MEAT QUALITY OF KUDU (*TRAGELAPHUS STREPSICEROS*) AND IMPALA (*AEPYCEROS MELAMPUS*)

By

ANALENE C. MOSTERT

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Study Supervisor: Prof L.C. Hoffman

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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 other university for a degree.

Signature:_____

Date: _____

SUMMARY

Although kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*) are found in the same geographical area, there is variation in their diets as kudu are predominantly browsers, feeding on tree and shrub leaves, while impala are known as mixed feeders as they graze and browse. Therefore this poses the question whether the diet would influence their meat quality. The objective of this investigation was to evaluate the physical measurements and chemical composition of *M. longissimus dorsi*, *M. biceps femoris*, *M. semimembranosus, M. semitendinosus* and *M. supraspinatus* for kudu and impala, two southern African antelope species. The effects of age (adult and sub-adult) and gender (male and female) were also determined. The sensory characteristics of the *M. longissimus dorsi* muscle for sub-adult kudu and impala were investigated. Correlations between the various physical measurements and chemical composition of the meat were verified. Physical measurements and chemical composition of the *M. longissimus dorsi* muscle were tested for correlations with the sensory ratings of the meat.

Dressing percentage of impala (59.88%) (n=28) was higher than that of kudu (57.60%) (n=35). The main effects (species, gender and age) showed no differences for drip loss and cooking loss. However, muscles differed in terms of cooking loss with impala *M. semitendinosus* having the highest (38.28%) value and kudu *M. longissimus dorsi* having the lowest value (30.77%). For impala, the highest Warner–Bratzler shear (WBS) values were measured for *M. semimembranosus* (5.90 kg/1.27cmø), followed by *M. biceps femoris, M. longissimus dorsi,* and *M. semitendinosus* with the lowest WBS values measured for *M. supraspinatus* (3.61 kg/1.27cmø). All impala muscles had lower L* values and appeared darker in colour than kudu muscles, except for *M. supraspinatus*. Adult animals also had lower L* values than the sub-adult group. Kudu had significantly higher a* and b* values (more red) than impala. Chroma values were higher for kudu, thus appearing brighter in colour. The respective muscles of kudu and impala investigated differed significantly in terms of physical characteristics. However, gender and age did not have an effect on the physical measurements.

Moisture content was higher in kudu meat (76.46%) than in impala meat (75.28%). Muscles differed for both moisture and fat content. The highest fat was found in *M. supraspinatus* followed by *M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus* and *M. longissimus dorsi*. Protein content did not differ between species (kudu: 21.66%; impala: 22.26%), gender (male: 21.98%; female: 21.95%) and age groups (adult: 21.74%; sub-adult: 22.18%). Kudu *M. longissimus dorsi* (1.62%) had lower fat content than impala *M. longissimus dorsi* (2.22%) and female animals had a higher fat content than male animals. Sub-adults (1.20 ± 0.02%) had higher ash content than adults (1.10 ± 0.03%). The *M. supraspinatus* had the lowest protein

and also the highest fat content, with *M. semimembranosus* having the lowest fat content but the highest value for protein.

Myoglobin content did not differ between species, although females had higher (6.58 ± 0.20 mg/g) myoglobin content than males (5.11 ± 0.25 mg/g). Glycolitic muscles had the lowest myoglobin content with the highest values found in *M. supraspinatus*, an oxidative muscle. An interaction was noted between species and muscle for myoglobin content. Myoglobin content in impala *M. longissimus dorsi* was higher than that in kudu *M. longissimus dorsi*; however for all other muscles the myoglobin content was lower in impala.

Gender did not affect mineral content. Potassium levels were highest for kudu while phosphorus was more prevalent in impala meat. Adult and sub-adult groups differed in terms of potassium, calcium and zinc content. Potassium and calcium content were higher for sub-adult animals while zinc content was higher in adult animals.

In impala meat, stearic acid (22.67%) was the major fatty acid, followed by palmitic acid (16.66%). In contrast, oleic acid (24.35%) was the most profuse fatty acid in kudu, followed by linoleic acid (22.95%). The SFA's as a percentage of the total fatty acids differed between impala (51.12%) and kudu meat (34.87%). Kudu meat had a higher concentration of total PUFA (38.88%) than impala (34.06%) meat. The PUFA: SFA ratio for kudu meat (1.22) was more favourable than that for impala meat (0.73). The ratio of n-6 PUFA's to n-3 PUFA's for kudu and impala were determined as 2.22 and 3.76 respectively. From the current findings it is evident that kudu and impala meat have advantageous fatty acid profiles and can be a healthy substitute for other red meats.

Kudu meat (72.62 ± 1.86 mg/100g) had higher cholesterol than impala meat (55.35 ± 1.84 mg/100g). It is recommended that further studies be done in order to confirm the cholesterol content of kudu meat.

Within species, no gender differences for any of the sensory characteristics tested were noted. The impala meat had a more intense game aroma than the kudu meat, while kudu meat was found to be more juicy than impala meat. It can therefore be concluded that the marketing of game meat should be species-specific as there are distinct flavour and aroma differences between kudu and impala meat.

OPSOMMING

Alhoewel koedoes (*Tragelaphus strepsiceros*) en rooibokke (*Aepyceros melampus*) in dieselfde geografiese area voorkom, is daar variasie in hulle diëte. Koedoes is hoofsaaklik blaarvreters, terwyl rooibokke bekend staan as gemengde vreters aangesien hulle gras- sowel as blaarvreters is. Die vraag ontstaan dus of die verskil in diëet die kwaliteit van hulle vleis sal beïnvloed. Die doel van hierdie ondersoek was dus om die fisiese metings en chemiese samestelling van die *M. longissimus dorsi*, *M. biceps femoris*, *M. semimembranosus, M. semitendinosus* en *M. supraspinatus* vir koedoes en rooibokke te bepaal. Die invloed van ouderdom (volwasse en onvolwasse) en geslag (manlik en vroulik) op hierdie eienskappe is ook geëvalueer. Die sensoriese eienskappe van die *M. longissimus dorsi* van onvolwasse koedoes en rooibokke is ook ondersoek. Korrelasies tussen die fisiese metings en chemiese samestelling van die vleis is ondersoek. Die fisiese metings en chemiese samestelling van die *M. longissimus dorsi* is getoets vir korrelasies met die resultate van die sintuiglike evaluering van die vleis.

Die gemiddelde uitslagpersentasie van rooibokke (59.88%) (n=28) was hoër as die van koedoes (57.60%) (n=35). Daar was geen verskille in drupverlies en kookverlies vir die hoofeffekte (spesie, geslag en ouderdom) nie. Spiere het wel verskil in terme van kookverlies, met die hoogste waarde gemeet vir rooibok *M. semitendinosus* (38.28%) en die laagste waarde vir koedoe *M. longissimus dorsi* (30.77%). In rooibokke was die hoogste Warner-Bratzler skeurkrag waardes gemeet vir *M. semimembranosus* (5.76 kg/1.27cmø), gevolg deur *M. biceps femoris, M. longissimus dorsi,* en *M. semitendinosus* met die laagste Warner-Bratzler skeurkrag waardes gemeet vir *M. supraspinatus* (3.78 kg/1.27cmø). Alle rooibokspiere het laer L* waardes gehad en was donkerder van kleur as koedoespiere, behalwe vir *M. supraspinatus*. Laer L* waardes is ook verkry vir volwasse diere in vergelyking met onvolwasse diere. Die a* en b* waardes was hoër in koedoe- as in rooibokvleis, m.a.w. koedoevleis het rooier vertoon. Die onderskeie koedoe- en rooibokspiere het betekenisvol verskil in terme van fisiese eienskappe, terwyl geslag en ouderdom geen effek op die fisiese eienskappe gehad het nie.

Voginhoud was hoër in koedoe- (75.52%) as in rooibokvleis (74.52%). Verkille tussen spiere is opgemerk vir beide vog- en vetinhoud. *M. supraspinatus* het die hoogste vetinhoud gehad, gevolg deur *M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus* en *M. longissimus dorsi*. Geen verskille is opgemerk tussen spesies (koedoe: 21.66%; rooibok: 22.26%), geslagte (manlik: 21.98%; vroulik: 21.95%) en ouderdomme (volwasse: 21.74%; onvolwasse: 22.18%) in terme van proteïeninhoud nie. Die vetinhoud van koedoe *M. longissimus dorsi* (1.62%) was laer as dié van rooibok *M. longissimus dorsi* (2.22%) en die vetinhoud van vroulike diere was hoër as dié van manlike diere. Onvolwasse diere (1.20 ± 0.02%) het ‘n hoër asinhoud as dié van volwasse diere (1.10 ± 0.03%) getoon. In terme van die onderskeie

spiere het *M. supraspinatus* die laagste proteïen- en die hoogste vetinhoud gehad, terwyl *M. semimembranosus* die laagste vet- en die hoogste proteïeninhoud gehad het.

Die mioglobieninhoud was nie beïnvloed deur spesie nie, terwyl vroulike diere ‘n hoër (6.58 ± 0.20 mg/g) mioglobieninhoud as manlike diere (5.11 ± 0.25 mg/g) gehad het. Die *M. supraspinatus*, ‘n oksidatiewe spier het die hoogste mioglobieninhoud gehad, terwyl glikolitiese spiere die laagste mioglobieninhoud gehad het. ’n Interaksie tussen spesie en spier was opgemerk vir mioglobieninhoud. Rooibok *M. longissimus dorsi* het ‘n hoër mioglobieninhoud as koedoe *M. longissimus dorsi* gehad, terwyl die mioglobieninhoud vir al die ander spiere laer was in rooibokke.

Mineraalinhoud was nie deur geslag beïnvloed nie. Kaliumvlakke was hoër in koedoevleis, terwyl fosforvlakke hoër was in rooibokvleis. Kalium- en kalsiuminhoud was hoër in onvolwasse diere terwyl die sinkinhoud hoër was in volwasse diere.

Steariensuur (22.67%), gevolg deur palmitiensuur (16.66%) was die mees algemene vetsure in rooibokvleis. In teenstelling hiermee was oleïensuur (24.35%), gevolg deur linoleïensuur (22.95%) die mees algemene vetsure in koedoevleis. Die totale versadigde vetsure was laer in koedoevleis (34.87%) in vergelyking met rooibokvleis (51.12%), terwyl die totale poli-onversadigde vetsure in koedoevleis (38.88%) hoër was as dié van rooibokvleis (34.06%). Die verhouding van *n*-6 tot *n*-3 poli-onversadigde vetsure vir koedoe en rooibok was 2.22 en 3.76 onderskeidelik. Hierdie resultate bevestig dat koedoe- en rooibokvleis oor ‘n vetsuurprofiel beskik wat ’n gesonde alternatief bied tot ander rooivleise.

Die cholesterolinhoud van koedoevleis (72.62 ± 1.86 mg/100g) was hoër as dié van rooibokvleis (55.35 ± 1.84 mg/100g). Dit word egter aanbeveel dat verdere studies gedoen word om die cholesterolinhoud van koedoevleis te bevestig.

Binne spesies was daar geen geslagsverkille vir enige van die sensoriese eienskappe nie. Rooibokvleis het ‘n meer intense wildsvleis aroma as koedoevleis gehad, terwyl koedoevleis meer sappig was as rooibokvleis. Hierdie resultate dui daarop dat die bemarking van wildsvleis spesie-spesifiiek moet wees aangesien daar defnitiewe geur en aroma verskille tussen koedoe- en rooibokvleis is.

