THE ESSENTIAL AMINO ACID REQUIREMENTS OF SPRINGBOK, BLESBOK AND IMPALA FOR OPTIMAL GROWTH

by

LIANA VAN ZYL

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Supervisor:

Dr AV Ferreira

Department of Animal Sciences

University of Stellenbosch

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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.

Abstract

The essential amino acid requirements of springbok, blesbok and impala for optimal growth

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Liana van Zyl

Supervisor: Dr AV Ferreira

Department: Animal Sciences

University of Stellenbosch

Degree: MScAgric

Regardless of the extensive game eradication during most of the previous century, the game farming industry in South Africa has shown dynamic growth over the past few decades. Currently the approximately 8 000 game farms have a total income of more than R850 million per annum. Although there are various game species included in these farming enterprises, three of the most important species for commercial farming and meat marketing are springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*).

Since nutrition is a key factor in the productivity of animals, any information on this subject is essential for the successful management of a game farm. However, apart from the general lack in applied research on game animals (due to the different approaches by biologists and agricultural researchers), there is also only limited information available on the nutritional requirements of game species or any of the aspects affected by nutrition.

In order to address the above shortcomings in game animal nutrition, two separate studies were conducted. The purpose of the first study was to determine the physical body component and nitrogen (N) distribution in the springbok, blesbok and impala. The chemical composition of the three-rib cut was also compared with that of the

carcass. Amino acid requirements for growth of the three game species were investigated in the second study according to the ideal protein concept. The essential amino acid (EAA) profile of the whole empty body of the three game species was compared with the EAA profile of the duodenal digesta in order to detect any imbalances for optimal growth.

The same animals were used in both studies, namely eight of each of the three game species. Characterization of the physical body composition revealed that the dressing percentages (% of body weight; % of empty body weight) for the three game species were: springbok (57.1 ± 2.4 %; 64.0 ± 2.5 %), blesbok (50.2 ± 2.1 %; 62.8 ± 1.4 %) and impala (57.4 ± 2.2 %; 65.6 ± 2.0 %). The proportional distribution of N between the carcass, external offal and internal offal was also determined. The mean carcass N concentration of the impala was higher (P<0.05) than that of the springbok and blesbok on a dry matter basis. According to the carcass chemical composition, the three game species seem to have a better potential for lean meat production (fat content of carcass 4.7-5.2 %) than domestic sheep (17-25 % fat). Male animals had a lower (P<0.05) fat and higher (P<0.05) moisture percentage in the carcass and three-rib cut than the females. The fat correlation between the three-rib cut and the carcass on both an as-is and dry matter basis was significant across species and sexes. The protein content of the same cuts did, however, not yield a significant correlation on an as-is basis, and only the protein content of the springbok three-rib cut related (P<0.05) to that in the carcass on a dry matter basis.

The second study concentrated on the nutritional requirements of springbok, blesbok and impala, and more specifically the EAA requirements. Differences (P<0.05) were found between the whole empty body EAA composition of the three game species. These differences were present whether protein quantity was included in the calculations (g AA/100 g crude protein) or not (expressed as % of lysine). The chemical scores indicated that the four most limiting amino acids (three for impala) in the duodenal digesta for whole empty body growth were: arginine, histidine, threonine and methionine (springbok); methionine, arginine, histidine and lysine (blesbok); and methionine, histidine and arginine (impala). Further disproportion of the amino acids in the duodenal digesta was present in excess levels of isoleucine (blesbok) and lysine, valine, leucine, threonine, isoleucine and phenylalanine

(impala). The EAA:Lysine ratios of the whole empty body indicated a similar trend for the three game species.

Opsomming

Die essensiële aminosuurbenodighede van springbok, blesbok en rooibok vir optimale groei

deur

Liana van Zyl

Studieleier: Dr. A.V. Ferreira

Departement: Veekundige Wetenskappe

Universiteit van Stellenbosch

Graad: MScAgric

Ten spyte van die feit dat wild grootskaals uitgedun is gedurende die vorige eeu, het die wildboerdery-bedryf in Suid-Afrika oor die laaste paar dekades dinamiese groei getoon. Die totale inkomste van die ongeveer 8000 wildsplase beloop tans meer as R850 miljoen per jaar. Alhoewel daar verskeie wildspesies is wat by hierdie tipe boerdery ingesluit word, is die springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) en rooibok (*Aepyceros melampus*) van die belangrikste spesies vir kommersiële boerdery en vleisbemarking.

Voeding is 'n sleutelfaktor in die produktiwitieit van diere en daarom is enige inligting oor hierdie onderwerp noodsaaklik vir die suksesvolle bestuur van 'n wildsplaas. Afgesien van die algemene tekort aan toegepaste navorsing op wilde diere (as gevolg van die verskillende benaderings van bioloë en landboukundige navorsers), is daar ook slegs beperkte inligting beskikbaar oor die voedingsbehoeftes van wilde dierspesies of enige van die faktore wat deur voeding beïnvloed word.

In 'n poging om bogenoemde tekortkominge in die voeding van wilde diere aan te spreek, is daar twee aparte studies uitgevoer. Die doel van die eerste studie was om die fisiese liggaamsamestelling en die stikstof (N) verspreiding in die springbok, blesbok en rooibok te bepaal. Die chemiese samestelling van die drie-ribsnit is ook

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met díe van die karkas vergelyk. In die tweede studie is ondersoek ingestel na die aminosuurbehoeftes van die drie wildspesies deur van die ideale proteïen konsep gebruik te maak. Die bepaling van die essensiële aminosuurprofiel van die totale leë liggaam van die onderskeie drie wildspesies is bepaal en met die essensiële aminosuurprofiel van die duodenale-inhoud vergelyk, ten einde enige wanbalans vir optimale groei vas te stel.

Dieselfde diere is in beide studies gebruik, naamlik ag springbokke, blesbokke en rooibokke. 'n Beskrywing van die fisiese liggaamsamestelling het aangetoon dat die uitslagpersentasies (% van liggaamsmassa; % van leë liggaamsmassa) van die drie wildspesies as volg was: springbok (57.1 ± 2.4 %; 64.0 ± 2.5 %), blesbok (50.2 ± 2.1 %; 62.8 ± 1.4 %) en rooibok (57.4 ± 2.2 %; 65.6 ± 2.0 %). Die proporsionele verspreiding van N in die karkas, uitwendige afval en inwendige afval is ook bepaal. Die gemiddelde N konsentrasie in die karkas van die rooibok was hoër (P<0.05) as díe van die springbok en blesbok op 'n droë materiaal basis. Dit blyk vanaf die chemiese samestelling van die karkas dat die drie wildspesies 'n groter potensiaal het vir die produksie van maer vleis (vet-inhoud van karkas 4.7-5.2 %) as skape (17-25 % vet). Manlike diere het 'n laer (P<0.05) vetpersentasie en 'n hoër (P<0.05) vogpersentasie in beide die karkas en die drie-ribsnit teenoor die vroulike diere gehad. 'n Betekenisvolle korrelasie is tussen die persentasie vet in die drie-ribsnit en die karkas van al drie wildspesies en vir beide geslagte gevind, op beide 'n nat en droë materiaal basis. Die proteïeninhoud van dieselfde snitte was egter nie op 'n nat basis betekenisvol gekorreleerd nie, en slegs die proteïen-inhoud van die springbok se drie-ribsnit het verband gehou (P<0.05) met díe in die karkas op 'n droë materiaal basis.

Die klem van die tweede studie was op die voedingsbehoeftes van springbok, blesbok en rooibok, en meer spesifiek die essensiële aminosuurbenodighede. Daar is verskille (P<0.05) tussen die totale leë liggaam essensiële aminosuursamestelling van die drie wildspesies gevind. Hierdie verskille was aanwesig afgesien daarvan of die hoeveelheid proteïen in berekening gebring is (g aminosure /100 g ruproteïen) of nie (uitgedruk as % van lisien). Volgens die chemiese tellings was die vier mees beperkende aminosure (drie vir rooibok) in die duodenale-inhoud vir totale leë liggaamsgroei as volg: arginien, histidien, treonien en metionien (springbok); metionien, arginien, histidien en lisien (blesbok); en metionien, histidien en arginien

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(rooibok). Verdere wanbalanse in die aminosure van die duodenale-inhoud was aanwesig in die oormaat isoleusien (blesbok) en lisien, valien, leusien, treonien, isoleusien en fenielalanien (rooibok). Die verhouding van die essensiële aminosure tot lisien van die totale leë liggaam het by al drie wildspesies dieselfde tendens getoon.

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List of abbreviations

AA	- amino acid
CP	- crude protein
DAA	- dispensable amino acids
Dd	- duodenal digesta
EAA(s)	- essential amino acid(s)
GIT	- gastro-intestinal tract
HCl	- hydrogen chloride
IAA	- indispensable amino acids
N	- nitrogen
NAA	- non-essential amino acids
RDP	- rumen degradable protein
SD	- standard deviation
UDP	- rumen undegradable protein

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CHAPTER 3
AMINO ACID REQUIREMENTS OF SPRINGBOK (Antidorcas marsupialis), BLESBOK (Damaliscus dorcas phillipsi) AND IMPALA (Aepyceros melampus) ESTIMATED BY THE WHOLE EMPTY BODY ESSENTIAL AMINO ACID PROFILE FOR OPTIMAL GROWTH

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Chapter 1

General Introduction

Background

Africa is known as the continent of mammals and its mammal fauna is unsurpassed in variety and biomass. Until the end of the 1800's, large numbers and aggregations of game were a common sight in southern Africa. Sporadic appearances of springbok "treks" occurred on such a scale that a stroke of land "over a hundred miles long by fifteen miles wide, was covered by the trekbokken moving in an unbroken mass, giving the veld a whitish tint, as if covered with a light fall of snow" (Cronwright-Schreiner, 1925).

At the end of the nineteenth century in southern Africa, a devastating epizootic of rinderpest destroyed the larger part of the population of free-living artiodactyls, together with most cattle. As a consequence, it was discovered that in areas where there were fewer free-living (wild) animals, tsetse flies (*Glosina* spp.), the greatest enemy of the domestic cattle and colonial farmer, also declined. The solution was simple: eliminate indigenous mammals so as to eradicate the tsetse fly and, at the same time, open up land for settlement and farming. These "game eradication operations" were quite severe and only ended in 1980 in the valley of the Zambezi River (Féron, 1995). Livestock farming expanded at the expense of wild/game animals, because of the high commercial value of cattle and sheep at the time (Potgieter, 2001).

A peripetia in game animal numbers started around 1970 in South Africa. At present, wildlife expertise claim that South Africa has more wildlife than ever before in it's history. The reason for this change in numbers has been much debated. Today it is accepted that the implementation of a basic principle such as the sustainable use of wildlife, is the main reason for South Africa's conservation achievements. This principle caused the commercial value of wildlife to rise in such a way that it now

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exceeds that of livestock (Potgieter, 2001). The major driving force behind the sustainable use of wildlife is undoubtedly game ranching or game farming.

Game farming

What is game farming?

In short, game farming as an enterprise can be defined as "the economic use of game within the farm confines" (Conroy & Gaigher, 1982). Game farming projects are on a smaller scale than game ranching and more often than not, the game animals graze inside fenced areas (Ledger *et al.*, 1967).

As exemplified by practice in South Africa, game farming embrace many different types of exploitation of varying intensities. A few farms in South Africa are exclusively for game, but more often game animals co-exist with domestic stock. There are also farmers who tolerate or actively encourage game animals on their properties purely for aesthetic reasons; others have more commercial interests (Luxmoore, 1985).

For these systems to work, there must be potential benefits for both the farmers and the game animals. Game farming can benefit the human population by providing meat or income from otherwise unproductive land. Wildlife benefit from the species and habitat conservation that result from game farming (Luxmoore, 1985).

Increases in game farming

The expansion in game farming already started about three decades ago, before the financial viability of wildlife production was proved. It has been suggested that the rise in popularity of game farming was caused primarily by aesthetic rather than economic motives. Farmers like having game animals on their properties and are proud to boast a healthy game population (Luxmoore, 1985). Colvin (1984), however, mentioned that the importance of a potential economic return should not be

underestimated in affecting a farmer's decision to introduce and/or preserve game animals.

Apart from the aesthetic and economic reasons, an increasing number of farmers are also including game animals in their traditional farming activities because of the following factors:

- the importation of subsidized meat, which has a negative effect on the South African meat industry;
- livestock theft;
- the rise in game auction prices, because of the increase in game farms (Kieser, 2001);
- the increase in problem animals;
- the high fuel prices;
- the difficult labour situation (Botha, 2001);
- a greater possibility of secondary income, independent of animal production (ecotourism and accommodation fees); and
- the possible income from foreign currency through overseas hunters and tourists (Smit, 2000).

In 1990 it was estimated that approximately eight million hectares were utilized for game farming in South Africa (Jansen van Rensburg, 1992). Currently game farms extend over an area of 10.4 million hectares, in contrast to the combined 3.3 million hectares of all South Africa's National Parks (Potgieter, 2001). The number of game farms also increased from 4000 in 1990 (Bezuidenhout, 1999) to between 5000 and 6000 farms in 2000 (Kieser, 2001). The increase in game farms is calculated at 6.75 % per annum, while the total area covered by these farms increases at 7.25 % per annum (Potgieter, 2001).

Looking at the above statistics, the commercial use of wildlife is presently the fastest growing agricultural industry (Kieser, 2001). It is, however, true that this tendency cannot continue indefinitely. Much concern has been pronounced about what will happen when the increasing settlement of new game farms even out and the demand for game animals decrease. Although there is no easy answer to this, it can be

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assumed that competition in the game industry will increase. Game farmers must, therefore, ensure that they sustain a high level of economical and ecological management for future success. As mentioned before, the sustainable ecological utilization will play a major role in obtaining this (Smit, 2000).

