valine	57 ± 13.39	77 ± 7.90	74 ± 2.45	73 ± 8.87
Tryptophan	19 ± 4.70	- -	- -	11 ± 1.80

[1] EEA: Lysine expresses each essential amino acid as a percentage of lysine (lysine=100%)

[2] Values of SA Mutton Merino sheep (Ferreira, 1998)

[3] Values of beef cattle (Erasmus, 2001)

The duodenal digesta EAA expressed as a percentage of lysine is shown in Table 6. The two grazing area duodenal concentrations are very similar, but tend to be higher only in arginine and threonine compared to that of the feedlot diet. The WEB tend to be higher only in arginine, histidine and threonine compared to the three duodenal concentrations, which suggest a tendency to a shortage in arginine, histidine and threonine in the duodenal digesta compare to the WEB for optimal growth.

Buttery & Foulds (1988) mentioned that with a number of protein supplements, methionine was the only amino acid the concentration of which was raised relative to lysine after rumen fermentation. The average lower bacterial amino acid ratios to lysine could contribute to this change, altering the diet to a more balanced diet compared to the WEB requirement. Accordingly, the latter demonstrates the assumption that ruminants are less susceptible to imbalances through extensive microbial modification. However, the generation of certain reactive metabolites from specific amino acids during rumen degradation can induce detrimental effects (D'Mello, 1994). The ideal protein concept is thus dependent on a perfect balance of dietary amino acids in order to maximise the efficiency of protein utilisation and avoid the harmful effect of imbalances (D'Mello, 1994). With the knowledge that amino acid imbalances and toxicities occur, Loëst *et al.* (1999) stated that further research

should be aimed at addressing the imbalanced profiles in the duodenum in order to enhance the efficiency of utilisation of absorbed amino acids to maximise growth.

Conclusions

Results based on chemical scores and the resulting EAA index demonstrated the effect of microbial modification on the feed protein, resulting in a relatively well balanced profile of individual amino acids and hence an increased biological value in the duodenum. The amino acid composition of the duodenal digesta determined in the present study, differs from that of the mean microbial values in the literature. These differences occurred in spite of the fact that a relatively high degradable protein (± 75 %) diet was fed. Accordingly, it was suspected that the duodenal digesta would be predominantly of microbial origin. However, it seems as if other factors also affect rumen microbial protein synthesis. Therefore the mean microbial amino acid values in the literature do not seem to be representative of the amino acids available in the duodenum when a high degradable protein diet is fed. It is probably more accurate to compare the amino acid profile of the duodenal digesta content originating from a specific standard diet and type of animal with that of the whole empty body to detect the limiting amino acids. According to the results of the present study the amino acid composition of the duodenal digesta differs significantly from that of the WEB (P<0.05), except for theonine and valine, which are close to that of the whole empty body. The duodenal EAA concentration of Dorpers in this study tend to be low in arginine and histidine. The duodenal amino acid concentrations originating from two different grazing areas (Kalahari and Namakarro) and were remarkably similar, with only argenine that differs significantly, which is lower in the feedlot diet than that of the grazing areas. The WEB was higher in argenine compares to the three duodenal concentrations and lower in isoleucine, leucine and phenylalanine. The results also revealed that, according to the ideal protein concept, the duodenal concentrations were limiting in basically the same amino acids compared to the WEB. In all three the duodenal samples arginine and histidine were the two limiting amino acids for carcass growth of lambs. A summary of results in the literature (Nimrick *et al.*, 1970, Owens *et al.*, 1973; Storm & Ørskov, 1984) also demonstrated that these amino acids have previously been reported to be limiting for growing lambs. The two most limiting amino acids reported in the literature, however (methionine and lysine), were different to those found in the present study. These difference were most likely due to different diets and species

used during trials, as well as different methods applied to assess requirements. Past research (Nimrick *et al.*, 1970, Owens *et al.*, 1973; Storm & Ørskov, 1984) has focused on limiting amino acids and ignored essential amino acids which have occurred in excess, thus causing an imbalance which may stunt growth or depress feed intake and nutrient utilisation. According to the results of the present study, isoleucine, leucine, and phenylalanine would appear to be in excess for the WEB growth of Dorper lambs (Table 3). Table 6 suggests a tendency for arginine, histidine and threonine to be in short supply in the duodenal digesta. The effects of imbalances (under and over supply) of essential amino acids on the performance of ruminant animals thus requires further investigation.