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LIST OF ABBREVIATIONS

pH_u	Ultimate (final) pH reading at 24 hours post-mortem
DFD	Dark, firm and dry
PSE	Pale, soft and exudative
LD	*M. longissimus dorsi*
BF	*M. biceps femoris*
SM	*M. semimembranosus*
ST	*M. semitendinosus*
SS	*M. supraspinatus*
WHC	Water-holding capacity
WBS	Warner-Bratzler shear
SFA	Saturated Fatty Acid
MUFA	Monounsaturated Fatty Acid
PUFA	Polyunsaturated Fatty Acid

NOTES

The language and style used in this thesis are in accordance with the requirements of the Scientific Journal, Meat Science. This thesis represents a compilation of manuscripts where each chapter is an individual entity and therefore repetition may occur between some chapters.

Results from this study have been presented at the following symposiums:

Mostert, R. & Hoffman, L.C. 2005. Is the kudu male superior to the female from a meat composition viewpoint? Symposium of the South African Wildlife Management Association. Magoebaskloof (2-4 October).

Van Essen, R. 2007. Game Meat Quality. Does it really matter? Symposium of the South African Wildlife Management Association. Drakensberg (18-21 September).

An additional data set of kudu meat from a different region was analysed and the results have been published in the following journal:

Mostert, R. & Hoffman, L.C. 2007. Effect of gender on the meat quality characteristics and chemical composition of kudu (*Tragelaphus strepsiceros*), an African antelope species. Food Chem. 104, 565–570.

However, to maintain the flow of the thesis this chapter was omitted from the final thesis but was included as an addendum.

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Chapter 1

INTRODUCTION

In the past wildlife had no monetary value, since game species were regarded as competition to domestic livestock for valuable grazing. However, certain species such as eland and springbok feed on plants and shrubs not eaten by domestic stock. Since only 23.3% of agricultural land in South Africa has a high production potential, farmers on marginal land were faced with finding an economically viable use for their land. It was during this period that the wildlife ranching industry was born. At first game ranching was restricted by ownership of wildlife. Since legislation was changed and ownership of wildlife was transferred from the state to the landowner, the industry has developed rapidly. Where the wildlife numbers were declining at the beginning of the previous century, there are currently more wildlife than at any time during the past 100 years (Bothma, 2002).

In southern Africa, game has been hunted for many years and the meat used for human consumption. Indigenous animal species have also been utilised as a food source in many other areas of the world. It is however paradoxical that on a continent with the greatest variety of land mammals, the diet of the major part of the population is protein deficient. There is great potential in using wild animals to supplement domestic livestock as a source of meat in Africa's developing countries (Bender, 1992). However, game animals are unlikely to compete directly with domestic animals as meat producers, as the evidence so far indicates that game animals are not as efficient in converting feed into live weight (Skinner, 1970).

During the late 80's, game meat in excess of 800 tonnes were exported annually from South Africa to Europe. In 1991 the game meat export market collapsed and during 1993 and 1994 South Africa was struck by a severe drought (Ebedes & Meyer, 2002). At present the export market is slowly re-emerging and it is estimated that deboned meat from 160 000 carcasses was exported during the 2005 season (Hoffman & Wiklund, 2006). Worldwide there is a tendency towards more natural and healthy food products. Meat that is free from antibiotics and growth stimulants are becoming more popular (Eloff, 2002).

The consumer is willing to pay more for meat that is free of microorganisms, antibiotics and hormones (Issanchou, 1996). South African game meat is still untamed and seen as organic. It therefore has the ability to distinguish itself from the domesticated game species from Australia, New Zealand and Europe (Hoffman & Bigalke, 1999).

Baseline data is required by the game industry to establish whether game meat products will meet the needs of modern markets and consumers. Restricted data is available on meat quality of

African game species. It is therefore imperative that the effects of physical, chemical and sensory characteristics on game meat quality be researched. Various authors have studied the meat of springbok (Veary, 1991; Jansen van Rensburg, 1997; Hoffman *et al.*, 2007). Some research has been conducted on impala (Hoffman, 2000a, b; Hoffman *et al.*, 2005). However, little data is available on kudu meat.

As these two species are important, not only for export, but also for local consumption, the nutritional value of the meat from these two species needs to be determined and the effect of know factors, such as gender and age, on these values quantified. This study therefore evaluates the effect of age and gender on five of the major muscles found in these two species.

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Chapter 2

Literature Review

THE GAME RANCHING INDUSTRY IN SOUTH AFRICA

In South Africa, game ranching continues to grow in popularity and more and more cattle farms are being game fenced and converted to game ranches or conservancies (Ebedes, 2002). A major reason for conversion to game ranching is poor profits realised from beef and other conventional farming operations. By August 1998 an estimated 2300 game ranches existed in the Northern Province (now Limpopo) of South Africa alone. These ranches covered an area of approximately 3.6 million hectares (Van der Waal & Dekker, 2000). Van Zyl (2000) estimated that between 17 and 18 million hectares of the country is being utilised for game farming purposes and still the industry is growing at a rate of 2.5% per year. The South African agriculture and conservation authorities have recognised game farming as a *bona fide* form of agricultural land use (Eloff, 2002). In 2005 it was estimated that ± 9000 farms were utilised for wildlife production. A further 15000 were used for a combination of wildlife production and cattle farming (Patterson & Khosa, 2005). Most of South Africa's exempted wildlife ranches are found in the Limpopo Province (49%), followed by the Northern Cape Province (19.5%) and the Eastern Cape Province (12.3%). However the mean size of a game ranch in the Northern Cape Province is 4920 ha compared to 1340 ha in the Limpopo Province.

Conroy & Gaigher (1982) define game ranching as the "economic use of game within the farm confines". According to Teer *et al.* (1993), game ranching is limited to free-ranging wildlife, usually on private property. Bothma (2002a) proposed a definition for game ranching to be "the managed extensive production of free-ranging wildlife on large, fenced or unfenced private or communal land for recreational hunting, wildlife products, tourism, live sales of wildlife to restock other areas, and for other non-consumptive uses". This is in contrast with game farming which is described by Bothma (2002a) as the "managed intensive production of wildlife in small, fenced enclosures on private or communal land for the production of marketable products and live animal sales". The well-established deer industry in New-Zealand is an example of game farming, while mostly game ranching is pursued in southern Africa. However, scarce species such as roan and sable antelope are bred in intensive production systems in South Africa which is a typical game farming enterprise.

When comparing the different aspects of utilisation on a game ranch, Berry (1986) stated that wildlife can be utilised in either a consumptive or a non-consumptive way. Consumptive utilisation includes trophy hunting, recreational or biltong hunting, live capture and live sales and game meat production. Game meat production is considered the harvesting or culling of game

for the production of meat. Non-consumptive utilisation is concerned with the provision of services to tourists such as game viewing, bird watching and wildlife photography and has become known as eco-tourism. When comparing the net revenue from the four pillars of consumptive utilisation, trophy hunting gives the highest net return on capital. This was followed by biltong or recreational hunting, live sales and lastly game meat production. When calculating the net weighted values, meat production was the most profitable followed by live sales and biltong hunting. Taking into account the low percentage of trophy animals on a particular game ranch, trophy hunting gives the lowest return per unit area. For instance, a kudu bull only reaches trophy status at an age of 8 years and older (Furstenburg, 2002) and there are only a small percentage of trophy animals on a given game ranch. Van der Merwe & Saayman (2004) describe the four pillars of game ranch tourism as eco-tourism, hunting (biltong and trophy), live game sales and game products.

In 2000 Van der Waal and Dekker estimated the annual turnover of the game ranching industry in the Northern Province (now Limpopo) alone to be in the region of R 221 million. The largest contribution was from hunting, followed by live sales and ecotourism. Game meat production contributed only 3.7% (R 7 million) to the annual turnover. The latest figures from the National Agriculture Marketing Committee (NAMC) showed the annual turnover of the game ranching industry in South Africa to be in the range of R 4.7 billion (Table 1). Meat production attributed the smallest percentage (1%) to the total turnover with live sales second lowest at 2% (Anon, 2007a).

Table 1. Contribution of different utilisation categories to the annual turnover of the game ranching industry in South Africa.

	Turnover (R million)	**Percentage (%)**
Biltong hunting	3 100	66
Translocation	750	16
Trophy hunting	510	11
Taxidermy	200	4
Live sales	94	2
Meat production	42	1
TOTAL	4 696	100

(Anon, 2007a)

In recent years auction prices for the more common game species have reached a plateau (Eloff, 2002). In Limpopo Province, the heads of game sold increased from 6802 in 2003 to 9163 in 2004. However, the monetary value decreased from R 39 million in 2003 to R 35 million in 2004 (Eloff, 2005). When considering the whole of South Africa, the heads of game sold increased from 8292 to 20022 since 1991 with an increase in turnover from R 8.9 million to R 105.1 million in 2002. However since 2002, animals sold decreased to 17569 with a turnover of R 93.5 million in 2005 (Anon, 2007a).

Biltong hunting is still the biggest earner of income for the game ranching industry. When considering the number of animals hunted, the species preferred by biltong hunters is springbok (*Antidorcas marsupialis*), followed by impala (*Aepyceros melampus*), blesbok (*Damaliscus dorcas phillipsi*), kudu (*Tragelaphus strepsiceros*), warthog (*Pachochoerus africanus*) and blue wildebeest (*Connochaetus gnou*), in that order (Table 2) (Van der Merwe & Saayman, 2005).

Table 2. Income generated and numbers of animals hunted by biltong hunters.

Species	Number Hunted	Total Generated (R)	Average Price (R)
Nyala	34	243 500	7 161.76
Eland	229	1 049 200	4 581.65
Waterbuck	52	228 900	4 401.92
Zebra	106	345 970	3 263.86
Kudu	**1 013**	**2 512 780**	**2 480.53**
Blue Wildebeest	**660**	**1 443 250**	**2 186.74**
Red hartebeest	219	474 650	2 167.35
Black Wildebeest	123	232 565	1 890.77
Bushbuck	77	92 900	1 206.49
Reedbuck	73	79 500	1 089.04
Ostrich	28	19 550	698.21
Blesbok	**1 547**	**914 735**	**591.30**
Impala	**2 240**	**1 308 205**	**584.02**
Bushpig	103	41 870	406.50
Mountain reedbuck	231	91 285	395.17
Warthog	**994**	**335 760**	**337.79**
Springbok	**3 277**	**961 175**	**293.72**
TOTAL	**11 808**	**11 901 315**	

(Van der Merwe & Saayman, 2005)

However, of these six species most often hunted by biltong hunters, kudu generates the highest income followed by blue wildebeest, while springbok generates the lowest income per animal. Although the hunting of nyala, eland, waterbuck and zebra earns the highest income, the numbers hunted are very low. These more expensive species are mostly hunted for status reasons. While biltong hunting is still the biggest earner of income in the game industry, the potential of meat production cannot be overlooked.