Economic utilization of wildlife

There are four main ways to generate income from game animals:
   a) cropping and sale of the game meat;
   b) hunting by paying clients (local and foreign);
   c) live animal sales to other game farms; and
   d) game viewing, where facilities are offered to visitors to view or photograph the game animals.

Hunting can be subdivided further into safari/trophy hunting and recreational/biltong hunting. With trophy hunting, the client is usually from overseas and pays for shooting large, mature animals and keeps the trophy (horns, skull, skin, etc.). On the other hand, it is usually South Africans who do the biltong hunting. In this case the client shoots surplus stock, primarily for meat for his own consumption (Luxmoore, 1985).

According to Jansen van Rensburg (1992), all the marketing possibilities from wildlife can be divided into two groups, namely utilization and non-utilization possibilities. Trophy hunting, biltong hunting, bow hunting, live animal sales, sell of game meat and taxidermy all belong to the first group. The non-utilization possibilities consist of game viewing, game farm holidays, hiking trails and photography, hunting schools and venues for seminars.

Experts estimate the gross income of the wildlife industry in South Africa to be between R850-100 million per annum (Kieser, 2001). The contribution of biltong hunters is about 67 %, trophy hunters 20 %, live sale of game animals 12.5 % and sale of game meat 0.5 % (Potgieter, 2001). Currently, game animals fetch record prices at game auctions, with a mean countrywide increase of 15 % per annum for the period 1992-1999 (Smit, 2000).

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Countrywide, there are now approximately 140 000 biltong hunters, compared to just 50 000 ten years ago (Bezuidenhout, 1999). About 5 000 overseas hunters visit South Africa per annum, of which more or less 65 % are from the United States of America. In 2000, at least 23 500 game animals were hunted by overseas hunters (Botha, 2001). There are three main communication channels used by game farmers to attract local and overseas hunters. Word of mouth is the most important way for both overseas and local hunters. The second most important channel for overseas hunters is by professional hunters and agents. However, for local hunters advertisements in brochures and magazines are the second most important communication channel (third most important for overseas hunters) (Botha, 2000).

Game animals vs. domestic livestock

Cattle, sheep, goats and perhaps donkeys first reached southern Africa from the north more than 2000 years ago. In this region multispecies pastoral and agro-pastoral systems developed spontaneously, combining indigenous livestock production with subsistence hunting of wild fauna for meat, skins and ivory. Over centuries this has been the most ecologically and economically sound land use systems (Nel, 1993).

Subsequent European colonization of the subcontinent led to the introduction of new livestock breeds. Their single species production systems resulted in the simplification and reduction of diversity (Féron, 1995), displacing the indigenous multispecies systems. However, since the late 1950's, an increasing number of commercial ranches have incorporated wild animals in their production systems (Nel, 1993).

It is true that the indigenous game species cannot compete with domestic livestock in terms of productivity under intensive farming. The main reason for this difference is because domestic livestock have, over a long period of time, been selected for milk, meat or wool production (Skinner, 1984). If these domesticated species are such efficient producers, the question arises why one would even bother with game farming.

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Several reasons can be brought forward to answer this question. At first, it must be noted that wild animal species are the products of millions of years of natural selection. Through this process the indigenous game animals are perfectly adapted to their environment (Davies, 1991) and developed inherent resistance to diseases, parasites and poisonous plants (Skinner, 1984). These animals can also travel long distances looking for food and still have little energy losses (Smit, 2000).

In terms of veld utilization, cattle and sheep predominantly select grass species, while game animals have a much broader utilization spectrum (Bothma, 1989). Antelope, in particular, will also feed on forbs, bushes and trees in addition to grass (Spinage, 1986). This, however, does not mean that the different animal species utilize totally different plant species. Bothma (1989) confirmed that there are ample overlapping in game and domestic livestock's selection of grass and shrub species, as well as in habitat selection and grazing height. Spinage (1986) observed that antelope have less effect on the habitat than does the same density of cattle. Antelope do not create so much trampling and erosion, because they are more spread out when they feed and they follow narrow paths to watering points.

Looking at productivity, game animals do have a few advantages compared to domestic livestock. Game animals generally grow more quickly than livestock and attain 75 % or more of their mature mass at a relatively young age. Thus, young game animals can be cropped relatively early and their meat can be marketed (Bothma, 1989). In terms of the dressing percentage, most game species have a carcass yield of between 55 and 61 %. Cattle with a similar carcass yield would contain about 25 % fat (Conroy & Gaigher, 1982). In game animals, however, the fat content of the meat is between 1 and 2 % (Bothma, 1989). The gradual deterioration of natural veld, because of prolonged over-utilization and climatologic droughts, causes reduced production of livestock. Game animals are, however, adapted to these environmental constraints and could be more productive under these circumstances (Smit, 2000).

Taking all the above-mentioned factors into consideration, game farming cannot/should not compete with livestock farming. The objective must rather be to complement the productivity of livestock with that of game animals and thereby increasing the productivity per hectare (Skinner, 1984). In the more arid regions of

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South Africa and Namibia, farmers realised that game farming can be an excellent alternative for the precariousness of the livestock industry (Claassen, 2000). On the other hand, the idea of multispecies land utilization is not a new way of animal production. This system is rather reappearing on the arid and semi-arid savannas in southern and central Africa (Nel, 1993).

Game farming can also be a profitable enterprise on its own. In the more marginal livestock areas of South Africa, farming with only game animals has become very popular. An interesting fact is that in many of these areas, game has a more economical ratio of profit to land value than livestock (Gouws, 1995).

Problems with game farming

Although the game farming industry is currently experiencing enormous growth and although there are many advantages with mixed farming systems, there have been (and still are) problems with this industry.

Until 1990 a considerable amount of game meat was exported overseas, mainly to Europe. The largest company, Kovisko, hunted 60 000-70 000 springbok per annum on game farms and most of this meat was exported. In 1990, Germany (the largest importer of springbok meat from South Africa) announced that only deboned meat (free of foot-and-mouth disease in the marrow) would be imported in the future. This extra processing of meat increased its price almost threefold (Kruger, 1991).

There are two main factors responsible for the decrease in the demand of South African game meat. First, the embargo in western Europe on game meat from eastern Europe, since the nuclear disaster in Russia, was abolished (Coetsee, 1991). After West and East Germany were unified, it was much cheaper to import game from eastern Europe (Kruger, 1991). Secondly, the western Europeans are more used to the traditional roe and red deer and, therefore, the South African game meat was only an alternative (Coetsee, 1991). Gouws (1995) mentioned that in 1995, only one of the five companies involved in game meat exports was still in business and would export about 160 tons of deboned meat.

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A logic alternative to game meat exports would be to sell the meat to local people. Unfortunately, the local demand for game meat tends to stay small (Potgieter, 2001), in spite of the fact that game meat is a natural product that is not contaminated by antibiotics, growth stimulants and dipping fluids, and can be included in a healthy diet (because of the low fat content) (Eloff, 2001). Farmers sell their game meat mainly to individuals, butcheries, restaurants and hotels in the form of whole carcasses or as cuts (Jansen van Rensburg, 1992). A questionnaire sent out by Jansen van Rensburg (1992) showed that only 40 % of all the participants have eaten game meat in a form other than biltong. It also appears that lack of information exits among retail butchers regarding the availability or possible resources of game meat (Van Zyl, 1990). Since 425 000 game animals have to be cropped annually to allow enough food for the remaining animals (Potgieter, 2001), clearly there should not be a shortage in the supply of game meat. The only thing that is lacking, however, is an effective marketing strategy for the sell of game meat. Jansen van Rensburg (1992) suggested that a co-ordinative body for game meat production and marketing should be founded to satisfy this need.

Other problems with the game meat industry are: the high transport costs from remote areas; the discontinuous supply of meat for only three to four months of the year; and the ignorance of consumers about the preparation of game meat (Van Zyl, 1990).

Looking at game farming in general, it appears to have benefited the conservation of wild ungulates in South Africa. In future, however, possible adverse effects might occur from translocation, genetic mixing, loss of local adaptation and increased exposure to diseases of domestic livestock (Luxmoore, 1985).

According to Du Plessis (2000), game farming is also expensive compared to cattle farming. Any income derived from hunting only realises after a long time and the game animals that are utilizable have a slow increase of 20-25 % per annum. Although management costs are usually low with game farming, the management is generally more complex (Davies, 1991).

Species suitable for game farming

Nineteen species of wild ungulates (out of a total fauna of 44) are important on farmed land in South Africa, in terms of numbers, distribution, or both (Bigalke, 1974). Since antelope are the most suitable for farming, they have logically attracted the most attention. Proposals to try and domesticate indigenous wild ruminants were made as early as 1948, with the prospects of the buffalo (*Syncerus caffer*) and the eland (*Taurotragus oryx*) being discussed (Skinner, 1973).

There are certain antelope species that are no longer strictly feral, because the farmer can exercise lawful ownership by enclosing them in ordinary paddocks. Two of these species are the springbok (*Antidorcas marsupialis*) and the blesbok (*Damaliscus dorcas phillipsi*). The browsing antelope that received some interest are the eland, the impala (*Aepyceros melampus*) and the kudu (*Tragelaphus strepiceros*). However, the last three species have to be enclosed by 2,5 m fences (Skinner, 1973). Gemsbok (*Oryx gazella*), eland, blue wildebeest (*Connochaetes taurinus*) and hartebeest (*Alcelaphus buselaphus*) are also important, but mainly on large holdings where extensive pastoral farming is practised (Bigalke, 1974).

There are, however, different factors that need to be considered before a decision is made as to which game species are most suitable for a certain game farm. The predominant habitat on the farm is the most important factor to consider, because only game species adapted to that specific habitat will be suitable. Species or subspecies that can hybridise should not be kept on the same farm as this can result in the loss of genetic integrity. The main objective of the game farm (biltong hunting, trophy hunting, live animal sales or ecotourism) should play an important part in deciding which game species to purchase. Both the purchasing costs and the requirements for game fences are two major expenditures and, therefore, needs to be considered carefully (Smit, 2000).

Of all the above-mentioned species, springbok, blesbok and impala are the three dominant farm species (Bigalke, 1974). In a study by Jansen van Rensburg (1992), it was shown that of all the different antelope species cropped for meat marketing, the four most important species were springbok, kudu, impala and blesbok. Local or

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biltong hunters usually prefer these four game species because they are still affordable (Jooste, 2001).

Since only springbok, blesbok and impala were used for the studies in the present study, the discussion below will concentrate on these three gregarious game species.

Springbok

Springbok are mixed feeders, which seem to use grasses mainly in the rainy season and shrubs in the dry season. They prefer a habitat of open plains and sparse savannah (Skinner *et al.*, 1971). These animals are able to move hundreds of kilometres in extensive areas in search of green veld produced by scattered rains. The restriction of these migrations in smaller areas can create a problem that demands more intensive management (Bothma, 1989). Springbok drink water where it is available, but have the ability to survive in the absence of water (Bigalke, 1974). In general, springbok do not compete significantly with domestic stock for food, but because of their natural range of distribution, there is potential competition with sheep (Bothma, 1989).

Populations of springbok have the ability to recover quickly after a drop in numbers during protracted droughts by means of opportunistic breeding. The springbok ram can mate throughout the year and the ewe can be stimulated to breed again by cropping the lamb early or by removing it from the ewe (Bothma, 1989).

Blesbok

Blesbok are grazers of open grassland and are water dependent (Bigalke, 1974). They are partial to sprouting grasses that appear after a burn and will move onto burnt areas even before the green flush is apparent (Skinner & Smithers, 1990). The blesbok's ability to survive on the sour grassveld during the dry winter months makes it a suitable game species to ranch in the eastern Highveld of South Africa, in combination with livestock (Bothma, 1989).

Impala

Impala are by preference grass-eaters, although they also utilize a wide variety of other plants (intermediate mixed feeder) (Stewart, 1971). They inhabit open woodland and prefer firebreaks in the early summer and thorn-tree veld in the dry season

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(Bothma, 1989). Impala are dependent on the availability of drinking water. However, under certain circumstances, they can obtain their moisture requirements from succulent plants (Skinner & Smithers, 1990).

Impala will compete seriously with cattle for food only at the beginning of the growing season. After that, impala pay more attention to broad-leaved plants to satisfy their protein and energy requirements. This results in little competition with the mainly grass diet of cattle (Bothma, 1989).

Shortcomings identified in game farming

The key to a successful farming enterprise is the productivity of the animals or crops being farmed. However, productivity is not a simple concept, but an integration of both intrinsic (e.g. animal) and extrinsic (e.g. management) factors.

The productive capacity of any animal depends on its growth rate, its reproductive rate and its mortality. In game animals the reproductive rate is not very high but stable, even under adverse conditions (Fairall, 1984). Growth of game animals are fast – although not as rapid as in improved domestic stock – and in general, game animals mature early (Fairall, 1976; Penzhorn, 1978). In natural populations mortality is usually confounded by predation, but even then a surplus production is possible (Fairall, 1969).

Looking at the extrinsic factors, a basic but very important way of influencing animal productivity is by means of *nutrition*. If animal nutrition can be optimised, animal growth, reproduction and products (e.g. meat, milk, wool) can be maximized, resulting in higher profits for the farmer. For example, if maximum growth of young females up to puberty can be ensured through management, this rapid growth should result in precarious sexual development and earlier breeding, as in domestic livestock (Skinner, 1984). Where eland were exposed to poor weather and nutrition, their growth was negatively affected and the asymptote for growth (best stage for cropping and meat production) was delayed by several months (Jeffery & Hanks, 1981).