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General Conclusions

The productive capacity of any animal is highly dependent on the satisfaction of the animal's nutritional requirements. Since the production of mutton is very important in extensive and intensive sheep farming, information on the body components distribution, carcass chemical composition and the whole empty body EAA requirements are essential for effective management on any farm.

Results from the present study show that the Dorpers have a higher water consumption than the Merinos which contributes to a lower water efficiency (mℓ/kg$^{0.75}$/day) in Dorpers (285.97 ± 37.94) than in Merinos (240.67 ± 1.63)(P<0.05). Previous studies with the Dorper showed a higher water efficiency than the Merino. In this study Dorpers had a higher ADG and therefore probably had to drink more water. Dorpers had a lower water intake per kg feed intake than the Merinos (2.76 vs 3.01). A 22% difference in water intake between wool and hair sheep was also obtained by Quick & Dehority (1986) who reported values which varied from 2.3 to 2.8 ℓ/kg feed intake. The energy retention of the Dorper and Merinos did not differ significantly. The Dorper had a higher (P<0.05) nitrogen (gN/kgW$^{0.75}$/day) retention than the Merino. Due to the higher water intake and feed consumption of the Dorper, it had a higher nitrogen excretion (P<0.05) than the Merino.

The WEB weight differ significantly (P<0.05) between the two types at 40 kg live weight but not at 30 kg live weight (P>0.05) whereas the carcasses differ at both the slaughter weights (P<0.05). The Dorpers' carcass weight was significantly heavier than that of the Merino at 30 and 40 kg live weight. The same tendency could be seen from the dressing percentage (P<0.05). It is probably because the Dorper is a mutton breed and the Merino a wool type. The dressing percentages in Dorpers are higher (55.9%) than in Merinos (48.2%) because of the fleece cover of the latter. Sheep also have a proportionally generally higher external offal (21.9%) than game (15.1%) and cattle (13.3%). Internal offal percentages in sheep are lower (18.1%) than in cattle (15.8%). The Dorper's internal and external offal percentages are higher at 30 kg than at 40 kg, which shows that the Dorper's organs, head, feet and skin are well developed at an early stage, whereas the Merinos' internal offal is smilar at 30 kg and 40 kg live weight, but the external offal is higher at 40 kg, because of the heavy fleece. There were no significant differences between the Dorper's and Merinos' slaughter weight, but a difference did occur at 30 kg and 40 kg live weight, within the same breeds. The buttock and loin (representing the

hindquarter), of the Dorper has a higher (45.3%) percentage than Merino (42.5%) at 40 kg live weight (P<0.05). Therefor the Dorper has a better meat production potential than the Merino.

The Dorpers' WEB EAA patterns compared to the EAA of the feedlot diet differ significantly. The Dorpers' WEB has a similar EAA concentration as that of the wool-free and cattle species, but differs from the wool sheep, especially histidine, leucine and phenylalanine.

The duodenal samples from the two extensive grazing areas were remarkably similar even with the vegatation differences. The EAA from the duodenal digesta fell within the boundaries of the minimum and maximum values obtained in literature (Rulquin & Vérité, 1996), except for histidine and threonine from the feedlot diet. These examples illustrate the variation in duodenal amino acid composition from different duodenal samples. The intestinal amino acid profile was generally assumed constant due to the smoothing effects of microbial protein on the variation (Oldham & Tamminga, 1980).

In this study there were only two limiting amino acids, arginine and histidine, and these two are limiting for all three duodenal digesta samples according to the chemical score. According to the literature, in most cases, methionine was first limiting and lysine second limiting. The high SD-values associated with the EAA concentrations in the present study could have been partly responsible for the difference in limiting amino acids to a certain extent. The comparison of individual EAA: Lysine ratios indicates that there are differences (P<0.05) between the whole empty body of Dorpers in the present study and those of other species reported in the literature, irrespective of protein quantity. There was a tendency for the WEB to differ from the duodenal digesta, which suggested a short supply to the small intestine. With the knowledge that amino acid imbalances and toxicities may possibly occur, further research should be aimed at addressing the imbalanced EAA profiles in the duodenum in order to enchance the efficiency of utilization of absorbed amino acids to maximise growth. (D'Mello, 1994).

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