Recent controversies around the quality of meat in Europe make it an attractive market for game meat. Species such as springbok, kudu, impala and blesbok are in demand in the European market and are exported regularly (Olivier & Van Zyl, 2002). The species and numbers of game harvested commercially for meat production is shown in Table 3. Overseas, game meat is regarded as exotic and is sold mostly to hotels, delicatessens and restaurants (Patterson & Khosa, 2005). The demand for game meat is expected to grow, not only on an international

level but also on the local market. In a survey of restaurants in the Eastern Cape, a popular hunting destiny, it was noted that only 15% offered game meat on their menus (Radder, 2002). From a purchasing and marketing study on game meat, Hoffman *et al*. (2003) concluded that it is mostly tourists who ordered game meat in South African restaurants. The South African game species mostly eaten by tourists include warthog, springbok and kudu. In contrast South Africans mostly consume springbok, kudu and gemsbok, in that order. South Africans, to a large extent do not like game meat in another form other than biltong, considering it to be dry and having a "gamey" flavour. The reason for this is often related to the way in which the meat is harvested, for instance the animal is not bled sufficiently or the animal suffered from ante mortem stress resulting in dark, firm dry (DFD) meat. Also a lack of knowledge of appropriate cooking methods is more often the problem than the quality of the meat itself (Patterson & Khosa, 2005). For the game meat industry in South Africa to succeed, the development of a scientific basis of knowledge on the quality of game meat as well as extensive marketing is essential (Bothma, 2002b).

Table 3. Species and numbers of game harvested commercially for meat production for the period 2002 to 2004.

Species	**2002**		**2003**		**2004**	
	Number	**Weight (tons)***	**Number**	**Weight (tons)***	**Number**	**Weight (tons)***
Springbuck	19 252	287 956	25 133	322 030	20 664	307 374
Kudu	733	64 572	256	21 155	646	51 869
Blesbuck	811	29 755	31	1 002	1 379	49 241
Black Wildebeest	285	22 460	0	0	222	18 744
Zebra	84	14 240	337	64 914	88	16 633
Eland	14	3 282	0	0	82	16 343
Gemsbok	29	2 491	7	820	139	13 537
Impala	117	3 616	28	794	169	4 296
Deer, Fallow	51	1 519	1	33	65	1 733
Bushbuck	6	190	1	32	0	0
Blue Wildebeest	29	3 005	1	72	0	0
TOTAL	21 457	433 771	25 816	411 080	23 455	479 783.0

*Weight of the animals comprises the carcass and skin

(Patterson & Khosa, 2005)

GAME HARVESTING AS A MANAGEMENT TOOL

The management of a game ranch or conservancy inevitably includes the control and regulation of animal numbers. In order to maintain the natural habitat and vegetation and ensure that it is not degraded due to too large a number of animals in excess of the sustainable carrying capacity, surplus animals need to be removed annually. Harvesting can also be used to keep a population at economic capacity for optimum growth. Therefore, harvesting of game can be

seen as an ecological management tool (Barnett, 2000). There are various ways of reducing game numbers such as live sales, hunting (either biltong or trophy) or harvesting. Although biltong and trophy hunting are economically a good option it is not always possible to remove enough animals or animals from the preferred age or gender groups. Trophy hunting will only take care of old male animals, and biltong hunters also prefer to hunt the larger male animals. It might also not be possible to remove the full quota of surplus animals using these strategies during the hunting season.

Another option is to harvest the surplus animals for meat production. Hoffman & Wiklund (2006) describes harvesting as the killing of animals for the purpose of meat production, whereas cropping is defined as the removal of animals from an area in order to maintain a balanced eco-system. Therefore, cropping can include harvesting as well as capture for live sales. There are many reasons for harvesting game such as recreational hunting, trophy hunting or as part of the management strategy of the game ranch manager in order to reduce animal numbers (Caughley & Sinclair, 1994). The ethical harvesting of wildlife, whether it is for recreation or profit, should be a quota from the population that can be removed year after year without having a negative impact on the population. This is known as the sustainable yield (SY) and can also be described as a product of the annual harvesting rate (H) and the mean size of the population ($\overline{N}$) during that period:

$$SY = \overline{N}H$$

The annual harvest of game on a specific game ranch or farm will depend on the growth rate of the population (r), but also on the management objectives of the manager. If the objective is to maintain a stable population size, the annual harvesting rate (H) should be equal to the population growth rate:

$$H = r$$

If the management objective is for the population to grow, the annual harvesting rate should be between zero and the population growth rate:

$$H < r$$

Once the harvesting rate is set according to the objectives of the game ranch, data on monthly natural mortalities are still required in order to calculate the actual number of game to be removed by harvesting.

According to Furstenburg (2006), the mean growth rate (r) of the kudu population in the Eastern Cape is between 19 and 21%. However, this figure can be as low as 13% in years of drought and as high as 28% in rainy years. The mean growth rate of the kudu population in the Kruger National Park is estimated at 14.8%. The annual growth rate of impala is estimated at 22%.

In order to maintain an optimum sex ratio for a healthy kudu population structure, the annual harvesting quota should consist of 61% young bulls (2-3 years), four percent trophy bulls (> 8 years) and 35% cows older than six years (Furstenburg, 2006).

GAME HARVESTING TECHNIQUES

The harvesting technique applied depends on the species, its habitat and the vegetation of the area. In order to be economically competitive, harvesting techniques are continuously being altered so as to harvest the most animals in the least amount of time. For export quality meat only head or high neck shots are acceptable (Hoffman, 2003).

Night harvesting

Night harvesting is usually done with a spotlight from open vehicles so as to cause the least amount of stress to the animals. The shooting is done by professional shots that typically have a success rate of over 90%. Hoffman (2000b) concluded that night cropping of impala had no detrimental effects on meat quality. Research done by Kritzinger *et al.* (2003) clearly showed that night cropping produces meat with a better quality than meat from day-cropped animals. The work done by Veary (1991) and Von La Chevallerie & Van Zyl (1971) indicated that ante mortem stress, which is limited during night harvesting, could have unfavourable effects on meat quality.

Animals like kudu are not suitable for night harvesting as they are predisposed to look away from the spotlight or to close their eyes. In contrast the impala is ideal for night harvesting as they have a tendency to stay still once caught in the spotlight (Lewis *et al.*, 1997). In the open areas of the Northern Cape springbok are mostly harvested at night from vehicles (Anon, 2007b). From personal observation it is evident that night harvesting is not as successful in the dense Bushveld areas of the Limpopo Province. The dense vegetation makes it difficult to see the animals and it is not always possible to get an open shot, particularly if only head and upper neck shots are acceptable. Another disadvantage of night harvesting is that it is more difficult to determine the gender of an animal, especially in species where both genders have horns.

Day harvesting

Animals can be enticed to feeding points where they are shot from a hide. This method will cause no stress to the animal, however, this is a very time consuming method and would not be economically viable.

On large game ranches or areas where the vegetation is too dense, helicopters can be used to herd the animals into a boma as with a game capture operation. The animals are left in the large boma to settle down and from there small groups (± 10) are moved to a smaller boma. They are then shot from above with a small calibre silenced rifle. From here the animals are loaded on a truck (hanging head down and exsanguinated) and transported to a mobile abattoir set up in the veld. Although the effect on the meat quality has not been researched, this method seems to work well with impala, kudu and blue wildebeest. This method also has practical advantages for the dense bushveld areas which are not always accessible with vehicles; however the costs involved is the major restricting factor for using this method.

In the dense bush areas of the Eastern Cape springbok and kudu are harvested during the day from a helicopter. Animals are shot from the helicopter with a 12-gauge shotgun, while a ground team follows to collect the dead animals. From personal observation it was noted that these animals are not all killed by head or neck shots. Broken legs were also noticed as springbok tend to jump when fleeing. The influence of this harvesting technique on the meat quality also needs to be quantified.

GAME MEAT AS A HEALTHY ALTERNATIVE

In recent years consumers have become more aware of the health implications of the food they eat. Meat, especially red meat, has been labelled as containing high levels of unsaturated fat and high cholesterol. On the contrary, the average fat content of most game species is less than 3%, thus being significantly lower than that of domesticated species such as beef and lamb (Schönfeldt, 1993a). Fat content for springbok from three production regions ranged between 1.32% and 3.46% (Hoffman *et al.*, 2007a). Stevenson *et al*. (1992) also commented on the low energy and cholesterol profile of venison. Aidoo & Haworth (1995) noted the low total energy of game meat, which is less than 500 kJ/100 g meat. These aspects make game meat a low-fat, nutrient dense alternative for the health-conscious consumer. Not only is game meat low in fat, but several studies have shown that the protein content of game meat is high (Table 4). Jansen van Rensburg (2001) noted that there is great potential for game meat production since it meets the modern consumer's need for lean meat.

South African game meat can be considered an organic product as the animals are wild and free-roaming in contradiction with many game species that have been semi-domesticated in other parts of the world (Hoffman & Bigalke, 1999; Hoffman & Wiklund, 2006).

From a health point of view, the fatty acid composition of meat, especially the ratio of polyunsaturated fatty (PUFA) acids to saturated fatty acids (SFA), is of greater importance than the total fat content. Oleic (C18:1), palmitic (C16:0), and stearic (C18:0) acids, all SFA's are the most omnipresent fatty acids in meat. However, meat from several game species has shown to

have high levels of PUFA's. Also of importance is the ratio of omega 6 (*n*-6) to omega 3 (*n*-3) PUFA's in meat which will be discussed in "Parameters that define Meat Quality - Fatty Acids and Cholesterol content".

Table 4. Nutritional values for game species compared to that of beef.

Species	Protein (%)	Fat (%)
Beef [a]	19.2	14.2
Springbok [b]	20.0	2.20
Nyala [a]	22.2	0.8
Blesbok [c]	22.2 - 22.5	0.9 - 1.2
Impala [d]	23.8	2.5

[a] Jansen van Rensburg, 2001

[b] Hoffman *et al.*, 2007a

[c] Smit, 2004

[d] Hoffman, 2000a

Game meat offers a healthy alternative to South African red meat eaters; however the correct marketing strategy and availability of game products that require less cooking time is needed (Radder & Le Roux, 2005). Also, consumers need to be educated on the health advantages of game meat over other red meats (Radder, 2002).

MEAT QUALITY MEASUREMENTS

Although the quality of a commodity is a perception of the consumer, there are several factors that can be measured (Webb *et al.*, 2005). The physical measurements of meat such as colour, water-holding capacity (WHC) and tenderness are the characteristcs that drive consumer purchasing decisions. These are also the quality characteristics most likely to be altered by pre-mortem stress and poor ante-mortem handling. With game animals the harvesting technique is of importance so as to cause the least amount of stress to the animal. As discussed in the previous section, different harvesting techniques need to be implemented depending on the species harvested and on the topography and vegetation of the area. Thus, by making informed decisions on the harvesting of game animals the game ranch owner or manager can add to the quality of the meat.

Meat quality can be defined by the physical measurements (water-holding capacity, colour and tenderness), the compositional quality (chemical composition) and the palatability (juiciness, tenderness, flavour and aroma) of the meat.

Tenderness

Tenderness is a principal determinant of meat quality. Koohmaraie (1988) noted that it is the most important sensory characteristic of meat and Jeremiah (1982) concluded that consumers rate the acceptability of meat on tenderness. Tenderness can be described as the ease by which the consumer is able to disorganise the meat structure during mastication (Lepetit & Culioli, 1994). It is a complex measurement which is influenced by a plethora of pre- and post-mortem factors. Considerable research has been done on this quality measurement in the last century; however the causes of variation in tenderness are not yet fully understood (Lepetit & Culioli, 1994; Tornberg, 1996; Byrne *et al.*, 2000).