The nutritional requirements of domestic livestock have been determined in great detail and only small refinements are being made under different circumstances. In game animals, however, nutritional studies have been limited. Most of these studies concentrated on: ruminal and fecal analysis to determine the foraging strategy and plant species selected (McAllister & Bornman, 1972; Liversidge, 1972; Novellie, 1978; Kilian & Fairall, 1983; Klein & Fairall, 1986); the apparent digestibility of dietary components (Voster, 1976); determination of rumen function (Van Hoven, 1983); assessment of the diet quality (Wrench *et al.*, 1997); and the influence of nutritional status on physiological indices (Knox *et al.*, 1991). According to Conroy & Gaigher (1982), the different approaches followed by biologists on the one hand, and agricultural researchers on the other, have hampered applied research on game animals in South Africa. They also mentioned that apart from future research on genetic manipulation, population dynamics and disease control, further studies on the nutritional requirements of game should be rewarding.

Considering the importance of nutrition in productivity, it is clear that there are still a few gaps to be filled in game animal nutrition before this can be used as an effective management tool in game farming. Looking at the current market for game, more than two thirds (67.5 %) of the total income of the game industry is derived from game meat (biltong hunters and sales of game meat) (Potgieter, 2001). Therefore, the production of meat should be optimised to ensure its sustainability and definitely deserve further research.

To address the above-mentioned shortcomings, the aim of this project was to focus the attention on certain aspects of game animal nutrition.

i.   The body component distribution and chemical composition of the carcass are no new concepts in domestic livestock, but detailed studies in game animals are generally lacking. Since nutrition has an effect on measurements such as live weight, carcass weight, carcass yield and degree of fatness (Ledger *et al.*, 1967), this information is essential for further nutritional studies.

ii.   Besides energy, protein is one of the most important nutrients in the animal diet. For optimal growth production, it is essential that the protein available to the animal meet the protein requirement of the animal body.

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Body component distribution and carcass chemical composition

The distribution of body components mainly refers to the weights of the different components (carcass, external offal, internal offal) and the percentage of the live weight that each composes. According to Von la Chevallerie (1970), the meat production potential of an animal can be inferred from the carcass weight, when sufficient data is available on carcass conformation and composition. Although the carcass is the most important body component for human consumption, the edible offal components (heart, liver, kidneys, spleen, brain) are also useful in many areas of the world. Therefore, in evaluating the suitability of game animals for meat production, attention should also be paid to their total yield of usable products (Riley *et al.*, 1989).

Body composition is dynamic and changes continuously in response to environmental factors. Knowledge of the chemical composition of the carcass (protein, fat, moisture, ash) is, therefore, valuable in any growth and feeding study for proper evaluation of responses to treatments (Kock *et al.*, 1995). In meat production it is also of primary importance to establish the percentage of the carcass weight that consists of edible tissues, i.e. meat and fat, and non-edible tissues such as bone and sinews (Von la Chevallerie, 1970). Any information on the carcass chemical composition of a particular animal can also assist in the more efficient pricing of the carcass and the potential markets to be targeted (Owen & Norman, 1977).

Protein/amino acid requirements

Importance of protein for optimal production

Proteins are the most abundant of all cellular components – on a fat and moisture free basis the animal body consist of 80 % protein and 20 % minerals. Proteins itself are composed of 20-25 different amino acids, but only 20 are important in body protein and protein in animal products (Van der Merwe & Smith, 1991).

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In general, proteins or amino acids are necessary for: the synthesis of body tissues (muscle, organs, hair or wool, etc.); the synthesis of enzymes and hormones; to support maintenance processes; and to synthesize glucose for energy (Oldham, 1993). A continuous supply of dietary protein must be available to the animal for all these functions. In terms of animal production, muscle, skin (including associated wool or fibre) and the mammary gland are the most important tissues of the body (Harris & Lobley, 1991). Since these tissues are the major sites of nutrient (energy and protein) retention in the animal body, protein itself plays an important part in animal production.

Protein metabolism in ruminants

In non-ruminant (monogastric) animal species, the available protein in the diet is hydrolysed in the digestive tract by enzymes secreted by the stomach, pancreas and small intestine. The digestion products (peptides and amino acids) are absorbed mainly in the small intestine. However, a certain amount of dietary material (structural carbohydrates and fibre) are resistant to digestion by these enzymes, but it might be broken down by microbes in the ceacum (Van der Merwe & Smith, 1991).

Ruminants have a more complex digestive tract, because the stomach consist of four parts, namely the rumen, reticulum, omasum and abomasum. The combination of all these parts enables ruminants to utilize a wider variety of plant material than non-ruminants.

Bacteria and protozoa in the reticulo-rumen produce the necessary enzymes to digest the structural carbohydrates and fibre in the diet. Hereby they provide volatile fatty acids for the energy requirements of the ruminant. However, at the same time, a certain part of the dietary protein is hydrolysed to peptides and amino acids by these rumen micro-organisms. Some amino acids are degraded further into organic acids, ammonia and carbon dioxide. All these degradation products are then used by the micro-organisms to synthesize microbial protein. The part of the dietary protein that is degraded and digested is called the rumen degradable protein (RDP). The rest of the dietary protein, the rumen undegradable protein (UDP) or bypass protein, flows to the duodenum with the microbial protein (Erasmus, 1992).

Thus, the protein that arrive in the small intestine originate from different sources. Generally, the largest fraction (60-85 %) consists of microbial protein synthesized during carbohydrate fermentation in the rumen. The second fraction, of varying proportion, consists of undegraded dietary protein. The relative sizes of these two fractions depend on the rumen degradability of the dietary protein. A third fraction derives from endogenous protein contained in the enzymes secreted and the sloughed epithelial cells from the digestive tract (Ørskov *et al.*, 1986). With normal diets, endogenous protein-N may constitute 9-12 % of non-ammonia-N passing to the small intestine (NRC, 2000).

Since the microbial protein constitutes a major portion of the nitrogen-containing compounds reaching the small intestine, numerous studies have been undertaken to qualify and quantify this fraction. One aspect of these studies was to determine the influence of changes in the diet on the microbial protein. Meyer *et al.* (1967) and Bergen *et al.* (1968) found no differences in the bulk amino acid composition and protein quality of the microbial protein in sheep and cows fed different diets. However, Harrison *et al.* (1973) and Rulquin & Vérité (1993) showed that a change in the diet could significantly alter the relative proportions of individual amino acids in the duodenal digesta. It was also found that the quantity of bacterial nitrogen entering the duodenum changed when different diets were fed.

Absorption of amino acids takes place in the small intestine and subsequently they are transported through the intestinal wall and into the portal blood. Although the absorptive activities are not uniformly apportioned throughout the length of the small intestine, the ileum is the dominant site of amino acid absorption in sheep (Phillips *et al.*, 1979). Williams (1969) found that the order of absorption of individual amino acids varied with intestinal location, because of the differing affinities for the transport systems at each site. Apart from individual amino acids, small peptides are also absorbed from the mucosa of the intestine (Webb & Bergman, 1991). Direct comparisons showed that peptides are absorbed more rapidly from the intestinal lumen than are amino acids (Burston *et al.*, 1972).

It has also been shown that the proportional disappearance of essential amino acids is greater than that of non-essential amino acids from the intestine of sheep (Christiansen & Webb, 1990a), preruminant calves (Guilloteau *et al.*, 1986) and cattle (Christiansen & Webb, 1990b). In studies with non-ruminant species, the ratios and amounts of amino acids absorbed have been compared with amino acid intake. Such direct comparisons are not possible with ruminants, because of the varying degree of protein hydrolyses in the rumen and the variable amount of ruminal microbial protein synthesized (Hume *et al.*, 1972).

Qualitative and quantitative aspects of amino acids

Classification of amino acids
The twenty amino acids that constitute protein can be divided into the nutritional classifications of essential/indispensable amino acids (EAA or IAA), semi-essential/conditionally indispensable amino acids and non-essential/dispensable amino acids (NAA or DAA). Diets can often be evaluated based on a) the relative concentrations of these three categories of amino acids and b) their abilities to stimulate different physiological responses, such as rate of growth, tissue amino acid concentration, etc. (Mercer *et al.*, 1989).

There are nine amino acids that cannot be synthesized by most animal species and, therefore, a continuous supply of these amino acids from the diet is essential. The nine EAAs are: lysine, methionine, threonine, tryptophan, leucine, isoleucine, valine, histidine and phenylalanine (Boisen *et al.*, 2000). Arginine, cystine and tyrosine are considered semi-essential amino acids. Although arginine is an essential amino acid for many animal species (e.g. fish and birds), mammals can synthesize it in the urea cycle. On the other hand, most arginine produced is broken down and some animals thus need a dietary supply. Cystine and tyrosine are also semi-essential because they can only be synthesized by animals from methionine and phenylalanine respectively (Boisen, *et al.*, 2000). The remaining eight amino acids (including alanine, asparagine, aspartic acid, glutamine, glutamic acid, serine, glysine and proline) can all be synthesized from metabolites produced during the oxidation of glucose (Boisen *et al.*, 2000).

EAA/NAA-ratio

Considering the classification of amino acids, protein quality is invariably a function of the concentrations and ratios of its constituent amino acids. Therefore, proteins that dispose of a high EAA/NAA ratio will have a high biological value. Another important consideration in the assessment of biological value is the distribution of amino acids within the EAA and NAA classifications. Proteins can have a reasonable EAA/NAA ratio, but be deficient in one or more EAA and thereby still have a poor biological value (Mercer *et al.*, 1989).

Imbalances, antagonisms and toxicities

If the quantities of essential and non-essential amino acids that are consumed, or the patterns in which it is absorbed, are disproportionate to those required for optimum tissue utilization, adverse effects might arise. These deleterious effects range from depressions in growth, food intake and nutrient utilization, to acute neurological aberrations and even death (D'Mello, 1994).

Two types of amino acid imbalances can be recognized: 1) that caused by the addition of a relatively small quantity of an amino acid to a low protein diet and 2) that precipitated by an incomplete mixture of amino acids (D'Mello, 1994). Amino acid antagonisms occur between structurally similar amino acids and result in negative interactions. For example, excess leucine depresses the utilization of the other two branched-chain amino acids (isoleucine and valine), even when they are not limiting in the diet (D'Mello & Lewis, 1970). Toxic effects of amino acids may occur when excess quantities of individual amino acids are fed. The unique effects depend on the particular structural and/or metabolic features of the amino acid. These effects range from acute growth depressions to profound lesions in tissues and organs (D'Mello, 1994).

Most studies on the effects of amino acid imbalances in farm livestock concentrated on poultry and pigs. Ruminants are usually less susceptible to the effects of imbalances because of the extensive microbial metabolism of amino acids in the rumen. However, when microbial protein production is limited or when amino acid requirements are high (during growth, pregnancy, lactation), ruminally microbial protein may not meet the needs of the host animal. This shortage in amino acids may

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result in less optimal production, unless amino acids of non-microbial origin are supplied (Merchen & Titgemeyer, 1992).

Methods of estimating amino acid requirements

There have been a number of approaches to determine the amino acid requirements of animals. The first attempts were made by analysing the *amino acid composition of the diets* that were found to give satisfactory performance (Fuller, 1994). Hereby a single point (specific to the amino acid concentration in the diet) is identified at which some response is maximized or optimised (Owens & Pettigrew, 1989).

The second method of estimating the amino acid requirements was derived from the observation that proteins of high nutritional value for growing animals tended to have amino acid compositions comparable to the animals' bodies. This led to the concept that the amino acid requirements for a growing animal are determined primarily by the needs for *body protein accretion* (Fuller, 1994).

In more recent years, quantitative estimates of dietary amino acid requirement have generally made use of the dose-response and the factorial methods. In *dose-response experiments*, the requirement of an amino acid is deduced from the animal's response to graded intakes of that particular amino acid. With these experiments it is supposed that there are adequate intake of every other amino acid and of all the other nutrients. The problem with this approach is that separate experiments must be made for each amino acid, with similar animals under similar conditions (Fuller, 1994).

The *factorial method* treats the dietary amino acid requirement as the sum of the requirements in all the physiological components. The strength of the approach is that it also takes into account the need for maintenance, the need for the deposition of productive proteins and the efficiency with which absorbed amino acids are used to meet these needs (Chen & Ørskov, 1994). Although the requirements for all the amino acids can be estimated simultaneously and can be applied to animal populations with different production potentials, the factorial approach also has some limitations. Information on the following must be available before the factorial method can be used: the efficiency of absorption of amino acids from the intestine;

the net loss of endogenous amino acids from the gut; the efficiency with which the amino acids is incorporated into tissues; and the extend of the obligatory catabolism of amino acids by the animal (Buttery & Foulds, 1985).

Referring back to the second method mentioned above, this estimation of the amino acid requirement from body protein accretion led to a new concept that is frequently used in present-day amino acid requirement studies. This *ideal protein concept* and the derivation of ideal amino acids patterns will be discussed in more detail.

The ideal protein concept

According to Cole & Van Lunen (1994), the most important single factor affecting the efficiency of protein utilization for production of meat and other products is the dietary balance of amino acids. Therefore, 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 of utilization (Chen & Ørskov, 1994).

In short, this concept basically involves the determination of the amino acid composition of the carcass or whole body (the ideal protein) and uses this as a guideline for the amino acid requirements (the ideal amino acid pattern) of the animal. The quantity of amino acids in the ideal protein is then compared to the composition and/or quantity of amino acids in the diet/duodenal digesta. Hereby a chemical score can be determined to identify any amino acids of which the supply does not meet the demand or requirement. The essential amino acid composition of the different protein components can also be expressed as a percentage of a single amino acid before it is compared. This method allows comparisons to be made regardless of the protein quantity of the components. Although various amino acids may be suitable as a standard for calculating requirements (Williams *et al.*, 1954), lysine is selected for three primary reasons:

1) unlike several other amino acids, absorbed lysine is used only for protein accretion (Williams *et al.*, 1954; Williams & Hewitt, 1979; Baker & Han, 1994);

2) its analysis in feedstuffs is relatively simple and straight-forward (Baker & Han, 1994);

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3) and together with methionine, lysine seems to be limiting in most ruminant diets (Storm & Ørskov, 1984; Cole & Van Lunen, 1994).

Already in 1950, Mitchell suggested that the amino acid requirements for growth in mammals might be determined from the pattern of amino acids in body tissues. Subsequently, Williams *et al.* (1954) found good agreement between the carcass amino acid composition and empirically based estimates of dietary amino acid requirements for growth in the chicken, rat and pig. In recent years much attention has been given to the development of an ideal protein in pigs (Moughan & Smith, 1987; Wang & Fuller, 1989; Chung & Baker, 1992). Only a few studies, however, focussed on an ideal protein for ruminants (Cole & Van Lunen, 1994; Loëst *et al.*, 1999; Ferreira *et al.*, 1999; Froidmont *et al.*, 2000).

There are two basic differences in the determination of the ideal protein in non-ruminants and ruminants. In non-ruminants (e.g. pigs) the amino acid supply is largely determined by the diet (Zhang *et al.*, 1984), but in ruminants the rumen micro-organisms modify the amino acid patterns in the diet (Van der Walt & Meyer, 1988). Therefore, in ruminants it will be more accurate to determine the amino acid patterns of the duodenal digesta content and use this pattern as the supply of amino acids to the animal. Secondly, Ferreira *et al.* (1999) reported that the carcass is most probably not representative of the ideal protein needs in growing lambs. They suggested that the whole empty body should be used with ruminants, rather than only the carcass as with non-ruminants.

This project was undertaken to obtain more information on a few of the above-mentioned shortcomings in game animal nutrition. Although similar studies can be conducted with other game species, only springbok, blesbok and impala were used, since these species are the most important game species for commercial game farming. In Chapter 2 the aims were to a) characterize the physical body component and nitrogen distribution in the springbok, blesbok and impala and b) to compare the chemical composition (moisture, protein, fat, ash) of the three-rib cut with that of the carcass. The ideal protein concept was also investigated (Chapter 3) by comparing the EAA profile of the whole empty body with that of the duodenal digesta content, to detect any imbalances for optimal growth in the three game species.

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Chapter 2

Body composition of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*)

L van Zyl and AV Ferreira

Department of Animal Sciences, Faculty of Agricultural and Forestry Sciences, University of Stellenbosch, Stellenbosch, 7600

Abstract

Chemical composition of the carcasses and three-rib cut samples of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*) were investigated. The dressing percentages (% of body weight; % of empty body weight) for the three game species were: springbok (57.1 ± 2.4 %; 64.0 ± 2.5 %), blesbok (50.2 ± 2.1 %; 62.8 ± 1.4 %) and impala (57.4 ± 2.2 %; 65.6 ± 2.0 %). The proportional distribution of N between the carcass, external and internal offal was determined. The mean carcass N concentration of the impala was significantly higher than that of the springbok and blesbok. The game species seem to have a better potential for lean meat production (fat content of carcass 4.7-5.2 %) than domestic sheep (17-25 %). Male animals had a significantly lower fat but higher moisture content in the carcass and three-rib cut than the females. The fat percentage of the three-rib cut, expressed either on an as is or dry matter basis, was significantly correlated with carcass fat content in all three game species and across sexes. However, no significant correlation was obtained between the chemical protein (on an as is basis) content of the carcass and three-rib cut samples for any of the game species studied, while the protein content of three rib cut samples from springbok correlated with the protein content of the carcass on a dry matter basis.

Keywords: carcass yield, game three rib cut, chemical composition

Introduction

Game farming has become increasingly important during the last four decades in South Africa and, according to Jooste (1983), plays a considerable role in the optimum utilization of agricultural resources. Luxmoore (1985) mentioned that more than 10 000 farmers derive some income from wildlife utilization. Yet, this number is probably an underestimation when the growing numbers of farmers that change to mixed or game farming are taken into account. It was reported by Eloff (2001) that a total of 5061 farms in South Africa are fenced in by game fences. These farms cover an area of more than 10.3 million hectares and are increasing by 7.25 % per annum.

Different forms of wildlife utilization have been evaluated by Berry (1986), namely trophy hunting, non-trophy recreational hunting, live animal sales and venison (game meat) production. Since the contribution of game meat production (biltong hunters and game meat sales) constitutes 67.5 % of the total income from the game industry in South Africa (Potgieter, 2001), this aspect deserves further investigation. The meat production potential of various species of wild ungulates found in southern Africa has long been recognized (Ledger *et al.*, 1967; Skinner, 1984). Three such species are the springbok, *Antidorcas marsupialis*, the blesbok, *Damaliscus dorcas phillipsi*, and the impala, *Aepyceros melampus*, and were, therefore, included in this study. When producing meat from wild ungulates, the same criteria apply as for meat production from domestic livestock. These criteria include factors such as yield, chemical composition and meat quality (Hoffman, 2000).

There has been a general lack in detailed information on the physical body composition of the above-mentioned species. 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. There is also very little uniformity in the methods used to describe this composition, in order to compare the results with domesticated species (e.g. sheep and cattle). Besides the physical body composition, the estimation of carcass chemical composition is also important when nutritional, physiological or genetic differences are evaluated. In order to do this without sacrificing the entire carcass, several authors

(Kirton & Barton, 1962; Crouse & Dikeman, 1974; Nour & Thonney, 1994) have considered the three-rib cut to be a useful predictor of the carcass chemical composition. No published studies could be found in connection with if there is any correlation between the carcass and the three-rib cut chemical composition in springbok, blesbok or impala.

The aims of the present study were to investigate the body composition of springbok, blesbok and impala and to compare the chemical composition (moisture, protein, fat, ash) of three-rib cut samples with that of the carcass.

Materials and methods

Animals

Eight springbok (5 male; 3 female), blesbok (4 male; 4 female) and impala (2 male; 6 female), of different ages (between 17-19 and 36 months), were cropped during June/July 2000. The springbok were collected from a mixed farm (sheep and game) in the central Karoo (31°30′S; 22°30′E). The blesbok were cropped at a game farm in the north-eastern Free State (27°45′S; 29°00′E). The impala were collected from the Overberg Test Range (Denel) near Bredasdorp in the Western Cape (35°45′S; 20°15′E).

Collection and preparation of samples

The animals were randomly cropped by a shot in the head or shoulder. The shot animals' body weights were recorded before they were bled (by cutting the throat) and they were then transported to the slaughter facilities on the farm or premises to be dressed. The head, feet, skin, heart, heart fat, liver, lungs and trachea, kidneys, kidney fat, spleen, GIT (gastro-intestinal tract) fat, diaphragm, stomachs (rumen, reticulum, omasum and abomasum combined) 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. Dressed carcasses were chilled overnight at 4 °C and cold carcass weight was determined the next morning. Cold carcass weight instead of hot carcass weight was used, as recommended by Van Zyl *et al.*

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(1969). Blood weight was calculated as the difference between the weight of the dressed carcass, internal and external offal and the body weight.

The carcasses were split medially through the vertebrae. Only the right sides of the carcasses were used in this study to estimate body composition. The three-rib cut (9-10-11 section) was removed from each carcass and ground three times through a meat grinder, including the bone. The remaining portion of the right side of each carcass was stored at –20 °C before it was twice milled with a carcass mill, while in the frozen state. The three-rib cut and a representative sample taken from the carcass (included the proportional contribution of the three-rib cut) were freeze-dried. The dry sample was then milled through a 1 mm screen, thoroughly mixed and stored at –10 °C for later analyses.

Sample analysis

The carcass and three-rib cut were analysed for moisture, crude protein and ash according to A.O.A.C. (1997). The lipid content of both these components was determined by solvent extraction according to the method of Lee *et al.* (1996). Nitrogen analyses were also performed on the right side of each carcass, internal and external offal. The data were compared statistically, following the guidelines from SAS Procedures Guide (1989). Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS. The following model was fitted for main effects (sex, species) 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 sex of the jth species, μ = the overall mean, G_i = the sex effect, S_j = the species effect, GS_{ij} = the interaction between sex and species and e_{ij} = the residual error.

The difference between sex and species 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 (± 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 sex and species.

Results and discussion

Physical composition

The body, whole empty body and carcass weights, dressing percentages and proportional distribution of tissue components relative to whole empty body weight of springbok, blesbok and impala across sexes are presented in Table 1. The whole empty body weight was calculated as the live weight minus the stomach and intestinal contents. The body, whole empty body and carcass weights and dressing percentages of the springbok and blesbok do not differ (P<0.05) between the sexes. The differences (P<0.05) found between the male and female impala for the same measurements were most likely due to the age difference between the sexes (approximate age: males = 18 months; females = 36 months). Although Hoffmann (2000) also found significant differences between the live and dressed weight of the male and female impala (the male being significantly heavier than the female), he also reported no significant difference in the dressing percentage (expressed as % of empty body weight) between the sexes, as was found in the present study. Comparing the contribution of the head, feet and skin to the whole empty body (or all three together as external offal), it was evident that there were differences (P<0.05) between the sexes in all three species, with a tendency for the males having higher percentages (P<0.05) than the females. The females of all three game species also had higher percentages (P<0.05) of kidney fat than the males.

In Table 2 the body, whole empty body and carcass weights, dressing percentages and proportional distribution of tissue components across the three game species are shown. The body weights and whole empty body weights of springbok and impala did not differ (P>0.05) from each other, but these weights were lower (P<0.05) than that of the blesbok.

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Table 1   **Body, whole empty body and carcass weights (kg) (mean ± SD), dressing percentages and proportional distribution (mean ± SD) of tissue components in springbok, blesbok and impala across sexes**

Measurement	Springbok		Blesbok		Impala	
	Male	Female	Male	Female	Male	Female
n	5	3	4	4	2	6
Body weight (kg)	33.7 ± 4.6^c	27.1 ± 2.5^c	50.4 ± 5.0^{ab}	56.2 ± 9.9^a	26.3 ± 4.5^c	42.6 ± 1.8^b
WEB[1](kg)	29.9 ± 4.1^c	24.4 ± 2.1^{cd}	39.8 ± 4.4^{ab}	45.5 ± 7.8^a	22.7 ± 4.0^d	37.5 ± 1.5^b
Cold carcass[2](kg)	19.4 ± 2.5^b	15.3 ± 2.1^{bc}	24.9 ± 2.2^a	28.6 ± 5.3^a	14.5 ± 2.2^c	24.8 ± 1.0^a
Dressing %[3]	57.6 ± 2.3^{ab}	56.2 ± 2.6^{ab}	49.5 ± 0.9^c	50.8 ± 2.8^c	54.7 ± 2.7^b	58.2 ± 1.2^a
Dressing %[4]	64.9 ± 1.8^{ab}	62.6 ± 3.3^b	62.9 ± 1.5^b	62.7 ± 1.4^b	63.5 ± 2.9^{ab}	66.3 ± 1.2^a
Body weight[5]	112.8^{bc}	111.3^c	127.0^a	123.5^a	116.0^b	113.8^{bc}
SD	± 1.9	± 0.8	± 2.1	± 5.5	± 0.4	± 1.7
WEB[1]	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Cold carcass[5]	64.9 ± 1.8^{ab}	62.6 ± 3.3^b	62.9 ± 1.5^b	62.7 ± 1.4^b	63.5 ± 2.9^{ab}	66.3 ± 1.2^a
Head[5]	6.5 ± 0.4^c	6.0 ± 0.5^c	8.6 ± 0.3^a	7.6 ± 0.5^b	6.4 ± 0.3^c	5.2 ± 0.2^d
Feet[5]	3.0 ± 0.4^{abc}	3.1 ± 0.2^{ab}	3.1 ± 0.1^a	2.6 ± 0.2^c	3.3 ± 0.1^a	2.7 ± 0.2^{bc}
Skin[5]	5.5 ± 0.2^{ab}	4.7 ± 0.2^c	5.6 ± 0.2^{ab}	5.4 ± 0.1^{ab}	5.8 ± 0.7^a	5.3 ± 0.3^c
Heart[5]	0.8 ± 0.1^{cd}	0.8 ± 0.1^d	1.1 ± 0.0^a	1.0 ± 0.1^{ab}	1.0 ± 0.1^a	0.9 ± 0.1^{bc}
Heart fat[5]	0.0	0.0	0.2 ± 0.0^a	0.1 ± 0.0^a	0.0	0.1 ± 0.0^a
Liver[5]	2.8 ± 0.4^{ab}	2.9 ± 0.3^a	1.3 ± 0.2^d	1.3 ± 0.1^d	2.5 ± 0.3^b	2.1 ± 0.1^c
Lungs & trachea[5]	1.9 ± 0.5	2.1 ± 0.3	1.9 ± 0.5^a	1.9 ± 0.1	2.3 ± 0.2	2.0 ± 0.4
Kidneys[5]	0.6 ± 0.1^a	0.6 ± 0.0^a	0.3 ± 0.0^c	0.3 ± 0.0^c	0.6 ± 0.1^a	0.4 ± 0.0^b
Kidney fat[5]	0.1 ± 0.1^b	0.4 ± 0.2^a	0.1 ± 0.1^b	0.4 ± 0.1^a	0.0	0.2 ± 0.1^b
Spleen[5]	0.3 ± 0.1^{bc}	0.2 ± 0.1^c	0.3 ± 0.0^{bc}	0.3 ± 0.3^{cb}	0.7 ± 0.2^a	0.4 ± 0.1^b
Testis[5]	0.3 ± 0.1^a		0.1 ± 0.0^b		[6]	
GIT fat[5]	0.0	0.0	0.3 ± 0.0^{ab}	0.7 ± 0.3^a	0.0	0.5 ± 0.3^{ab}
Diaphragm[5]	0.5 ± 0.1^{ab}	0.6 ± 0.3^{ab}	0.7 ± 0.2^a	0.6 ± 0.2^{ab}	0.4 ± 0.2^b	0.6 ± 0.1^{ab}
Stomach full[5]	12.8 ± 1.7^b	12.6 ± 0.7^b	28.2 ± 1.8^a	26.0 ± 5.6^a	16.5 ± 0.5^b	15.5 ± 1.6^b
Stomach empty[5]	4.0 ± 0.7	3.8 ± 0.5	3.9 ± 0.8	3.8± 0.3	3.8 ± 0.4	4.4 ± 0.5
Stomach contents[5]	8.8 ± 1.3^b	8.7 ± 0.7^a	24.2 ± 2.4^a	22.2 ± 5.4^a	12.7 ± 0.1^b	11.1 ± 1.2^b
Intestine full[5]	6.6 ± 1.5^a	5.9 ± 0.2^{abc}	4.9 ± 1.0^{bc}	4.7 ± 0.6^c	6.4 ± 0.7^{ab}	5.9 ± 1.1^{abc}
Intestine empty[5]	2.6 ± 0.6^{ab}	3.4 ± 0.1^a	2.2 ± 0.9^b	3.4 ± 0.4^a	3.1 ± 0.4^a	2.9 ± 0.3^{ab}
Intestine contents[5]	4.0 ± 1.2^a	2.6 ± 0.3^{ab}	2.7 ± 1.1^{ab}	1.3 ± 0.5^b	3.3 ± 0.3^a	2.7 ± 1.0^{ab}
Blood[5]	7.2 ± 2.5^{ab}	9.8 ± 3.9^a	6.5 ± 1.3^{ab}	6.3 ± 0.9^b	6.6 ± 1.0^{ab}	6.3 ± 1.8^b
External offal[5]	14.9 ± 0.4^b	13.8 ± 0.6^c	17.3 ± 0.5^a	15.6 ± 0.7^b	15.6 ± 0.9^b	13.1 ± 0.5^c
Internal offal[5]	20.8 ± 2.1^b	24.6 ± 4.2^a	18.5 ± 1.7^b	19.7 ± 0.9^b	21.0 ± 1.2^b	20.6 ± 2.0^b