When measuring tenderness, different types of forces can be applied, i.e. compression, tension or shear force. The method most widely used (78%) for assessing the texture of whole meat is the Warner-Bratzler shear (WBS) technique. This method is also known to give the best correlation with sensory panel scores on tenderness (Tornberg, 1996). When measuring tenderness, the orientation of the strain in relation to the myofibres is important. In most cases the shearing plane is perpendicular to the muscle fibres (Lepetit & Culioli, 1994).

Interpretation of tenderness results is often difficult as there are so many factors affecting meat tenderness. Bouton *et al.* (1973) noted that tenderness of *M. longissimus dorsi* (the most frequently studied muscle) depends amongst others, on the cooling rate of the carcass. In a study on mutton, he also found that tenderness decreased with an increase in animal age. In contrast, in a different study it was shown that WBS values decreased (i.e. tenderness increased) in *M. longissimus dorsi* muscle from 9, 16, 27 and 42 month old beef animals (Bouton *et al.* 1978). It is therefore necessary to minimise pre-rigor myofibrillar shortening when assessing meat tenderness (Shorthose & Harris, 1990).

On a microscopic level there are three primary sources of variation in tenderness, i.e. collagen content and solubility, sarcomere length and protein proteolysis. For the purpose of this study only collagen content and solubility will be determined. Collagen content will be discussed separately.

Water-Holding Capacity

By weight, water makes up the largest part of meat. In the muscle water is stored in the myofibrils – the spaces between the thin (actin/ tropomyosin) filaments and the thick (myosin) filaments (Lawrie, 1998). The extent to which water is bound in the myofibrils is referred to as the water-holding capacity (WHC) of meat. The WHC has an effect on the appearance of meat before cooking, its behaviour during cooking and the juiciness of the meat during eating. Changes in the volume of the myofibrils cause water loss from the muscles. Factors such as

pH, sarcomere length and pre- or post-rigor status of the muscle all have an influence on the volume of the myofibrils (Honikel, 1998). As the pH of the muscles decrease post-rigor and denaturation of proteins take place, there is a decrease in the WHC. This results in the accumulation of moisture between the fibre bundles. When the muscle is cut, the fluid will drain from the muscle, resulting in drip.

The extent of cooking loss is determined by the time, temperature and method of cooking as high temperatures will cause denaturation of proteins that result in various structural changes (Lawrie, 1998). Muscles respond differently to cooking depending on pre- and post mortem conditions i.e. a fast rate of pH fall will increase cooking loss. Destruction of cell membranes, shrinkage of muscle fibres and especially changes in the connective tissue causes cooking loss in meat (Honikel, 1998). Expulsion of water from the myofibrils is slow between temperatures of 40-53°C, however at 60°C it is more rapid and the WHC drops noticeably from 80°C to 100°C (Lawrie, 1998). Collagen of the perimysium and endomysium shrink at temperatures above 64°C (Sims & Bailey, 1981). For the purpose of this study the methods described by Honikel (1998) will be used to determine drip and cooking loss.

Colour

The visual appearance of meat is the main characteristic affecting the consumer's decision at the point of purchase. Many options are available for the measurement of meat colour. Not only are there different instruments available, but there also exist a variety of systems i.e. Hunter, CIE and tristimulus. Colour can also be measured by subjective analysis by a sensory panel. The method used for defining colour depends on the specific project and its objectives. The CIELab colour system (Commission International de L'Eclairage, 1976) is commonly used for colour measurement and will be used in the current study. In the CIELab system, the L* values indicate lightness, a* the red-green range and b* the blue-yellow range.

Brewer *et al.* (2001) reported that in pork meat L* could be the best indicator for dark, firm and dry (DFD) or pale, soft and exudative (PSE) meat. Mancini & Hunt (2005) reported that L* and a* can easily be applied to meat and muscle colour. However, b* (blue and yellow) is more difficult to interpret as it is not typically associated with meat. Stevenson *et al.* (1989) studied the relationship between perceived colour and acceptability by a trained panel and concluded that venison colour can be evaluated by making use of an objective method with CIELab values instead of a trained panel. L*, a* and b* values should be measured and a minimum of three observations per sample is required. In South Africa, game meat is often perceived to be dark and unattractive in colour and can be compared to beef that has been classified as DFD (Scanga *et al.,* 1998).

Myoglobin content

Myoglobin, one of the two main haem proteins in meat, is important in the determination of meat colour (Kranen *et al.*, 1999) as it is the basic colour pigment in meat. Oxygenation at the surface of the meat causes the myoglobin to change from purple-red to bright red oxymyoglobin. When myoglobin oxidises, metmyoglobin which has an unattractive brown colour is formed. Consumer perception is that meat that does not have a bright red colour, is unhealthy and not fresh (Dikeman, 1990).

There are primarily three factors responsible for colour variation in meat (Honikel, 1998). The first is the concentration of myoglobin which depends on species, age, nutritional status and muscle type. Kranen *et al.* (1999) and Warris *et al.* (1990) confirmed that myoglobin varies between species. In a study by Onyango *et al.* (1998), myoglobin concentrations were significantly different between species. Zebra meat was reported to be the darkest in colour in comparison with beef, oryx and kongoni, due to its high myoglobin content. Lawrie (1998) stated that myoglobin concentration of muscle increases with age resulting in young animals having lighter, brighter coloured meat. Shorthose & Harris (1991) suggested that free-range grazing animals had higher concentrations of myoglobin than animals in a feedlot since they get more exercise. With regards to the type of muscle, Kranen *et al.* (1999) found myoglobin levels to be low in glycolitoc muscles and high in oxidative muscles. The second factor is pre-mortem handling, pH and temperature decline. In this regard, Swatland (1990) observed a high ultimate pH to cause the meat to appear darker in colour. Shorthose & Harris (1991) also noted that as the ultimate pH increased from 5.4 to 7.0, the meat became darker. The third factor is the colour changes that occur during handling and storage caused by oxygenation and oxidation of myoglobin. Therefore, Honikel (1998) proposed that colour readings be taken after rigor mortis and after blooming of the meat until the surface myoglobin is fully oxygenated.

Proximate composition

The protein, moisture and fat content of meat are important determinants of its nutritional value. Moisture constitutes the biggest proportion of meat and several authors have reported on the moisture content ranging from 73-76% (Table 5).

World Health Organisation recommendations state that fat should supply between 15 and 30% of calories in the diet (WHO, 2003). Various factors can influence meat fat content i.e. species, gender, nutrition (diet), muscle and season. One of the major differences between game meat and other red meats is the lack of marbling fat in game meat (Aidoo & Haworth, 1995).

As water and protein is contained mainly in the lean portion of meat, the low fat content of game meat will cause the moisture and protein content of game meat to be relatively higher than in

other red meats (Aidoo & Haworth, 1995). Hoffman (2000a) reported moisture, protein and ash contents of 72.4%, 23.8% and 2.1% for impala (no significant differences between genders). However, the fat content was reported to be higher ($P < 0.05$) in females (3.39%) than in males (2.45%).

Table 5. Proximate composition of several game species compared to beef and sheep.

Species	Protein (%)	Moisture (%)	Ash (%)	Fat (%)
Springbok [a]	18.80-21.16	73.35-74.40	1.18-1.28	1.32-3.13
Blesbok [b]	22.68	73.47	1.38	2.09
Blue wildebeest [c]	22.73-23.43	74.77-76.17	1.26-1.38	1.26-1.47
Camel [d]	19.3	77.2	0.9	2.6
Beef [e]	-	70.52	7.74	1.20
Sheep [f]	13.9	60.7	-	-

[a] Hoffman *et al*., 2007a

[b] Du Buisson, 2006

[c] Van Schalkwyk, 2004

[d] Elgasim & Alkanhal, 1992

[e] Von Seggern *et al*., 2005

[f] Sayed *et al*., 1999

Collagen content

Intramuscular connective tissue (IMCT) has long been recognised to influence meat tenderness and therefore its basic structure and composition have been studied by many authors (Light *et al.*, 1985; Bailey & Light, 1989; Shorthose & Harris, 1990). It is not only the amount but also the solubility of the connective tissue that influences meat tenderness. Depending on the age of an animal and the position of a muscle, there is a difference in the IMCT content within muscles (Purslow, 2005). Other factors such as animal breed or species, nutrition and exercise also influence the amount and distribution of connective tissue in muscles (Purslow, 2005).

The proteins, collagen and elastin which are surrounded by a proteoglycan matrix comprise the fibres of IMCT. Three structural components; endomysium, perimysium and epimysium constitute the IMCT. Several studies have shown that while meat tenderness decreases with age, this effect is more pronounced in muscles with high collagen content (Dransfield, 1977; Light *et al.*, 1985; Shorthose & Harris, 1990). Light *et al.* (1985) observed that the best correlation of collagen with variation in toughness in the muscles studied was seen in the different quantities of heat-stable crosslinks in epimysium, perimysium and endomysium. Another contributing factor to meat toughness is heat-soluble cross-link formation, especially with age. The earlier work of Bailey & Light (1989) indicates that as cross-links increase with older animals, the heat dependant solubility of collagen decreases. In young animals fibre adhesion is lost at 60˚C, but not in old animals, therefore collagen solubility can be related to

cooked toughness. Variation in meat tenderness of different aged animals seems to be dependant on the heat soluble collagen content, while total collagen is the best indicator of tenderness among muscles (Dransfield, 1994b). Young & Braggins (1993) noted a distinct correlation between total collagen and collagen insolubility and the tenderness of meat. This is supported by McKeith *et al.* (1985) who determined the collagen content of thirteen beef muscles. They proposed that the percentage of soluble collagen was more important to meat tenderness as collagen content was not a good indication of tenderness.

Only 12 % of variation in meat texture is related to connective tissue content, whereas 44% of meat texture variability is explained by the activity of the protease inhibitor calpastatin (Taylor, 2004). In a given muscle type from animals of similar gender, age and nutrition, there can be up to a two-fold variation in connective tissue content as measured by hydroxyproline content, and collagen solubility. Connective tissue does change structurally and biochemically for up to 2 – 3 weeks post mortem. Structurally there is a separation of the perimysium and endomysium, and biochemically there is some degradation of proteoglycan and collagen (Taylor, 2004). With conditioning of raw meat there is a reduction in the strength of the perimysium however, this effect was cancelled after cooking of the meat.

Fatty acids and cholesterol content

Meat has been implicated in causing obesity and cardiovascular diseases because of its fat and cholesterol content. However it is not only the amount of fat, but also the fatty acid composition that is of importance where the health aspect of meat is concerned. Meat consists mainly of monounsaturated (MUFA) and saturated fatty acids (SFA). Oleic acid (C18:1), palmitic acid (C16:0) and stearic acid (C18:0) are the most abundant fatty acids in meat (Valsta *et al.*, 2005).

The lipids in ruminants are known to contain high amounts of SFA's thereby contributing to the unfavourably high SFA intake in the human diet. The World Health Organisation (WHO) guidelines recommend that less than 10% of the fat intake in the human diet should be from SFA's. Various authors have concluded that the PUFA: SFA ratio in the diet is more important than the total fat content (Chizzolini *et al.*, 1999; Wood *et al.*, 2003). A PUFA to SFA ratio of 0.4 and more has been recommended by the Department of Health (1994) in the UK. Recent studies have revealed that meat from most game species have favourable fatty acid profiles. Springbok meat had a PUFA: SFA ratio between 0.96 and 1.18 with an average of 1.06 (Hoffman *et al.*, 2007b). The ratio was calculated as 1.16 for mountain reedbuck and ranged from 0.94 to 1.21 for black wildebeest (Van Schalkwyk, 2004).