[1] WEB = live weight minus stomach and intestinal contents
[2] Including kidneys and kidney fat
[3] Expressed as a % of body weight
[4] Expressed as a % of empty body weight
[5] The percentage of the weight of an organ or tissue relative to that of the whole empty body weight
[6] not determined
[a, b, c, d] Values in rows bearing different superscript letters are significantly different (P<0.05)

Comparing the cold carcass weights, it was evident that the blesbok had a higher (P<0.05) carcass weight than the other two game species and that the impala also had a higher (P<0.05) carcass weight than the springbok (17.9 kg). The body and carcass weights of springbok (31.3 kg; 17.9 kg) and impala (38.5 kg; 22.2 kg) in the present

study compared well with that found in previous studies (Van Zyl, 1968; Van Zyl *et al.*, 1969; Von la Chevallerie, 1970; Hoffman, 2000).

Table 2 **Body, whole empty body and carcass weights (kg) (mean ± SD), dressing percentages and proportional distribution (mean ± SD) of tissue components in springbok, blesbok and impala across species (n=8)**

Measurement	Springbok	Blesbok	Impala
Body weight (kg)	31.3 ± 5.1^b	53.3 ± 7.9^a	38.5 ± 7.9^b
WEB[1](kg)	27.8 ± 4.2^b	42.6 ± 6.2^a	33.8 ± 6.9^b
Cold carcass[2](kg)	17.9 ± 3.1^c	26.8 ± 4.3^a	22.2 ± 5.0^b
Dressing %[3]	57.1 ± 2.4^a	50.2 ± 2.1^b	57.4 ± 2.2^a
Dressing %[4]	64.0 ± 2.5^{ab}	62.8 ± 1.4^b	65.6 ± 2.0^a
Body weight[5]	112.3 ± 1.7^b	125.2 ± 4.3^a	114.4 ± 1.8^b
WEB[1]	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Cold carcass[5]	64.0 ± 2.5^{ab}	62.8 ± 1.4^b	65.6 ± 2.0^a
Head[5]	6.3 ± 0.5^b	8.1 ± 0.7^a	5.5 ± 0.6^c
Feet[5]	3.0 ± 0.4	2.9 ± 0.3	2.9 ± 0.3
Skin[5]	5.2 ± 0.4	5.5 ± 0.2	5.4 ± 0.4
Heart[5]	0.8 ± 0.1^c	1.0 ± 0.1^a	0.9 ± 0.1^b
Heart fat[5]	0.0	0.2 ± 0.0	0.1 ± 0.0
Liver[5]	2.8 ± 0.3^a	1.3 ± 0.2^c	2.2 ± 0.2^b
Lungs & trachea[5]	2.0 ± 0.4	1.9 ± 0.4	2.1 ± 0.4
Kidneys[5]	0.6 ± 0.1^a	0.3 ± 0.0^c	0.5 ± 0.1^b
Kidney fat[5]	0.3 ± 0.2	0.3 ± 0.2	0.2 ± 0.1
Spleen[5]	0.2 ± 0.1^b	0.3 ± 0.0^b	0.5 ± 0.2^a
Testis[5]	$0.3 \pm 0.1^{a\,[6]}$	$0.1 \pm 0.0^{b\,[7]}$	[8]
GIT fat[5]	0.0	0.5 ± 0.3	0.4 ± 0.2
Diaphragm[5]	0.6 ± 0.2	0.7 ± 0.2	0.5 ± 0.2
Stomach full[5]	12.7 ± 1.4^c	27.1 ± 4.0^a	15.8 ± 1.4^b
Stomach empty[5]	3.9 ± 0.6	3.9 ± 0.6	4.3 ± 0.5
Stomach contents[5]	8.8 ± 1.1^c	23.2 ± 4.0^a	11.5 ± 1.3^b
Intestine full[5]	6.4 ± 1.2^a	4.8 ± 0.8^b	5.8 ± 1.0^{ab}
Intestine empty[5]	2.9 ± 0.6	2.8 ± 0.9	2.9 ± 0.3
Intestine contents[5]	3.5 ± 1.2^a	2.0 ± 1.1^b	2.9 ± 0.9^{ab}
Blood[5]	8.2 ± 3.1	6.5 ± 1.1	6.4 ± 1.6
External offal[5]	14.5 ± 0.7^b	16.5 ± 1.0^a	13.7 ± 1.3^b
Internal offal[5]	22.3 ± 3.4^a	19.2 ± 1.5^b	20.7 ± 1.3^{ab}

[1] WEB = live weight minus stomach and intestinal contents
[2] Including kidneys and kidney fat
[3] Expressed as a % of body weight
[4] Expressed as a % of empty body weight
[5] The percentage of the weight of an organ or tissue relative to that of the whole empty body weight
[6] n=5
[7] n=4
[8] not determined
[a, b, c] Values in rows bearing different superscript letters are significantly different (P<0.05)

However, the same measurements for blesbok (53.3 kg; 26.8 kg) seemed to be lower than the average live (70 kg) and carcass (38.7 kg) weights in previous studies (Von la Chevallerie, 1970; Huntley, 1971; Kroon et al., 1972). The higher live and carcass weights found for the blesbok in the literature might be because only males of an older age and probably on a different habitat (diet) were used in these studies.

In Table 2 the dressing percentage is expressed both in terms of the body weight and the empty body weight of the animals (as in Table 1). When calculated as a percentage of body weight, blesbok had a lower (P<0.05) dressing percentage than both springbok and impala. However, the dressing percentage of blesbok was only lower (P<0.05) than impala when it is calculated as a percentage of empty body weight (body weight minus stomach and intestinal contents). This shift in significance can be explained by the two different methods of calculating dressing percentage. In the springbok and impala, the difference between the two dressing percentages varied between 6.9-8.2 %, but for the blesbok it was 12.6 %. The reason for this latter difference to be almost twice as much as that for springbok and impala, was because the blesbok's stomach and intestinal contents (P<0.05) were almost twice that of the other two game species. According to McCulloch & Talbot (1965), even with similar animals of the same species, variations in the weight of the stomach content can amount to 10 % of live weight. Therefore, it appears that the dressing percentage expressed in terms of empty body weight is the more accurate method of the two. With this method, the variance between individuals and species due to food and water intake before shooting was accounted for. This method was also recommended by Kroon et al. (1972) when they compared seasonal differences in live and empty body weights of blesbok.

Van Zyl et al. (1969) have shown that springbok and impala have dressing percentages (calculated as % of live weight) of 57.9 % and 58.8 %, respectively. These percentages are in accordance with the results from the current study. The 50.2 % for blesbok was lower than the dressing percentage (as a % of live weight) of 52.9 % found by Huntley (1971). When these three game species were compared to the domesticated species of sheep (Dorper lambs and South African Mutton Merino wethers) and goats (Spanish, Angora and indigenous Botswana goats), it was found that the latter two species had a lower dressing percentage (as % of live weight), with

sheep at 47-50 % and goats at 46-52 % (Owen & Norman, 1977; Cloete *et al.*, 2000; Mavimbela *et al.*, 2000; Oman *et al.*, 2000). Hoffman (2000) pointed out that some of the above-mentioned differences in dressing percentage might be because of differences in the methodologies used for game and domestic animals. A common problem found in the calculation of the dressing percentage in wildlife, is whether carcass blood is included or excluded and if full or empty stomach and intestines were used. This is particularly important when comparisons are made with domestic stock, which are fasted for 24 h prior to being slaughtered. Von la Chevallerie (1970) mentioned that wild ungulates achieve the same dressing percentage as fat domestic stock without having the same proportion of fat in their carcasses.

In Table 2, body weight, carcass weight and internal and external offal are also expressed as a percentage relative to the whole empty body weight to compare the difference in the proportional distribution of organs and tissues between the three game species. When cold carcass was expressed as a % of empty body weight (Table 2), the blesbok had a lower (P<0.05) percentage than that of the impala . Comparing all the external and internal offal, it seemed that the blesbok's head contributed a higher proportion (P<0.05) of empty body weight (8.1 %) than the head of the springbok (6.3 %) and impala (5.5 %). Therefore the head also contributed to the lower (P<0.05) cold carcass percentage in blesbok. The internal offal components that also differed (P<0.05) between the three game species (but did not influence the carcass percentage as much as the head) were the heart, liver, kidneys and spleen (Table 2). There is a good resemblance between the live weight percentage of the different offal components and that found in previous studies with springbok, blesbok and impala (Van Zyl *et al.*, 1969; Huntley, 1971; Hoffman, 2000).

The external offal of blesbok was higher (P<0.05) than springbok and impala , while on the other hand the internal offal of blesbok was lower (P<0.05) than that of springbok . An interesting aspect is that the game species had an equal or higher internal offal percentage of 19.2-22.3 % than the domesticated species (sheep 21.4 %; goats 22.7 %; cattle 15.8 %). The domesticated species used in the comparison included different breeds of sheep (Barbary ewes, South African Mutton Merino lambs and indigenous Botswana sheep), goats (Boer goats, indigenous Botswana goats, Angora goats and Spanish goats) and cattle (Danish Friesian cows, Limousin

cows and Charolais cows). In general, sheep has a higher percentage of external offal (head, feet and skin) (average 19.1 %) than the game species (13.7-16.5 %), mainly because the skin (including the wool) contributes a higher proportion in all the sheep breeds. The total digestive tract of the sheep, with an average of 13.1 %, composes a higher percentage of empty body weight than that of the springbok (6.8 %), blesbok (6.7 %) and impala (7.2 %) (Owen & Norman, 1977; Ferreira *et al.*, 1999; Atti *et al.*, 2000). Similarly, goats also have a higher percentage of external offal (average 20.6 %) and total digestive tract (average 12.5 %) than the three game species (Owen & Norman, 1977; Riley *et al.*, 1989). Although cattle have a higher percentage of skin (average 7.7 % vs. game 5.2-5.5 %), the head and feet's contribution (average 5.6 %) to the empty body weight were lower than in the game species (8.4-11.0 %) (Robelin *et al.*, 1990; Shemeis *et al.*, 1994).

Considering that the internal offal is more edible than the external offal, the former can also be included in the animals' total yield of usable products (Riley *et al.*, 1989). Based on the above comparisons, the three game species have a higher production of total usable products, with an average of 84.8 % vs. 76.7 % in sheep and cattle (Owen & Norman, 1977; Robelin *et al.*, 1990; Shemeis *et al.*, 1994). It therefore seems that wild ungulates have a higher edible portion than the domesticated species, not only because of the higher dressing percentages (Table 1), but also because of the equal or higher internal offal production (Table 2). Farmers can benefit from the higher production of edible products from the game species, if there is an efficient market for these products. Cilliers (1995) showed that for the period 1980-1995, not only the income from sheep carcasses increased fivefold, but the income from sheep offal had the same trend. There are, however, many factors that can influence the production of offal. Riley *et al.* (1989) reported differences among breeds and sexes of sheep and goats for offal item percentages. Furthermore, it was found that as animals age, the proportions of the head, feet and skin decreased and the internal organs and digestive tract increased (Shemeis *et al.*, 1994). When the effects of underfeeding and refeeding were investigated, several studies showed that the components of low metabolic activity in adult animals (feet, lungs, trachea) and the abomasum and intestines were not affected. The weights of the skin, blood, liver, reticulo-rumen and omasum did, however, show a decrease (Taylor & Murray, 1991; Kabbali *et al.*, 1992a; Atti *et al.*, 2000).

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Chemical composition

The mean nitrogen (N) concentration of the whole empty body was similar between springbok (43.4 ± 1.5 g/kg) and blesbok (44.1 ± 1.5 g/kg), but both were higher (P<0.05) than impala (40.9 ± 0.8 g/kg). In similar studies with sheep (Suffolk x Finn Dorset and South African Mutton Merino lambs), both MacRae *et al.* (1993) and Ferreira *et al.* (1999) obtained lower N concentrations of the whole empty body (24.9-33.4 g/kg). There also seems to be a larger variation between the N concentrations of the whole empty body for the different breeds of sheep (24.9-33.4 g/kg) than for the different game species (40.9-44.1 g/kg). The nitrogen content of the carcass, external offal and internal offal are expressed as a percentage of the whole empty body nitrogen content in Table 3. Impala had a higher (P<0.05) percentage of N in the carcass compared to springbok and blesbok. The percentage N in the external offal was higher (P<0.05) for the blesbok compared to the springbok and impala, and also for the springbok compared to the impala. However, comparing the percentage nitrogen in the internal offal, the springbok had a higher (P<0.05) percentage than the blesbok.

Table 3   Nitrogen content (%) (mean ± SD) of the carcass, external offal and internal offal of springbok, blesbok and impala (n=8) on a dry matter basis

Component	Springbok % N[1]	Blesbok % N[1]	Impala % N[1]
Carcass	57.5 ± 3.2[b]	57.3 ± 3.1[b]	62.8 ± 3.8[a]
External offal	20.7 ± 2.2[b]	25.7 ± 2.2[a]	17.9 ± 2.2[c]
Internal offal	21.9 ± 4.8[a]	17.0 ± 2.2[b]	19.3 ± 4.0[ab]

[1] As percentage relative to whole empty body nitrogen content

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

Comparing these N percentages to that of sheep (S), the three game species (G) have a higher percentage N in the carcass (G 57.3-62.8 % vs. S 38.4-49.2 %) but a lower percentage N in the external offal (G 17.9-25.7 % vs. S 34.0-38.1 %). There is, however, a good comparison between the percentage N in the internal offal of sheep (16.5-23.5 %) and the game species investigated (17.0-21.9 %) (MacRae *et al.* 1993; Ferreira *et al.* 1999). There were no differences (P>0.05) between the male and

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female animals of the three game species for either the mean N concentration of the whole empty body or when the N content of the carcass, external offal and internal offal were expressed as a percentage of the whole empty body N content.

The protein, fat, moisture and ash percentages of the carcass and three-rib cut across sexes are presented in Table 4. There were significant differences (P<0.05) between the fat percentages of the males and females in both the carcass and three-rib cut of all three game species. The same tendency was shown for springbok, blesbok and impala, in that the females had higher (P<0.05) fat percentages than the males.

Table 4 **Chemical composition (%) (mean ± SD) of carcass and three-rib cut samples of springbok, blesbok and impala expressed on an as-is basis across sexes**

Component	Springbok		Blesbok		Impala	
	Male	Female	Male	Female	Male	Female
n	5	3	4	4	2	6
Carcass						
Protein	24.2 ± 1.8	22.9 ± 1.8	23.3 ± 1.5	23.7 ± 1.0	22.1 ± 0.3	22.6 ± 0.8
Fat	3.5 ± 1.2^c	8.0 ± 1.2^a	4.5 ± 0.7^{bc}	9.0 ± 1.6^a	1.3 ± 0.3^d	5.8 ± 1.4^b
Moisture	63.1 ± 1.1^b	60.8 ± 1.4^c	62.7 ± 0.7^b	58.4 ± 1.3^d	65.0 ± 1.0^a	59.7 ± 1.1^{cd}
Ash	6.4 ± 0.3^{bc}	6.3 ± 0.3^c	6.1 ± 0.6^c	6.1 ± 0.2^c	7.0 ± 0.5^{ab}	7.5 ± 0.5^a
Three rib cut						
Protein	17.4 ± 3.7	18.4 ± 1.2	19.3 ± 0.3	19.8 ± 1.9	18.9 ± 0.1	20.0 ± 1.1
Fat	2.5 ± 0.8^c	5.3 ± 0.7^b	4.6 ± 0.6^b	6.8 ± 0.7^a	1.2 ± 0.1^c	4.3 ± 0.8^b
Moisture	75.3 ± 5.5^a	70.4 ± 1.3^{bc}	71.1 ± 1.1^{abc}	68.2 ± 2.4^c	74.0 ± 0.8^{ab}	70.2 ± 1.3^{bc}
Ash	4.2 ± 1.1	4.3 ± 0.8	4.0 ± 0.4	4.2 ± 1.3	4.6 ± 0.6	4.4 ± 1.0

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

A similar study done by Hoffman (2000) on impala also indicated that there is a significantly higher fat content in the females than in the males. The data of Ledger *et al*. (1967) indicated that generally the female in the majority of wild ungulate species was inclined to have a higher fat content than the male. This was substantiated by Von Chevallerie & Van Zyl (1970) in a growth study with springbok lambs and is a known fact in domestic animals. As suggested by Hoffman (2000), another possible explanation for the lower fat content of the carcass (Table 4) and kidney fat percentage (Table 1) in males is that during the breeding and rutting season the rams

loose condition owing to the strenuous activities in fighting for and maintaining a harem.

The moisture percentages (Table 4) in the carcass (all three game species) and in the three-rib cut (springbok) also differed significantly (P<0.05) between the sexes. In this case, however, the tendency was for the females to have lower (P<0.05) moisture percentages than the males. Kirton & Barton (1962) found a high negative correlation (r^2 -0.98) when they compared the carcass water and fat percentages of lambs. In the present study, similar results were obtained for springbok (r^2 -0.89), blesbok (r^2 -0.93) and impala (r^2 -0.92). The reason for this negative correlation is the lower water content of fat compared to protein.

The protein, fat, moisture and ash percentages of the carcass and three-rib cut across species are presented in Table 5. According to the carcass chemical composition, only the ash percentage was higher (P<0.05) in the impala than in the other two species. In the three-rib cut, however, the fat percentage of the blesbok was higher (P<0.05) than that of the springbok and impala. The blesbok also had a lower percentage (P<0.05) of moisture in the three-rib cut than the springbok.

Table 5   **Chemical composition (%) (mean ± SD) of carcass and three-rib cut samples of springbok, blesbok and impala (n=8) expressed on an as-is basis across species**

Component	Springbok	Blesbok	Impala
Carcass			
Protein	23.7 ± 1.7	23.5 ± 1.1	22.5 ± 0.7
Fat	5.2 ± 2.4	6.7 ± 2.5	4.7 ± 2.3
Moisture	62.3 ± 1.6	60.6 ± 2.5	61.1 ± 2.6
Ash	6.4 ± 0.3[b]	6.1 ± 0.4[b]	7.4 ± 0.5[a]
Three rib cut			
Protein	17.7 ± 2.7	19.6 ± 1.2	19.7 ± 1.0
Fat	3.5 ± 1.5[b]	5.7 ± 1.6[a]	3.5 ± 1.5[b]
Moisture	73.4 ± 5.0[a]	69.6 ± 2.3[b]	71.1 ± 2.1[ab]
Ash	4.24± 0.9	4.1 ± 0.9	4.5 ± 0.9

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

The limited data on the carcass chemical composition of wild ungulates (Kroon *et al.*, 1972; Skinner, 1973) supports the percentages of protein, fat, moisture and ash found in the present study. Comparing the carcass composition to that of several sheep (S) breeds, it is evident that the three game (G) species have higher protein (G 22-24 % vs. S 14.5-18.5 %), moisture (G 60.5-62.3 % vs. S 52-58 %) and ash (G 6.1-7.4 % vs. S 4-4.9 %) percentages, while a much lower fat content occur (G 4.7-5.2 % vs. S 17-25 %) (Kirton & Barton, 1962; Kabbali *et al.*, 1992b; Kock *et al.*, 1995; Löest *et al.*, 1997).

The chemical composition of the three-rib cut samples of the game species show the same tendency as the carcass, in that the percentage moisture was higher (G 69.6-73.4 % vs. S 50-54 %) and the percentage fat was lower (G 3.5-5.7 % vs. S 23-27 %) than previously observed in sheep rib cuts. The percentage protein in the three-rib cut of the game species (17.8-19.8 %) was, however, basically the same as for sheep (18-19.5 %) (Löest *et al.*, 1997). The low fat percentages of the carcass and three rib cut in the present study are in accordance with the 1.8-5.6 % carcass fat mentioned by Ledger *et al.* (1967) for 18 wild ungulate species. These low fat percentages, together with the higher carcass protein percentages might be an indication of a high content of lean meat (77-83 %), as was found by Ledger *et al.* (1967).

In Table 6, the correlations between the carcass and the three-rib cut show that, as for the different components, only the fat of all three game species were correlated ($P<0.05$) on both a dry matter and an as is basis.

Table 6 **Correlations (r^2) between carcass and three-rib cut of springbok, blesbok and impala (n=8) on an as-is and dry matter basis**

Component	Springbok		Blesbok		Impala	
	As-is	Dry	As-is	Dry	As-is	Dry
Protein	-0.06	0.76*	0.44	0.28	0.26	0.41
Fat	0.93**	0.98**	0.79*	0.85**	0.93**	0.95**
Ash	0.30	0.52	0.33	0.59	0.75*	0.92**
Moisture	0.38		0.55		0.76*	

*P<0.05; **P<0.01

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In this regard the moisture and ash content in the impala were also correlated (P<0.05) on an as is basis. The protein percentages of the carcass and three-rib cut were not significantly (P>0.05) correlated in any of the three game species on an as is basis. When the correlations between the carcass and three-rib cut were expressed on a dry matter basis, only the protein percentages of the springbok were correlated (P<0.05).

In previous studies with sheep (S) and cattle (C), high correlations between carcass and three-rib cut samples were found for moisture (S: r^2 0.88; C: r^2 0.77), protein (S: r^2 0.6; C: r^2 0.7-0.9) and fat (S: r^2 0.92; C: r^2 0.83-0.88) (Kirton & Barton, 1962; Crouse & Dikeman, 1974; Nour & Thonney, 1994). These authors and many others considered the three-rib cut to be a useful predictor of the carcass chemical composition of animals. However, two more recent studies (Ainslie *et al.*, 1993; Löest *et al.*, 1997) support the findings of the present study in that the correlations between the carcass and three-rib cut protein are not significant. The present study shows that the three-rib cut might be used as a prediction of the entire carcass chemical composition in game animals.

The correlations between the carcass and three-rib cut of a combination of all three game species' males and females are presented in Table 7. Only the fat percentages in the carcass and three-rib cut were significantly correlated (P<0.01) in both the males and females on an as is and dry matter basis.

Table 7   **Correlations (r^2) between carcass and three-rib cut of male and female game animals on an as-is and dry matter basis**

Component	Male n = 11		Female n = 13	
	As-is	Dry	As-is	Dry
Protein	-0.16	0.58	0.30	-0.21
Fat	0.81**	0.91**	0.80**	0.86**
Ash	0.51	0.69*	0.40	0.62*
Moisture	0.09		0.26	

*P<0.05; **P<0.01

There were also high correlations (P<0.05) for the ash percentages on a dry matter basis in the male and female animals. Thus, in general, only the fat percentage in the three-rib cut samples can be used as a prediction of the entire carcass fat content in both male and female game animals.

Conclusion

From the results of the present study it can be concluded that body and carcass weights as well as the dressing percentage (expressed as a % of body weight) of springbok, blesbok and impala were in accordance with previous estimations of these physical components. Except for the blesbok (50.2 %), these game species' dressing percentages were also in the range (55-61 %) of the majority of African ungulates (Von la Chevallerie, 1970). In general, the physical composition of all three game species followed the same pattern when it was expressed as a % of empty body weight. Differences (P<0.05) were however found between the external offal and kidney fat percentages of males and females. The proportion of N in the carcass of the three game species investigated was much higher, compared with literature reports on domesticated species.

In comparison to domestic stock, the game species seem to have a much better potential for meat production in terms of dressing percentage and lean meat production (fat content). However, this will only be an advantage if problems with cropping, slaughter facilities and personal prejudices can be overcome (Skinner, 1984; Féron, 1995).

Sex seems to have an influence on the carcass and three-rib cut chemical composition, with males having lower (P<0.05) fat but higher (P<0.05) moisture percentages than females. The results also suggest that, in the three game species, the three-rib cut was not that closely related to the total carcass composition as was previously found in domestic farm animals. The fat percentage of the three-rib cut was closely related (P<0.05) to that in the carcass across species and sexes. On the other hand, protein (on a dry matter basis) was only correlated (P<0.05) in the three-rib cut and carcass of

springbok. In future investigations a larger number of animals should be used for each game species in order to verify the results of the current study.

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Chapter 3

Amino acid requirements of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*) estimated by the whole empty body essential amino acid profile for optimal growth

L van Zyl and AV Ferreira

Department of Animal Sciences, Faculty of Agricultural and Forestry Sciences, University of Stellenbosch, Stellenbosch, 7600

Abstract

The essential amino acid (EAA) profiles of the duodenal digesta and whole empty body growth of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*) were investigated. Significant differences were found between the whole empty body EAA composition of the three game species, whether protein quantity was taken into account (g AA/100 g crude protein (CP)) or not (expressed as % of lysine). The chemical scores indicated that the four most limiting amino acids (three for impala) in the duodenal digesta for whole empty body growth were: arginine, histidine, threonine, methionine (springbok); methionine, arginine, histidine, lysine (blesbok); and methionine, histidine, arginine (impala). Excess levels of amino acids were present in the duodenal digesta of blesbok (isoleucine) and impala (lysine, valine, leucine, threonine, isoleucine, phenylalanine). A similar trend was found in the EAA:Lysine ratios of the whole empty body for the three game species.