Of equal importance is the right balance of omega-6 (*n*-6) and omega-3 (*n*-3) fatty acids, which is necessary to lower blood pressure, reduce inflammation and encourage healthy blood flow. In most Western diets the ratio of *n*-6: *n*-3 fatty acids are in the region of 15:1. A ratio of less

than 5:1 is recommended as a healthy balance. In modern society meat from intensively reared animals add to this imbalance as their meat contains high quantities of *n*-6 fatty acids (Simopoulus, 2000). In contrast, animals raised on grazing have more *n*-3 fatty acids, as grass contains high amounts of α-linolenic acid, an *n*-3 polyunsaturated fatty acid (PUFA). The earlier work of Crawford (Crawford *et al.*, 1970) showed that the meat of wild and domesticated animals differ significantly in terms of fatty acid profile, which has important implications for human health. The *n*-6: *n*-3 ratio of meat from game species was all below 4.0. Providing baseline data on the fatty acid profiles of kudu and impala meat will not only benefit the game industry but also nutritionists and meat scientists.

Cholesterol is an integral part of the cell membranes of animals (Chizzolini *et al.*, 1999) and therefore consumption of red meat can not be dissociated with cholesterol intake. According to the WHO (WHO, 2003) cholesterol intake should be limited to 300 mg/day. In general the cholesterol content of meat and meat products are in the region of 75 mg/100g. Chizzolini *et al.* (1999) reported the cholesterol in offal such as brains, kidney and heart to be considerably higher. The mean cholesterol content of meat for selected species is represented in Table 6.

Myristic (C14:0) and palmitic (C16:0) acids have been implicated in raising total and low-density lipoprotein (LDL) cholesterol levels which is a major risk for coronary heart diseases (Valsta *et al.*, 2005). However, not all SFA's have cholesterol elevating properties. In general, MUFA's and PUFA's do not increase cholesterol levels. The PUFA, arachidonic acid is associated with serum-cholesterol-lowering properties. Despite these negative associations, cholesterol has some positive functions in the body such as the production of hormones such as cortisol and the production of bile acids.

Table 6. Mean cholesterol content in meat for selected animal species.

Species	Cholesterol content (mg/100g)
Nyala [a]	51
Alpaca (*Lama pacos*) [b]	51.14
Blesbok [c]	49.74 – 54.56
Springbok [d]	54.45 – 59.34
Llama (*Lama glama*) [e]	56.29
Beef [f]	76

[a,f] Jansen van Rensburg, 2001

[b] Christofanelli *et al.*, 2004

[c] Smit, 2004

[d] Hoffman *et al.*, 2007b

[e] Polidori *et al.*, 2007

Limited data is available on the fatty acid composition and cholesterol content of kudu meat. Although some research has been done on impala fatty acids (Hoffman *et al.*, 2005) the effect of

age has not been considered. In order to market game meat more effectively, data on the fatty acid profile and cholesterol content is necessary.

Sensory Characteristics

Tenderness

Physical tenderness of meat has been discussed previously. Tenderness as evaluated by a sensory panel can be described as the impression of tenderness after the first two to three chews between the molar teeth, and the amount of residue left in the mouth after 15 chews (AMSA, 1995). The "eating" characteristics of meat are not easy to measure objectively, therefore a trained sensory panel or a group of typical consumers will be used. Tornberg (1996) proposed that sensory panel scores correlate the best with WBS values.

Juiciness

Lawrie (1998) described sensory juiciness of meat as the amount of moisture released during mastication and also the degree of saliva production during mastication. The initial impression of wetness after the first few chews can be described as initial juiciness. The continued perception of juiciness that is associated with saliva production in the mouth is known as sustained juiciness. The intramuscular fat acts as a means of lubrication during mastication and stimulates saliva production (Cross *et al.*, 1986). This explains why the meat of young animals often have an impression of initial juiciness, but after continuous chewing, due to the lack of fat, leaves a dry sensation in the mouth. Several studies have shown that there is a direct relation between fat content of the muscle and juiciness of the meat, hence; fatter animals have juicier meat (Pearson, 1966; Cross *et al.*, 1986; Hopkins *et al.*, 2006). In contrast, Schönfeldt *et al.* (1993b) found no significant differences in initial juiciness of *M. longissimus dorsi* and *M. semimembranosus* from sheep having three levels of fat (14.30%, 17.26% and 23.31%).

Flavour and aroma

Flavour can be described as a combination of the aroma, the taste and the overall mouth feel during mastication. Amino acids, fatty acids and carbohydrates undergo chemical reactions during cooking, which produces compounds that contribute to meat flavour. There are hundreds of compounds that add to the flavour and aroma of meat. Mottram (1998) found sulphurous and carbonyl compounds to be the major contributors to meat flavour. Some fat is necessary in meat to transmit flavour and juiciness (Melton, 1990) as lipid breakdown products also add to meat smell and flavour. Especially important in development of flavour is the unsaturated phospholipid fatty acids and consequently nutrition and diet will have an affect on meat flavour. In order to produce a consistent product a better understanding of the factors that influence

flavour is necessary. Little is known about the flavour characteristics of game meat and the volatile compounds that influence the flavour. Some consumers associate game meat with an undesirable “gamey” flavour.

The aroma of meat is the sensory quality attributed to the effect of the volatile compounds on the olfactory organ (Cross *et al.*, 1986). The meaty aroma is largely caused by sulphur-containing compounds. During the Maillard reaction heterocyclic compounds are formed that are associated with a roast meat aroma (Mottram, 1998).

FACTORS AFFECTING MEAT QUALITY

pH and Stress

The ultimate pH (pH_u) of a carcass usually varies from 5.3 to 6.8. It is known that the tenderness of meat is influenced by the pH_u, which is mostly affected by pre-slaughter handling. Animals stressed prior to death are more likely to have a high pH_u than unstressed animals. When an animal is stressed prior to death, it causes a depletion of muscle glycogen resulting in lower lactic acid production during glycolosis and hence a high pH_u. This condition causes the meat to have an unattractive dark colour resulting in dark, firm and dry (DFD) meat. Purchas & Aungsupakorn (1993) observed that tenderness (measured in Warner-Bratzler shear force) decrease from a pH of 5.5 up to a maximum near pH 6.0 and then tenderness increases. Although the reason for this curvilinear relationship is not yet fully understood, it is suggested that it could be due to less proteolytic activity at a pH range from 5.8 – 6.3. Calpain activity is at a maximum near neutral pH, thus an increase in tenderness as the pH_u rises from 6 to 7. On the other hand, as the pH_u falls below 6 acidic protease activity is higher.

It is not only pH_u but also rate of pH decline that influences meat quality. In pigs a rapid pH decline post-mortem results in pale, soft and watery (PSE) meat. This phenomenon has also been observed in warthog *Pachochoerus africanus* (Hoffman & Wiklund, 2006).

Species

Species is probably one of the most apparent factors affecting meat quality. Although moisture and protein content is fairly similar for different species, there is great variation in other parameters. For example, myoglobin content of pig muscles (0.6mg/g) differ significantly from that of beef muscles (5.0mg/g) (Lawrie, 1998). The myoglobin contents of beef and oryx meat were found to be significantly different from that of zebra and kongoni meats, but not different from each other (Onyango *et al.*, 1998). In the same study Onyango *et al.* (1998) ascribed the differences in cooking loss to species differences. Zebra loin had a cooking loss of 21.9% compared to 36.4% in oryx leg samples.

Species is also known to affect the sensory quality characteristics of meat. The difference in flavour and aroma between species is attributed to carbonyl compounds present in the fat. While the species-specific flavour of sheep meat is sought after by South African consumers, there is a low consumption of sheep meat in the United States (Schönfeldt *et al.*, 1993b).

Just as domesticated species differ from each other in terms of various meat quality aspects, so does game species. Therefore the question is not whether impala and kudu differ from each other, but in terms of which parameters.

Age

The age of an animal can affect the quality of meat in several ways. Probably one of the most studied parameters influenced by animal age is tenderness (Bouton *et al.*, 1978; Shorthose & Harris, 1990; Wulf *et al.*, 1996). Research studies demonstrated that tenderness decreased with an increase in animal age (Bouton *et al.*, 1978). Shorthose & Harris (1990) measured tenderness in 12 muscles from eight beef age groups and found that tenderness of the muscles decreased with age. It was also noted that the rate of decrease in tenderness was related to the strength of connective tissue in the muscle. As cattle mature, intramuscular collagen solubility decreases, resulting in tougher beef (Hill, 1966; Dikeman & Tuma, 1971).

Another factor affected by animal age is flavour. According to Sink & Caporaso (1977) the meat from younger animals has a more pleasant flavour compared to older animals as the intensity of flavour increases with chronological age. The natural flavour of a particular species has not developed fully until the animal reaches maturity (Ford & Park, 1980).

Gender

The most obvious difference between genders is in the fat content of the meat. In general, males have less intramuscular fat than females. Female blesbok (1.14%) had significantly more fat than male blesbok (0.76%) (Smit, 2004). Hoffman (2000a) obtained intramuscular fat content of 3.39% in impala female compared to 2.45% in the males. In a different study it was noted that impala males showed higher levels of poly-unsaturated fatty acids compared to females (Hoffman *et al.*, 2005).

Muscle

Different muscles are known to vary in tenderness and to a certain extent this can be ascribed to the variation in proportions of epimysial, perimysial and endomysial connective tissue in different muscles (Lawrie, 1998). Muscles can broadly be classified as “red” (slow-twitch) or “white” (fast-

twitch) depending on the way they carry out actions, i.e. sustained action or short bursts of action. *M. longissimus dorsi* has the characteristics of "white" muscle as it is capable of short bursts of activity. Due to lower concentrations of proteolytic enzymes in "red" muscle, there is a tendency that they tenderise less noticeably than "white" muscle.

In a study on tenderness of ten beef muscles, Schackleford *et al.* (1995) concluded that tenderness of *M. longissimus dorsi* is not a good indicator of tenderness of other muscles in the same carcass (Table 7). They noted that *M. longissimus dorsi*, a muscle that is valued among consumers had the second highest standard deviation. Also, WBS values did not differ between muscles, but overall tenderness rated by a sensory panel differed significantly (Schackleford, *et al.* 1995).

Table 7. Variation in overall tenderness and Warner-Bratzler shear force within and among muscles (SD = standard deviation).

	Overall tenderness [a]				**Warner-Bratzler shear force (kg/1.27cmø)**			
	Mean	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**
Longissimus dorsi	6.5	0.8	5.1	7.4	4.1	1.1	2.7	6.7
Biceps femoris	5.0	0.6	3.2	6.1	4.3	0.8	3.2	6.0
Semimembranosus	5.0	0.8	3.6	6.8	4.3	0.9	3.1	6.3
Semitendinosus	5.7	0.4	4.8	6.4	4.1	0.7	3.3	5.8
Supraspinatus	5.6	0.6	4.6	6.8	4.3	0.9	3.0	5.8

[a]Overall tenderness scored on 8-point scale (1 = extremely tough; 8 = extremely tender).

(Schackleford et al., 1995)

Muscles also vary in texture, i.e. the size of the bundles of muscle fibres. The *M. semimembranosus* is a coarse-grained muscle as most of the growth in this muscle takes place post-natal. On the other hand, the *M. semitensdinosus* is a fine-grained muscle with small fibre bundles.

Different muscles from the same carcass also differ in collagen content. Muscles in the same animal with relatively high collagen contents, were tougher than those with smaller amounts of collagen (Dransfield, 1977). Cross *et al.* (1972) found significant differences between ovine leg muscles with the *M. semimembranosus* and *M. semitendinosus* having a mean collagen content of 4.2 mg/g, *M. gluteobiceps,* 5.3 mg/g, and *M. vastus lateralis*, 7.2 mg/g. Differences were also noted for percentage solubility with 7.0%, 7.5%, 10.4%, and 7.3% for the *M. semimembranosus*, *M. semitendinosus*, *M. gluteobiceps*, and *M. vastus lateralis*, respectively.

The type of muscle fibres present is responsible for differences in myoglobin content between muscles. Red muscle fibres have higher myoglobin content than white muscle fibres; therefore muscles with a relatively high proportion of red muscle fibres (30-40%) will appear darker in color (Romans *et al.*, 1994).

Nutrition/ diet

It is well known that diet has an influence on the sensory characteristics of meat (Melton, 1990; Muir, *et al.*, 1998, Wiklund *et al.*, 2003). Purchas & Davies (1974) found that meat from steers finished on a cereal diet was more tender and the flavour more acceptable when compared to steers finished on pasture. Research has shown that in New Zealand consumers favour the flavour of grass-fed lambs (Purchas *et al.*, 1979). On the other hand, Medeiros *et al.* (1987) reported grain-feeding of beef to produce a desirable flavour for the American consumer. A different range of flavour precursors is produced from *n*-6 PUFA, *n*-3 PUFA or SFA, for that reason the lipid fatty acid composition is of importance in flavour development in meat. Higher levels of n-3 PUFA and lower levels of n-6 PUFA have been noted in grass-fed animals resulting in flavour differences between grass- and concentrate-fed beef (Medeiros *et al.*, 1987).

THE KUDU (*TRAGELAPHUS STREPSICEROS*)

Taxonomy and Description

Order: ARTIODACTYLA
Family: BOVIDAE
Subfamily: BOVINAE
Genus: *Tragelaphus*
Species: *Tragelaphus strepsiceros*

The kudu *Tragelaphus strepsiceros* is one of five species in the genus *Tragelaphus*. The adult male stands about 1.4 meters high at the shoulder and can weigh up to 250 kg (Table 8). With an average shoulder height of 1.25 meters and weights of up to 200 kg, the female kudu is distinctly smaller (Skinner & Smithers, 1990). The live mass of kudu males range from 190.3 kg to 258.2 kg and in the female gender it ranges from 119.6 kg to 210.2 kg. The live mass of a kudu bull varies throughout the year, with breeding bulls being at their heaviest towards September when they occur in bachelor herds (Bothma, 2002c). According to Bothma (2002c), the dressing percentage of the kudu is 57%. The buttock, which is a high quality cut accounted for 29.2% of the carcass weight, compared to 24.2% in sheep. With a lean meat yield of 43.4%, the kudu carcass is more productive than that of domestic animals in terms of quality retail cuts (Huntley, 1971).

Habitat and Nutrition

The kudu is predominantly a non-selective browser and feeds on tree and shrub leaves, woody branches, pods, seeds, broad-leaved forbs and succulents (Furstenburg, 2006). Due to the wide distribution area of the kudu and the variation in habitat, the diet of the kudu differs from

area to area. While the diet of a kudu in the savanna bushveld consists of 18% grass, 21% forbs and 61% browse, a kudu in the valley bushveld of the Eastern Cape will consume 5-12% grass, 15-18% broad-leaved forbs and 70-80% browse (Furstenburg, 2005a). During the early stages of the growing season kudu favour the young shoots of woody plants (Skinner & Smithers, 1990). In the dry season when browse is less available, kudu will eat deciduous shrubs, flowers, and fallen fruits and pods. In spring kudu will also eat young grass shoots.

Trees not only provide food to the kudu, it also acts as shelter against the cold and protection against predators. Tree and shrub density is the most critical factor determining the suitability of an area as habitat for the kudu. The ideal habitat for kudu is also the limiting factor in harvesting and culling of kudu.

Horn Development and Tooth Eruption as Ageing Criteria

The spiralled horns are carried by male kudu only, although cases of horns in female animals have been reported (Furstenburg, 2005a). At the age of 18 -21 months, the first inward twist occurs. At approximately 30 months (2.5 years) of age the first complete spiral has developed (Table 8) (Furstenburg, 2005a).

Table 8. Mean body weight and horn length in relation to age in the greater kudu from the Eastern Cape region, South Africa.

Age	Body weight (kg)		Male horn length	
	Female	Male	(mm)	(inches)
0 months	13	13	0	0
6 months	50	60	5-80	0.2-3
1 year	90	95	51-432	2-17
1.5 years	105	120	178-635	7-25
2 years	120	140	483-787	19-31
2.5 years	125	160	635-889	25-35
3 years	130	165	838-991	33-39
4 years	140	180	1041-1143	41-45
5 years	145	205	1143-1245	45-49
6 years	138	220	1245-1295	49-51
7 years	130	240	1270-1346	50-53
8 years	130	250	1295-1372	51-54
9 years	128	260	1346-1372	53-54
10 years	125	265	1346-1397	53-55
11 years	120	270	1372-1397	54-55
12 years	-	275	1372-1410	54-55.5
13 years	-	280	1397-1422	55-56

(Furstenburg, 2005a)

In a study by Simpson (1966) on kudu in Rhodesia (now Zimbabwe), tooth eruption was considered as a means of age determination. In the kudu, premolar$_4$ has erupted at the age of 34 months (Simpson, 1966). The nyala (*Tragelaphus angasi*) attain adult dentition by the age of 24 months (Anderson, 1986). Although tooth cementum layers can be used as an indicator of age, it is not accurate for determining the exact age of an animal (Simpson & Elder, 1969). In the study by Simpson & Elder (1969) adult kudu were divided into classes based on tooth wear. However, the accuracy of ageing decreases after the animal has attained permanent dentition since tooth wear is influenced by environmental factors such as vegetation, topography and habitat.

Herd Structure

Social structures that can be identified in kudu populations are: a) family groups with 1 to 2 socially mature males, 2 to 4 mature females and 1 to 3 youngsters, b) bachelor groups of 2 to 6 males, c) male groups of 2 to 4 mature bulls and d) non-breeding (post-mature) male groups of 2 to 6 bulls (Furstenburg, 2002). The average herd size varies seasonally, but cow herds in the Kruger National Park consisted on average of 5-6 animals (Estes, 1990). During the rutting period (April to July) the bulls will accompany a female group.

A sex ratio of one bull (older than 5 years) for every four cows (older than 3 years) will ensure optimal reproduction of the herd (Furstenburg, 2006) and the ratio should never exceed 1:8. Cows in the range of three to nine years make up 47% of the natural population with heifers from one to three years adding 14% and heifers less than one year adding eight percent to the population. Four percent of the population is bulls older than eight years, 18% is bulls between one and eight years and nine percent is bull calves under one year old.

Females mature at the age of 3 years, while males mature at 5 years of age (Estes, 1990). The gestation period is 9 months and calves are born during the rainy season when the grass is tall and there is ample food available (Estes, 1990).

Production Potential

Kudu has an annual long-term growth rate of 19 to 21%. But, the population growth rate is dependant on environmental conditions and can range from 13% in drought years to 28% in good rainfall years (Furstenburg, 2002). A mating sex ratio of 1 male to 4 females will ensure optimal production. Therefore, females also need to be harvested to achieve optimal productivity.

Depending on age and gender, the dressing percentages for kudu carcasses range from 54% to 57%. Harvesting or hunting will have the least negative effect on production if it is done from

August to September for cows. For bulls the best time for harvesting is from September to December and also from March to April (Furstenburg, 2002).

THE IMPALA (*AEPYCEROS MELAMPUS*)

Taxonomy and Description

Order: ARTIODACTYLA
Family: BOVIDAE
Subfamily: AEPYCEROTINAE
Genus: *Aepyceros*
Species: *Aepyceros melampus*
Subspecies: *Aepyceros melampus melampus*

The impala is one of the most abundant antelope species in the southern sub region of Africa. It is the only species classified in the subfamily *Aepycerotinae*. There are six subspecies of impala on the African continent of which only the southern impala (*Aepyceros melampus melampus*) and the black-faced impala (*Aepyceros melampus petersi*) occur south of the Zambezi River. An adult male impala stands 0.75 - 0.92 meters high and has a mean weight of 60 kg (Table 9). The mean shoulder height for an impala ewe is 0.80 meter with a mean weight of 45 kg (Estes, 1990).

Habitat and Nutrition

As the impala grazes and browses it is known as a mixed or intermediate feeder. The graze: browse ratio varies depending on the season, rainfall conditions and habitat. During the rainy summer season up to 92% of the impala's diet will consist of grasses, forbs and new growth. As the grazing material becomes less available or the lignin content of grasses increase during winter, the impala will adapt its diet. Browse and protein-rich fruit or pods will constitute 32 to 67% of the diet (Furstenburg, 2005b). As the impala has a preference for high quality food it can be considered a concentrate feeder. The kudu, on the other hand is considered a bulk feeder as it eats browse with a high crude fibre content throughout the year.

Horn Development and Tooth Eruption as Ageing Criteria

Only the male animals bear horns which can reach lengths of up to 600 mm (Furstenburg, 2005b). The horns of the impala are ringed for about 75% of their length with smooth tips. The number of rings relate to the age of the animal (Table 9). In a study on impala in the Rift Valley, animals were divided into two main age groups based on tooth eruption and replacement

(Roettcher & Hofmann, 1970). Impalas between 2 weeks and 2½ years (30 months) were regarded as sub-adult and animals older than 2½ years were adults.

Table 9. Mean body weight and horn length in relation to age in the impala.

Age	Body weight (kg)	Male horn length	
		(mm)	Number of rings
Birth	4.5	0	0
8 weeks	7	0	0
4 months	12	5-40	0
6 months	16	100-150	0
12 months	25-30	200-300	1
18 months	30-35	320-400	4-6
24 months	33-40	380-480	9-13
30 months	36-45	420-540	15-18
3 years	38-50	460-580	16-22
4 years	40-55	500-640	18-24
5 years	40-58	> 520	20-24
6 years	40-64	> 520	20-24

(Furstenburg, 2005b)

Herd Structure

Impala herd size range from 6 to 20 animals. In large game parks or conservancies herd sizes of 50 to 100 animals are also common. According to Fairall (1983), optimal reproduction will be attained at a sex ratio of five ewes per sexually mature ram resulting in an annual population growth of 22%. Productivity can be improved by manipulating the sex ratio. By changing the sex ratio from 1:3 to 1:10, productivity increased by 38%. In an area with predators present, a harvesting rate of 22% is possible. In an area without any predators, a harvesting rate as high as 25-30% is sustainable.

CONCLUSIONS AND OBJECTIVES

With the apparent growth in the South African game industry it is clear that scientifically based knowledge of the African game species has become indispensable. As there is a definite niche market for game meat production to be exploited it is of utmost importance that the right marketing strategy be followed. This will include base line data on species to be utilised for game meat production.