Keywords: essential amino acids, whole empty body, game animals

Introduction

Since 80 % of the fat- and moisture-free body of an animal consists of protein, and its constituents (amino acids) are responsible for the synthesis of most body tissues, enzymes, hormones and other metabolic molecules, no animal can grow or produce without a continuous supply of protein. Considerable attention has, therefore, been given to the protein requirements of ruminants and the development of various protein evaluation systems (Erasmus, 1990). The efficiency of protein utilization is, however, not only dependant on the amount of protein supplied in the diet, but also on the balance of amino acids (Cole & Van Lunen, 1994). The undersupply of a single amino acid can depress the production potential of an animal, while the amino acids in excess to the limiting amino acid(s) will be degraded and excreted (wastage of energy and nitrogen) (Cromwell, 1996). Although the amino acid requirements are well defined for non-ruminant species, the information available to allow proper description of requirements for, or production responses to individual amino acids in ruminants is insufficient (Erasmus, 1991; Kung & Rode, 1996).

The ideal protein concept, which is probably best developed for pigs, is a simple and effective approach to estimate amino acid requirements (Fuller & Chamberlain, 1982). According to Boisen *et al.* (2000), the ideal protein can be defined as the perfect ratio among individual amino acids and nitrogen required for optimal performance. Several studies reported that the amino acid composition of lean meat or body protein serves as an example of the amino acid balance of the ideal absorbed protein for growth in mammals (ARC, 1981; Whittemore, 1983; Cole & Van Lunen, 1994). Although the carcass amino acid composition is generally used to determine the amino acid requirements of pigs, sheep and cattle, Ferreira *et al.* (1999a) recommended that the whole empty body (whole body minus contents of stomachs and intestines) should rather be used for this purpose in ruminants. Their study on the growth requirements of South African Mutton Merino lambs showed that the carcass is responsible for only 57 % of the live weight gain. Owens & Pettigrew (1989) also mentioned that using only the carcass amino acid composition for growth requirements fails to include the maintenance needs of the animals.

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Once the amino acid profile of the ideal protein (e.g. carcass, whole empty body, milk) has been established, it can be used indirectly to identify the limiting amino acids in the protein supplied to the animal, in order to achieve a particular productive performance (Chen & Ørskov, 1994). In non-ruminants, dietary protein quality is assessed against the ideal pattern of amino acids (Moughan & Smith, 1987). This approach can, however, not be used in ruminants, because dietary proteins and amino acids are extensively metabolised by the rumen micro-organisms (Fenderson & Bergen, 1975), making it difficult to predict the quality and quantity of amino acids that are absorbed by the animal (Kung & Rode, 1996). Instead, Loëst et al. (1999) rather determined the amino acid patterns of the duodenal digesta content, in order to estimate the amino acid supply to the ruminant.

The recent increase in game farming in South Africa (Eloff, 2001) has placed emphasis on the commercial farming of various game species, especially springbok, blesbok and impala (Jansen van Rensburg, 1992). Since it is generally accepted that game animals are anatomically, physiologically and behaviourally adapted to subsist on the vegetation available in their natural habitat (provided that their movements are not confined) (Nel, 1998), little attention has been given to the dietary requirements of these animals. Nutritional studies on game species are mainly concerned with the foraging strategy (Novellie, 1978; Klein & Fairall, 1986), plant species selected (diet quality) (McAllister & Bornman, 1972; Liversidge, 1972; Grunow, 1980; Kilian & Fairall, 1983), food intake (Voster & Bigalke, 1991; Pietersen et al., 1993) and protein content of the diet (Monro, 1980; Dunham, 1980; Skinner et al., 1983; Meissner et al., 1996). Today, most game ranches/farms are, however, limited in size and force the animals to spend the whole year in the same general area, irrespective of herbage suitability (Nel, 1998). Both this, and the fact that adequate nutrition is essential for optimal growth and production in commercial game farming, emphasizes the need for information on the dietary EAA requirements of game animals.

In an attempt to obtain more information on the EAA requirements of game species, the ideal protein concept can be used to determine the optimal amino acid profile required for growth. In research on game animals, this method has the advantage that it does not necessitate the determination of the diet composition. When game animals occur in their natural habitat, such a determination can be time-consuming and

inaccurate (observations in the veld) (McAllister & Bornman, 1972) or indirect methods, such as microscopic analysis of plant tissues in the rumen samples and faeces, have to be used (Skinner *et al.*, 1983).

The purpose of the present study was to: a) to determine the EAA profile of the whole empty body (ideal protein) of springbok, blesbok and impala and b) to compare this profile with that of the duodenal digesta to detect imbalances for optimal growth of the three game species.

Materials and methods

Animals

The animals (eight springbok, eight blesbok and eight impala) were identical to those described in Chapter 2.

Study areas

The springbok were collected from a mixed farm (sheep and game) in the central Karoo (31°30′S; 22°30′E). According to the Köppen and Thornthwaite climatic classification, this region falls into the desert climate and is cold and dry, with the dry season in the winter (Schulze, 1947). The mean annual rainfall is about 200-250 mm and precipitation is largely confined to the late summer months (Milton & Dean, 1996). The mean air temperature varies between a minimum of 6 °C and a maximum of 24 °C (Anonymous, 1984). The study area is part of the Central Lower Karoo (Veld Type 30) (Acocks, 1988). The landscape is an alternating series of koppies and plains, with an elevation between 1200-1400 m. In this mixed Karoo veld, the vegetation consists of a mixture of shrubs and summer-growing grasses. Autumn is usually the best growing season (Milton & Dean, 1996). *Pentzia incana* (Ankerkaroo) and *Eberlanzia vulnerans* play an important part in the vegetation, while the grasses are predominantly *Stipagrostis obusta* (Small Bushman Grass) and *S. ciliata* (Tall Bushman Grass) (Acocks, 1988).

The blesbok were cropped at a game farm in the northeastern Free State (27°45′S; 29°00′E). The climate is classified as temperate (warm) (Schulze, 1947), with summer

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rainfall consisting mainly of thundershowers. The mean annual rainfall is approximately 700-800 mm and the mean air temperature varies between 8 °C (minimum) and 22 °C (maximum) (Anonymous, 1993). The topography consists of slightly irregular undulating plains with occasional hills. The altitude varies between 1500 m and 2000 m (Eckhardt, *et al.*, 1993). According to Acocks (1988), this area falls into the *Cymbopogon – Themeda* Veld (Veld Type 48), which is part of the short grassveld (Bothma, 1989). The general vegetation can be considered as the *Eragrostis curvula – Themeda triandra* Grasslands that occurs in the rocky outcrops and undulating plains. The dominant graminoid species are *Heteropogon contortus* (Spear Grass), *Themeda triandra* (Rooigras), *Cymbopogon plurinodis* (Narrow-leaved Turpentine Grass), *Eragrostis curvula* (Weeping Love Grass), *E. capensis* (Heart-seed Love Grass), *Aristida junciformis* (Ngongoni Three-awn) and *Elionurus muticus* (Wire Grass). Prominent forbs include *Helichrysum rugulosum*, *H. pilosellum* and *Veronia ligochephala* (Eckhardt, *et al.*, 1993).

The impala were collected from the Overberg Test Range (Denel) near Bredasdorp in the Western Cape (35°45′S; 20°15′E). This area has an arid (steppe) climate and is cold and dry (Schulze, 1947). The minimum mean air temperature is about 14,5 °C and the maximum 21 °C (Anonymous, 1993). The mean annual rainfall is 300-400 mm and precipitation can occur in all the seasons of the year (Milton & Dean, 1996). The altitude of the area ranges from 100 to 300 m. The veld can be classified as Coastal Fynbos (Veld Type 47) and occurs on sand and limestone (Acocks, 1988). Therefore, this vegetation is also referred to as limestone fynbos, or limestone proteoid fynbos, because of the presence of members of the Proteaceae family in the vegetation (Heydenrych, *et al.*, 1994).

Collection and preparation of samples

The same cropping methods were used as in Chapter 2. At slaughter, blood samples were taken and the digesta content of the first 4 m of the small intestine (representing the duodenum) 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 duodenum contains the potential amino acids that could be absorbed by the game animals.

The carcasses were split medially through the vertebrae. 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 twice milled through a carcass mill while still in the frozen state. Representative samples of all the components were mixed, according to weight, to obtain a whole empty body sample. Representative samples of the whole empty body and duodenal digesta were freeze-dried and stored at -10 °C. The dry samples were then milled through a 1 mm screen, thoroughly mixed and again stored at -10 °C.

Sample analysis

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 (A.O.A.C., 1997). Tryptophan was not quantified. However, tryptophan does not appear to be a limiting amino acid for ruminants in the available literature (Nimrick *et al.*, 1970; Richardson & Hatfield, 1978; Storm & Ørskov, 1984; Chen & Ørskov, 1994). The data was compared statistically, following the guidelines from SAS Procedures Guide (1989). Differences between species and sex were tested by means of contrast analyses and estimated least square means ($\pm$SE). There were no differences ($P>0.05$) between sexes in the various parameters measured. Therefore, the data was pooled and only species was considered as the main effect.

Results and discussion

For any animal, ruminant or non-ruminant, the most important single factor affecting the efficiency of protein utilization is the profile of digestible EAA entering the small intestine (Boisen *et al.*, 2000). These EAA arriving in the duodenum originates 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).

The EAA content of the duodenal digesta (g AA/100 g CP) for springbok, blesbok and impala are presented in Table 1. Comparing the three game species with each other, the data suggests that there were differences between the compositions of their duodenal digesta. The reason(s) for these differences can, however, be of a specie or environmental (diet) nature, or both, and therefore no further conclusions can be drawn from this data.

Several authors have reported that the main part of the intestinal amino acids is derived from microbial protein. According to Buttery & Foulds (1985), microbial protein accounts for 60-85 % of the total amino acid nitrogen entering the small intestine of sheep, and for at least 35-66 % in dairy cows (Clark *et al.*, 1992). When the three game species' duodenal digesta are compared to the EAA profile of microbial protein (Table 1), as was reported by Chen & Ørskov (1994), both springbok and blesbok contained lower concentrations of all the amino acids in their duodenal digesta than that in microbial protein. Only the impala's duodenal digesta seemed relatively similar to that of microbial protein, but it still contained lower concentrations of isoleucine, lysine, methionine, phenylalanine and threonine.

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Table 1   Essential amino acid content (mean ± SD) of duodenal digesta (Dd) of springbok, blesbok and impala (n=8) and microbial protein (g AA/100 g CP)

EAA	Dd Springbok	Dd Blesbok	Dd Impala	Microbial Protein[1]
Arg	2.52	4.10	5.86	5.3
SD	± 2.40	± 0.61	± 0.79	
His	1.55	1.67	2.43	2.1
SD	± 0.72	± 0.26	± 0.49	
Iso	3.49	4.07	4.82	5.8
SD	± 0.84	± 0.45	± 0.13	
Leu	6.15	6.66	8.49	8.0
SD	± 1.81	± 0.87	± 0.49	
Lys	6.95	6.02	7.74	9.2
SD	± 2.34	± 0.65	± 1.16	
Met	1.30	1.02	1.77	2.5
SD	± 0.53	± 0.23	± 0.19	
Phe	3.73	3.63	4.80	5.3
SD	± 0.49	± 0.59	± 0.28	
Thr	2.18	3.79	4.25	5.7
SD	± 1.14	± 0.38	± 0.10	
Val	4.61	4.81	5.87	5.8
SD	± 0.57	± 0.48	± 0.27	

[1] Data from Chen & Ørskov (1994)

According to Schwab (1996a), amino acids are joined together during the *de novo* synthesis of proteins, based on a predetermined genetic code. Therefore, the amino acid composition of a protein is the same every time it is synthesized. Gilka *et al.* (1989) also reports that the composition of muscle protein is genetically determined and not subjected to change, even if conditions during growth (e.g. the quality and quantity of the diet or health status) are different. Since the amino acid composition of the whole empty body is genetically determined and most likely not influenced by

diet, the EAA content of the whole empty body of the three game species, which serve as the ideal EAA requirement for growth, are presented in Table 2.

Table 2   **Essential amino acid content (mean ± SD) of whole empty body of springbok, blesbok and impala (n=8) and sheep and cattle (g AA/100 g crude protein)**

EAA	Springbok	Blesbok	Impala	Sheep[1]	Sheep[2]	Cattle[3]
Arg	6.87[a]	6.76[a]	6.16[b]	7.7	8.4	6.6
SD	± 0.33	± 0.54	± 0.30			
His	2.93[a]	2.58[b]	2.76[ab]	4.5	2.1	2.5
SD	± 0.17	± 0.18	± 0.32			
Iso	3.80[b]	4.02[b]	4.39[a]	3.1	3.2	2.8
SD	± 0.18	± 0.38	± 0.11			
Leu	8.15[a]	7.74[b]	8.0[ab]	8.5	6.4	6.7
SD	± 0.20	± 0.31	± 0.24			
Lys	8.10[a]	7.47[b]	7.32[b]	6.5	6.3	6.4
SD	± 0.12	± 0.52	± 0.36			
Met	1.94[ab]	1.83[b]	2.02[a]	3.6	1.8	2.0
SD	± 0.11	± 0.16	± 0.19			
Phe	4.02[b]	3.93[b]	4.31[a]	5.2	3.5	3.5
SD	± 0.09	± 0.21	± 0.23			
Thr	3.96	3.88	3.97	4.7	3.8	3.9
SD	± 0.21	± 0.24	± 0.14			
Val	4.84[b]	4.96[b]	5.53[a]	5.2	4.1	4.0
SD	± 0.12	± 0.53	± 0.25			

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

[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)

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

From Table 2 it is apparent that there were differences (P<0.05) between the concentrations of individual amino acids (except threonine) when all three game species were compared. There was, however, no definite trend in these differences.

Comparing only two species at a time, springbok and blesbok's whole empty body differed (P<0.05) on three amino acids (histidine, leucine, lysine) of which the concentrations were higher in springbok than in blesbok. There were five amino acids differing (P<0.05) in concentrations when springbok is compared to impala (arginine, iosleucine, lysine, phenylalanine, valine) and of blesbok compared to impala (arginine, isoleucine, methionine, phenylalanine, valine).