The objective of this study was to supply such data by means of:

- Evaluating the physical measurements and chemical composition of *M. longissimus dorsi*, *M. biceps femoris*, *M. semimembranosus, M. semitendinosus* and *M.*

supraspinatus for kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*)

- Establishing the effects of age (adult and sub-adult) and gender (male and female) on the physical and chemical quality of kudu and impala meat
- Determining the sensory quality of the *M. longissimus dorsi* muscle for sub-adult kudu and impala

Where applicable, correlations within the various physical measurements and chemical composition of the meat were verified. Physical measurements and chemical composition of the *M. longissimus dorsi* muscle were correlated with data on the sensory ratings of the meat. Although kudu and impala are found in the same geographical area, there is variation in their diets as kudu are predominantly browsers, feeding on tree and shrub leaves, while impala are known as mixed feeders as they graze and browse.

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Chapter 3

The effect of gender and age on the carcass yield and physical meat quality of kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*)

Abstract

Although research has been noted on the physical quality of meat from some of Africa's game species, data on the physical quality of kudu meat is lacking. In the present investigation the effect of gender and age on the yield and physical measurements of the *M. longissimus dorsi*, *M. biceps femoris*, *M. semimembranosus, M. semitendinosus* and *M. supraspinatus* for kudu (n=35) and impala (n=32) were determined. The kudu and impala are two antelope species found in southern Africa, often habituating the same area. However, their diet varies in that kudu are predominantly non-selective browsers, feeding on tree and shrub leaves, while impala are known as mixed feeders as they graze and browse. The mean dressing percentage of impala (59.88%) was higher than that of kudu (57.60%). Species, gender and age showed no differences for drip loss. There were no differences in cooking loss between species, gender or age groups. However, differences were noted for different muscles with impala *M. semitendinosus* having the highest cooking loss (38.28%) and kudu *M. longissimus dorsi* having the lowest cooking loss (30.77%). For impala, the highest Warner-Bratzler shear force (WBS) values were measured for *M. semimembranosus* (5.90 kg/1.27cmø), followed by *M. biceps femoris, M. longissimus dorsi,* and *M. semitendinosus* with the lowest WBS values measured for *M. supraspinatus* (3.61 kg/1.27cmø). All the impala muscles had lower L* values and were darker than the kudu muscles, except for the *M. supraspinatus*. Adult animals also had a lower mean L* value than the sub-adult group. As a species, kudu had higher a* and b* values (more red) than impala. The *M. longissimus dorsi* had the lowest b* value and the *M. semitendinosus* the highest b* value, differing from all other muscles. With the higher chroma values, kudu thus appeared brighter in colour. The *M. longissimus dorsi* had the lowest chroma value (13.89) that differed from all other muscles. It can therefore be concluded that the respective muscles of kudu and impala investigated in this study differed in terms of physical measurements. Differences between muscles were also noted for drip loss, cooking loss, WBS values and all colour measurements. However, when comparing genders and age groups within species, physical measurements did not differ significantly.

INTRODUCTION

Game ranching contributes significantly to the economy of the Limpopo province as well as the rest of South Africa. A survey in August 1998 indicated that an area of 3.6 million hectares, which constitutes 26% of the province's area, is utilised as game farms (Van der Waal & Dekker, 2000). The total gross income of the South African game ranching industry was reported to be R 820 million for the year 2000. Surprisingly, only 1% of this was from the sales of game meat. Almost 13% of South African land is used for the purpose of game farming. The game ranching industry has been growing at an annual rate of 5.6% (Eloff, 2002) with many cattle farms being converted to game farms. Statistical

data on the export volumes and quantities of South African game meat is lacking, nonetheless it is estimated that deboned meat from 160 000 carcasses was exported during the 2005 season. Of this, more than 80% was from springbok (*Antidorcas marsupialis*), with blesbok (*Damaliscus dorcas phillipsi*) and kudu adding to the total (Hoffman & Wiklund, 2006).

Tenderness is considered by many to be the most important component of meat quality (Dikeman, 1990). It is well documented that the tenderness of meat decreases with age, for example, in fallow deer (*Dama dama*); Volpelli *et al.* (2003) noted that older (30 month old) animals had more insoluble collagen and higher shear force values than 18 month old animals. However, Hoffman *et al.* (2007) found that neither age nor gender had an effect on the shear values of springbok which varied from 2.04 to 2.31 kg/1.27cmø for the different age categories. The shear force values obtained for springbok were low, compared to values (kg/1.27cmø) of 3.21-4.08 reported for impala (Hoffman, 2000a), 3.23-4.28 for black wildebeest (*Connochaetus gnou*), 3.77-4.60 for blue wildebeest (*C. taurinus*), 2.95-3.00 for mountain reedbuck (*Redunca fulvorufula*) (Van Schalkwyk, 2004), and 2.03-7.74 for beef (Belew *et al.*, 2003).

The colour of meat is vitally important as the consumer's first encounter with meat is usually visual - either when buying fresh meat or when being served meat in a restaurant. The consumer has the perception that meat that is too dark or too pale is of an inferior quality (Issanchou, 1996). Stress during the cropping process can lead to a high ultimate pH which can cause meat to appear darker in colour resulting in dark, firm and dry (DFD) meat (Kritzinger *et al.*, 2003).

Although research has been done on the subject of the physical quality of meat from some of Africa's game species, data on the physical quality of kudu meat is deficient. This study was therefore undertaken to supply some baseline data on the physical measurements of kudu meat and also to compare it to the meat of impala from the same region. The effects of gender, age and muscle on these measurements were also investigated.

MATERIALS AND METHODS

In this study, 35 kudu (14 male (KM) and 21 female (KF)) and 32 impala (17 male (IM) and 15 female (IF)) were harvested in the Limpopo Province, Mabula District (S 24 52.611, E 27 56.862). Harvesting of the animals took place over a period of 128 days (four months), starting in late autumn and extending over the dry winter months. Since animals were expected to lose physical body condition towards the end of winter due to a decline in available food, the day of harvest was used as a co-variant in the statistical analyses. All animals were harvested using standard techniques (Hoffman & Wiklund, 2006). The animals were killed instantaneously with head or upper neck shots using a .243 calibre rifle. So as to minimise the ante mortem stress effects, the animals were shot from a hide thereby ensuring that they were unaware of the presence of the hunter. Carcasses were bled and the full carcass weight recorded. After evisceration, skinning and cleaning (within 1 h post mortem), the

carcasses were weighed and then stored in a cold room (<4ºC). Weights were recorded for head, feet, skin and all internal organs.

After inspection of tooth eruption and horn development (where relevant), animals were divided into sub-adult and adult groups (Table 1). For the purpose of this study impala with full adult dentition were placed in the adult group and animals that had not established permanent dentition were placed in the sub-adult group. According to Roettcher & Hofmann (1970), male impala attain permanent dentition at about 30 months of age, while female impala attain permanent dentition between 24 and 30 months of age. Accuracy of ageing decreases after the animal has attained permanent dentition therefore all adults were grouped together. Kudu reach physical maturity (complete adult dentition) at 34 months of age (Simpson, 1966). Consequently, kudu that have not reached full adult dentition and are younger than 34 months were placed into the sub-adult group. All kudu with full adult dentition were placed in the adult group i.e. they were physically mature.

At 24 h post-mortem the cold carcasses were weighed and the dressing percentage calculated. For chemical analysis the *M. longissimus dorsi* (LD) was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra and the *M. biceps femoris* (BF), *M. semimembranosus* (SM), *M. semitendinosus* (ST) *and M. supraspinatus* (SS) were also removed. Ultimate pH (pH_u) was measured in the *M. longissimus dorsi* sample 24 h post-mortem. Samples were taken for determination of physical measurements, which was done on the fresh meat samples. Samples for chemical and sensory analyses (Chapter 4, 5 and 6) were vacuum packed and stored at -20 °C for analyses at the University of Stellenbosch laboratories.

Table 1. Sample distribution of kudu (n=35) and impala (n=32) according to age and gender.

	Kudu		**Impala**		**Total**
	Male	**Female**	**Male**	**Female**	
Adult	7	14	11	7	39
Sub-adult	7	7	6	8	28
Total	14	21	17	15	67

Physical analyses

Drip loss was determined by taking a freshly cut sample of ± 60-100 g meat (ca. 15 mm thick slice, cut perpendicular to the grain of the meat), weighing it and suspending it in an inflated plastic bag (Honikel, 1998) without the sample making contact with the sides of the plastic bag. The sample bags were left in a cold room at 1-5°C for 24 hours and then dried and weighed again. The drip loss is expressed as a percentage of the weight of the fresh sample.

Cooking loss was determined by using freshly cut samples of ± 80 g (ca. 15 mm thickness, cut across the grain of the meat), weighing it and placing it in separate plastic bags. The sealed plastic bags were cooked in a water bath at 80°C for 1 hour. The samples were then cooled under running water; the liquid decanted and the samples dried and weighed again. The cooking loss is expressed as a percentage of the initial weight (Honikel, 1998).

The cooled (4ºC) cooked samples were then used to determine the tenderness by measuring Warner-Bratzler shear (WBS) force values. Three to four 1.27cmø (cylindrical core) meat samples of the muscle were randomly removed from the cooked samples with a hand-coring device (Byrne *et al.*, 2000). The samples were cut perpendicular to the longitudinal axis of the *M. longissimus dorsi* muscle. Maximum shear force values (kg/1.27 cmø) to shear a cylindrical core of cooked meat (at a crosshead speed of 3.33 mm/s) were recorded for each sample and a mean was calculated for each individual animal using a Warner–Bratzler Shear attachment (with a circular cross section of 1.27 cmø blade) fitted to an electrical scale programmed to measure maximum weight (force).

A Color-guide 45°/0° colorimeter (Cat no: 6805; BYK-Gardner, USA) was used to determine the colour of the fresh meat samples of *M. longissimus dorsi*, *M. biceps femoris*, *M. semimembranosus, M. semitendinosus* and *M. supraspinatus* after a blooming period of 30 minutes. L*-, a*- and b*-values were determined, where L* indicates brightness, a* the red-green range and b* indicates the blue-yellow range (Commission International de L'Eclairage, 1976). The hue angles and chroma values were calculated according to the method of Hunter & Harold (1987),

where hue (H) = $\tan^{-1}$ (b*/a*)

and Chroma (S) = $((a^*)^2 + (b^*)^2)^{0.5}$

Statistical analyses

The data was analysed using repeated measures ANOVA as five muscles from each carcass were analysed. This was done with Statistica (version 7) statistical software. The full model was analysed (2 species x 2 genders x 2 age groups x 5 muscles), however, due to missing data the design was unbalanced and higher order interactions (4^{th} order) could not be estimated. In some cases lower order interaction results were also suspect due to the unbalanced design and it was therefore decided to conduct further analyses as follows:

- Analysis on the *M. Longissimus dorsi* only (2 species x 2 genders x 2 age groups as main effects)
- Analysis without gender (2 species x 2 age groups x 5 muscles as main effects)
- Analysis with only females included (2 species x 2 age groups x 5 muscles as main effects)
- Analysis without age (2 species x 2 genders x 5 muscles as main effects)
- Analysis with only sub-adults included (2 species x 2 genders x 5 muscles as main effects)

This was done in order to test the validity of significant differences noted in the unbalanced, full model. When a significant difference or interaction was noted throughout these different models, it was concluded to be of significant value and was therefore reported. In all cases harvest (day of culling)

was added to the model as a covariate. Post hoc differences between treatments were tested for by means of the Tukey HSD test. Pearson correlation coefficients were determined where applicable, using the linear regression procedure.