When comparing the whole empty body EAA composition of the three game species with that of domesticated species (sheep and cattle), it seemed that the three game species had higher concentrations of most of the amino acids in the whole empty body (Table 2). Only sheep had higher arginine concentrations and both wool-free sheep and cattle had similar concentrations of methionine and threonine in their whole empty body than that of the three game species. When the EAA composition of wool was included in the whole empty body composition, the concentration of especially methionine, phenylalanine and threonine (that are high in wool) were higher than in the game species. Thus, the present study shows that there are differences between the whole empty body concentrations of different animal species. This is in contrast to Smith (1980) who stated that the amino acid composition of the bodies of animal species is remarkably similar. Therefore, the present study also confirms the necessity to determine the amino acid composition of the body for specific species (Loëst et al., 1997).

In order to identify a first- and second-limiting amino acid for growth of the three game species, the chemical score and resulting EAA index was calculated (Table 3). The chemical score presents the proportion of a specific amino acid relative to that of the whole empty body, while the amino acid index represents the proportion of the nine essential amino acids (tryptophan excluded) relative to that of the whole empty body protein (Loëst et al., 1999).

Table 3   Chemical score and essential amino acid index for duodenal digesta of springbok, blesbok and impala (n=8)

EAA	Chemical score[1] Springbok	Chemical score[1] Blesbok	Chemical score[1] Impala
Arg	37.8	60.7	95.4
SD	± 38.4	± 7.7	± 13.8
His	53.5	64.4	88.2
SD	± 25.5	± 7.6	± 16.7
Iso	92.0	102.2	109.7
SD	± 22.3	± 15.4	± 3.7
Leu	75.5	86.0	106.1
SD	± 22.1	± 9.3	± 5.7
Lys	85.9	80.6	105.8
SD	± 28.9	± 6.5	± 15.5
Met	67.3	55.7	87.5
SD	± 28.3	± 11.2	± 8.0
Phe	93.1	92.6	111.4
SD	± 13.3	± 15.4	± 6.6
Thr	55.4	98.1	107.4
SD	± 29.6	± 10.3	± 4.7
Val	95.4	98.0	106.1
SD	± 12.2	± 15.2	± 4.1
EAA (Index)[2]	72.9	81.8	96.8

[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 EAAs studied relative to that of whole empty body protein

The chemical scores in Table 3 suggest that the first- to fourth-limiting amino acid (only three are limiting in impala) for growth in the duodenal digesta of the three game species are as follows: springbok (arginine, histidine, threonine, methionine), blesbok (methionine, arginine, histidine, lysine) and impala (methionine, histidine, arginine). More than adequate ratios are presented for isoleucine in blesbok and lysine, valine, leucine, threonine, isoleucine and phenylalnine in impala. It is

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interesting to notice the similarity between the limiting amino acids in die duodenal digesta of the three game species. Both arginine and histidine are first-, second- or third-limiting, while methionine is first-limiting in blesbok and impala but only fourth-limiting in springbok. The reasons for this shift in order of limitation of amino acids are most likely due to the differences in the concentration of these amino acids in the duodenal digesta (diet) (Table 1) and/or the whole empty body (genetic) (Table 2). The high SD-values in Table 3 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 synthesized or released at adequate rates to meet arginine requirements (Zinn & Owens, 1993). Furthermore, histidine requirements may also be overestimated by 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 emphasized that tissue chemical scores overestimate histidine requirements by 25-50 % (Izquierdo et al., 1988; Chung & Baker, 1992). Erasmus (1999) also stated that methionine and lysine are the first and second limiting amino acids in ruminally synthesized 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 seemed 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 diet high in rumen degradable 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 was the sole source of protein.

Thus, there was a 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 (irrespective of the order of limitation). The fact that lysine was second-limiting for

sheep and cattle could, however, not be confirmed in the present study, as was also the case with Ferreira *et al.* (1999b).

Based on the EAA index (Table 3), the duodenal digesta of the springbok contained only 72.9 % of the total EAA needed by the whole empty body for optimal growth. The blesbok (81.8 %) and impala (96.8 %) had higher indexes than the springbok, but these values were still below the optimum (100 %). Both the chemical score and the EAA index therefore indicated that the EAA patterns of the duodenal digesta were disproportionate to that of the whole empty body of the three game species. Although the EAA index of the impala was very high, six of the nine EAA concentrations measured occurred in excess of that required in the whole empty body (ideal amino acid balance) and could have negative effects. According to Loëst *et al.* (1999), focus should not only be placed on limiting amino acids, but also on EAAs 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 utilization. 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 utilization 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, 1996b), wool growth in sheep (Reis & Tunks, 1976) and body weight gain in cattle (Titegmeyer *et al.*, 1988; Veira *et al.*, 1991) 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.

A direct comparison of the essential amino acid composition, regardless of protein quantity, can be provided by expressing the values for the whole empty body as a percentage of lysine (Table 4). If the requirement for one EAA (e.g. lysine) is known in the ruminant body, the requirements of the other EAAs may be estimated from the

EAA to lysine ratio (Willams & Hewitt, 1979). According to Baker & Han (1994), a multitude of dietary factors, (e.g. protein and energy levels, feed intake), environmental factors (e.g. disease, crowding, feeder space, heat stress) and genetic factors (e.g. sex, capacity for lean vs. fat growth) may effect amino acid requirements, but the ideal ratio of EAAs to lysine should remain largely unaffected by these variables.

Table 4 **Whole empty body essential amino acids expressed as a percentage of lysine for springbok, blesbok and impala (n=8)**

EAA	EAA:Lysine[1] Springbok	EAA:Lysine[1] Blesbok	EAA:Lysine[1] Impala
Arg	84.9[b]	90.5[a]	84.1[b]
SD	± 3.2	± 4.8	± 2.0
His	36.1[ab]	34.6[b]	37.7[a]
SD	± 2.2	± 1.2	± 3.9
Iso	46.9[c]	54.0[b]	60.1[a]
SD	± 2.0	± 6.8	± 3.8
Leu	100.6[b]	103.8[b]	109.3[a]
SD	± 1.9	± 6.2	± 3.1
Lys	100.0	100.0	100.0
SD	± 0.0	± 0.0	± 0.0
Met	24.0[b]	24.6[b]	27.6[a]
SD	± 1.2	± 1.9	± 2.3
Phe	49.6[b]	52.8[b]	58.9[a]
SD	± 1.1	± 5.2	± 2.0
Thr	48.8[b]	52.0[ab]	54.3[a]
SD	± 2.2	± 3.6	± 3.6
Val	59.8[c]	66.6[b]	75.6[a]
SD	± 1.7	± 8.6	± 3.4

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

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

The comparison of individual EAA:Lysine ratios (Table 4) indicated that there were differences (P<0.05) between the whole empty body of the springbok, blesbok and impala, irrespective of protein quantity. Although these differences between the three game species were not the same as that found in Table 2 (where the EAA content was expressed as a percentage of protein), Table 4 confirmed that the amino acid composition of the whole empty body of the game species did differ from each other. It seems that, except for arginine and histidine, the largest differences were between the whole empty body of the springbok and impala. There wss, however, a similar trend in the EAA:Lysine ratios for the three game species, with only leucince having a more than 1:1 ratio.

When the EAA:Lysine ratios of the three game species were compared to that of sheep and pigs (in the literature), no similarities could be found. The sheep had higher EAA:Lysine values for all the amino acids, except for isoleucine (Ferreira *et al.*, 1999b). Although the pig whole empty body had closer values to that of the three game species than sheep, there were still relatively large differences between most of the EAAs (Moughan & Smith, 1987). Once again, this information suggests that the amino acid profile of the whole empty body of various animal species are not the same and might therefore be due to genetic differences (Schwab, 1996a; Gilka *et al.*, 1989). It should, however, be mentioned that in studies with pigs, it was found that the tissue amino acid pattern may be somewhat modified by the diet. Yet, it was not clear whether these changes are specifically related to individual amino acid deficiencies or are simply a consequence of slow growth (Fuller, 1994).

Conclusion

In this study, under these circumstances, there was a substantial difference between the EAA concentration of the duodenal digesta of the springbok, blesbok and impala (determined in the present study) and that of the mean microbial protein values in the literature. The differences can be ascribed to possible variations in the dietary protein as well as in the rumen microbial population (Boisen *et al.*, 2000).

It was concluded that the three game species differenced (P<0.05) in terms of the EAA composition of the whole empty body. This was true, whether the EAAs were expressed as a percentage of crude protein or as a percentage of lysine. Even larger differences were found in the whole empty body amino acid profile when the three game species were compared to domesticated species (sheep and cattle). Therefore, the present study does not support the view in the literature that the amino acid composition of the bodies of various animal species is the same.

The results also revealed that, according to the ideal protein concept, the duodenal digesta of springbok, blesbok and impala were limiting in basically the same amino acids for whole empty body growth, although not in the same order. In all three the game species arginine, histidine and methionine were one of the four most limiting amino acids. Except for lysine, these limiting amino acids were the same as for other growing ruminants (Nimrick et al., 1970; Richardson & Hatfield, 1978; Storm & Ørskov, 1984; Chen & Ørskov, 1994; Ferreira et al. 1999b). A number of amino acids also appeared to be in excess for whole empty body growth in the duodenal digesta of blesbok and impala. Excess levels of amino acids in the diets of pigs and chickens have resulted in growth depressions and reduced feed intake (Edmonds et al., 1987; D'Mello, 1994), and thus need attention in further research.

In order to correct the essential amino acid supply to the duodenum of the three game species, further investigations should focus on the modification/supplementation of the specific diet of each individual species. In turn, this will result in more appropriate essential amino acid patterns and could possibly enhance the efficiency of utilization of absorbed amino acids for maintenance and growth (Loëst et al., 1999). In future studies a larger number of animals should also be used to verify the current study's results for amino acid requirements of the three game species under extensive farming practices.

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Chapter 4

General Conclusion

The productive capacity of any animal is highly dependent on the satisfaction of the animal's nutritional requirements. Since the production of game meat is very important in commercial game farming, information on the body component distribution, carcass chemical composition and the whole empty body EAA requirements of various game species are essential for effective management on any game farm.

Reviewing the existing literature revealed that the determined body and carcass weight and the dressing percentage (as a % of body weight) of the springbok (31.3 ± 5.1 kg; 17.9 ± 3.1 kg; 57.1 ± 2.4 %) and impala (38.5 ± 7.9 kg; 22.2 ± 5.0 kg; 57.4 ± 2.2 %) were in accordance with previous estimations (Van Zyl, 1968; Van Zyl et al., 1969; Von la Chevallerie, 1970; Hoffman, 2000). The same measurements for the blesbok (53.3 ± 7.9 kg; 26.8 ± 4.3 kg; 50.2 ± 2.1 %) were, however, lower in the present study than that reported previously (70 kg, 38.7 kg; 52.9 %) (Von la Chevallerie, 1970; Huntley, 1971; Kroon et al., 1972). When the physical composition of the three game species was expressed as a % of empty body weight (more accurate for comparisons than expressed as a % of live weight), these compositions followed a similar pattern. Male animals had a lower (P<0.05) kidney fat and a higher (P<0.05) external offal percentage in the whole empty body than the females. The lower (P<0.05) cold carcass percentage in blesbok (62.8 %), compared to that of the impala (65.6 %), is most probably due to the much higher contribution (P<0.05) of the blesbok's head (8.1 %) than that of the springbok (6.3 %) and impala (5.5 %) The above-mentioned data confirmed that the three game species have a high potential for meat production (high dressing percentage), as well as the production of edible products. The carcass nitrogen contribution of the three game species (57.3-62.8 %) was much higher than the reported concentrations for domesticated sheep (38.4-49.2 %) (MacRae et al. 1993; Ferreira et al. 1999). Differences were found between the fat and moisture percentages in the carcass and three-rib cut of males and

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females, with the females having higher (P<0.05) fat and lower (P<0.05) moisture percentages than the males. It was also concluded that the three-rib cut might be used as a predictor of the carcass chemical composition in springbok, blesbok or impala, because only the fat percentage of the three-rib cut was related (P<0.05) to that in the carcass, across species and sexes.

A comparison between the EAA profile of the duodenal digesta of the springbok, blesbok and impala and that of microbial protein (Chen & Ørskov, 1994), showed that the three game species contain lower concentrations of the amino acids in their duodenal digestas. The differences (P<0.05) found in the EAA composition of the whole empty body of the three game species suggested that the body amino acid composition of various animal species is not the same, as was mentioned by Smith (1980). According to the ideal protein concept, the disproportionate duodenal digesta composition of the three game species was limiting in basically the same EAAs for whole empty body growth, while some amino acids appeared to be in excess. The first- to fourth-limiting amino acid (only three are limiting in impala) in the duodenal digesta of the three game species was as follows: arginine, histidine, threonine, methionine (springbok); methionine, arginine, histidine, lysine (blesbok); and methionine, histidine, arginine (impala). Future studies should keep variations to the minimum by including a larger number of animals for each game species.

In order to achieve the ideal protein at the duodenal level, it is necessary to supplement the current diets of the game animals with the appropriate proteins and/or amino acids. Much attention has been given to the inclusion of feedstuffs that are chemically or physically treated to be sources of rumen undegradable amino acids in the dietary supplementations given to domestic ruminants (Titgemeyer et al., 1989; Atwell et al., 1991; Merchen & Titgemeyer, 1992; Benchaar et al., 1993; Kung & Rode, 1996). It is recommended that future research should focus on the application of these supplementation strategies to game animal nutrition and also on the revision of the composition of the currently available game lick blocks. Meeting the protein requirements of game animals could result in the improvement of their body composition and growth rate, higher reproductive rates, larger trophies and consequently in more economically viable game farming enterprises.

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