RESULTS AND DISCUSSION

The mean live weight (kg), carcass weight (kg) and dressing percentages (%) are represented in Table 2. The mean live weight for all impala (n=28) was 46.20 kg. The sample groups within impala (male adult, male sub-adult, female adult, female sub-adult) did not differ ($P > 0.05$) in terms of live weight. For kudu (n=35), the mean live weight was 163.12 kg – almost four times heavier than impala. Kudu males were also heavier ($P \leq 0.05$) than kudu females. The strong dimorphism between species resulted in kudu and impala differing ($P \leq 0.05$) in all carcass yield measurements. As expected, values for carcass yield measurements differed ($P \leq 0.05$) between age groups within species.

When comparing the sample groups for kudu and impala (male adult, male sub-adult, female adult, female sub-adult), no differences ($P > 0.05$) were noted for dressing percentage (Table 2). However, when pooling the data within species, impala had a higher ($P \leq 0.05$) dressing percentage (59.88%) compared to that of kudu (57.60%). The weight of the stomach and its contents can influence the dressing percentage considerably. If the animal was shot after it has been feeding for some time, the effect would be a lower dressing percentage compared to that of an animal killed on an empty stomach. The stomach and intestines of the kudu attributed on average 43.11% to the live weight of the animals, whereas in impala the stomach and intestines made up 35.79% of the live weight. The kudu, a browser can also be considered a roughage or bulk feeder and consumes high volumes of browse with high crude fibre content (Furstenburg, 2005a). The impala on the other hand is a grazer that occasionally browses and is also a concentrate feeder as it prefers high quality food (Furstenburg, 2005b). Consequently, the difference in feeding preference of the two species can attribute to the variation in dressing percentages. In a study by Huntley (1971) the dressing percentage for 18 mature male kudu were estimated at 56.8%. Hoffman (2000b) recorded dressing percentages for impala male and female as 57.5% and 58.0% respectively. Another factor that could also influence the dressing percentage is the weight of the head.

An interaction between species, gender and age was noted for head weights as illustrated in Figure 1. Both these species exhibit sexual dimorphism with only the males having horns. It is evident that the weight of the heads of male adult kudu (16.70kg) was higher ($P \leq 0.05$) than any of the other groups. Horn lengths of up to 137 cm have been recorded for 8 year old male kudu with the Rowland Ward record trophy size measured at 187 cm (Furstenburg, 2005a). A 6-year old impala ram has horns in the range of 52 cm with the Rowland Ward record trophy measured at 81 cm (Furstenburg, 2005b). When the head weights of the animals were expressed as a percentage of live weight, the variation between the two species became less prominent, the head (percentage of live weight) of a male adult kudu (6.97%) compares well to the head (percentage of live weight) of a male adult impala (6.81%).

Table 2. Mean carcass yields for species, gender and age groups.

	Kudu				Impala			
	Male		Female		Male		Female	
	Adult (n=7)	Sub-adult (n=7)	Adult (n=14)	Sub-adult (n=7)	Adult (n=11)	Sub-adult (n=6)	Adult (n=7)	Sub-adult (n=8)
Live weight (kg)	246.67^{a}	126.45$^{c\,c}$	163.84^{b}	105.47^{cd}	47.83^{de}	41.56^{e}	40.73^{e}	43.48^{e}
Carcass weight (kg)	142.69^{a}	66.47^{c}	91.67^{b}	63.53^{c}	37.89^{d}	20.22^{d}	25.44^{d}	24.96^{d}
Dressing percentage (%)	58.79	58.35	55.66	57.61	60.13	60.34	58.96	60.09
Head (kg)	16.70^{a}	6.59^{bc}	7.01^{b}	5.06^{cd}	4.10^{de}	1.99^{f}	1.98^{ef}	1.99^{f}
Head (% of live weight)	6.97^{a}	5.35^{b}	4.19^{d}	4.47^{cd}	6.81^{a}	5.84^{b}	4.58^{c}	4.80^{c}
Feet (kg)	5.61^{a}	3.56^{bc}	4.04^{b}	3.21^{c}	1.42^{d}	1.05^{d}	1.08^{d}	1.02^{d}
Skin (kg)	14.33^{a}	6.00^{c}	9.44^{b}	6.46^{c}	3.35^{d}	1.49^{d}	1.68^{d}	1.53^{d}
Heart with fat (g)	1312.25^{a}	661.23^{bc}	1098.34^{a}	798.33^{b}	477.27^{cd}	282.28^{d}	339.88^{d}	365.24^{d}
Heart without fat (g)	1369.43^{a}	715.74^{c}	998.21^{b}	704.43^{c}	421.34^{d}	244.71^{d}	303.06^{d}	298.93^{d}
Lungs & trachea(kg)	3.64^{a}	1.61^{cd}	2.63^{b}	1.90^{bc}	0.96^{de}	0.43^{e}	0.62^{e}	0.55^{e}
Liver (kg)	2.71a	1.50c	2.19b	1.44c	1.02cd	0.51e	0.73de	0.65e
Spleen (g)	668.14^{a}	388.40^{bc}	468.38^{b}	403.57^{bc}	276.21^{cd}	151.20^{d}	166.43^{d}	221.33^{d}
Stomach & full intestines(kg)	48.40^{a}	28.76^{b}	44.23^{a}	27.30^{b}	9.80^{c}	7.05^{c}	10.21^{c}	8.90^{c}
Kidneys (g)	548.37^{a}	314.66^{c}	445.56^{b}	290.16^{c}	178.84^{d}	89.74^{e}	135.01^{de}	126.60^{de}

$^{a, b, c, d}$ Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

For the adult kudu males, the skin contributed 6.03% to the live weight of the animal compared to 5.63% in the adult kudu female. In impala the skin of an adult male contributed 5.52% to the live weight compared to 4.00% in the adult female impala. It is necessary to keep in mind the contribution of the skin to the carcass weight as game carcasses are normally sold with skin on and sold per kilogram weight thus affecting the overall price.

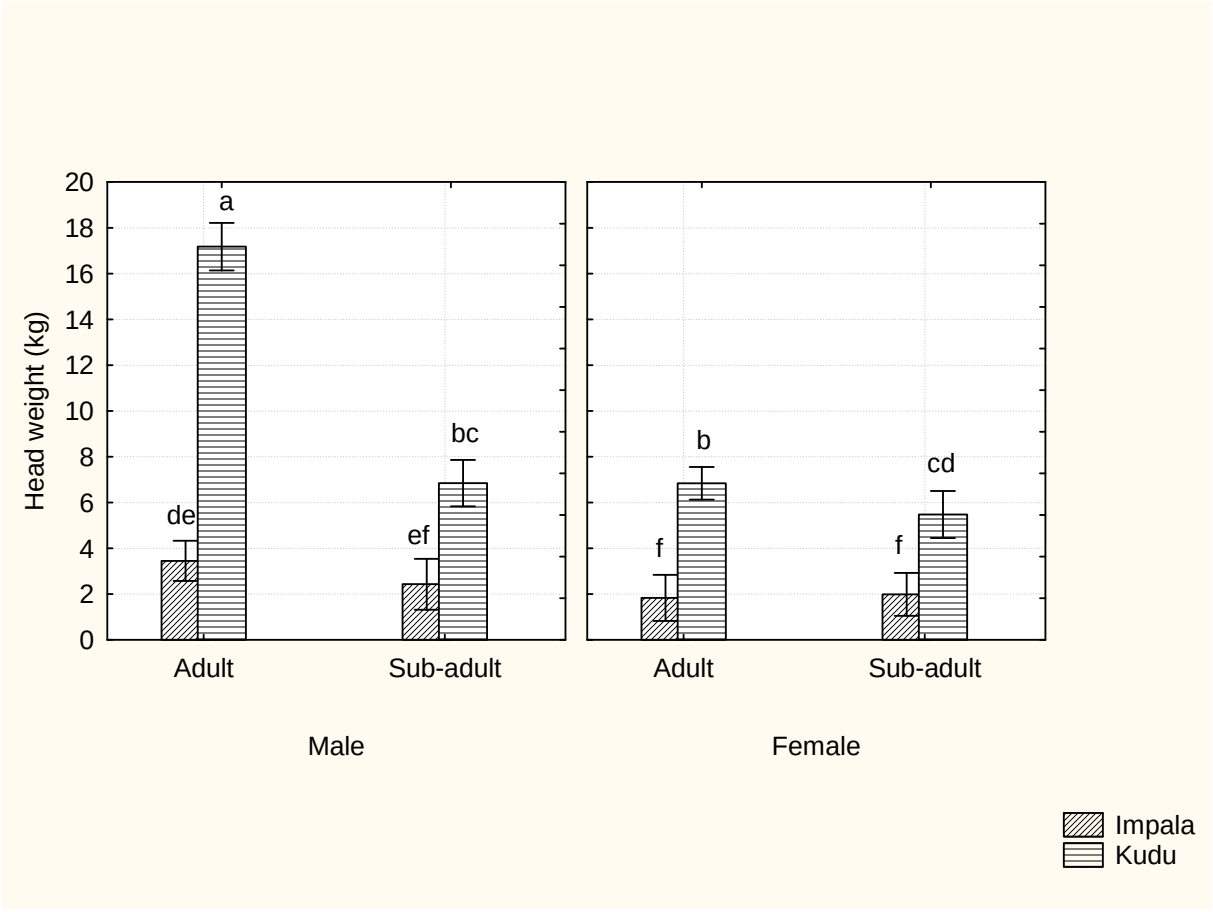

Figure 1. Interaction between species, gender and age for head weights of kudu and impala.

No differences ($P > 0.05$) were found for pH_u for the main effects of species, gender, age or any of their interactions (Table 3). The pH of the animals harvested in the present study ranged between 5.42 and 6.45 with a mean of 5.59. Only two animals had pH values above 6.00, one of them being an adult male kudu which was in poor physical condition and had an abscess on his cheek. Ante-mortem stress, such as poor physical condition, disease, etc. can cause the depletion of glycogen levels in the muscles which leads to a high ultimate pH (> 6.0) (Tornberg, 1996). This could result in dark, firm and dry (DFD) meat which has an unattractive dark colour. Tornberg (1996) concluded that DFD meat is usually tender. She explained that due to short sarcomere lengths and lateral swelling in DFD meat, the extra-cellular spaces are relatively small and hence the tender meat.

Table 3. Least square means (± s.e.) for pH, drip loss, cooking loss, and WBS for kudu and impala *M. longissimus dorsi*.

	Species		Gender		Age	
	Kudu	**Impala**	**Male**	**Female**	**Adult**	**Sub-adult**
pH_u	5.62 ± 0.05	5.59 ± 0.06	5.64 ± 0.07	5.58 ± 0.04	5.62 ± 0.06	5.59 ± 0.04
Drip loss (%)	1.40 ± 0.25	1.19 ± 0.16	1.25 ± 0.22	1.34 ± 0.21	1.33 ± 0.22	1.26 ± 0.20
Cooking loss (%)	31.38 ± 0.79	31.04 ± 0.83	31.77 ± 0.76	30.74 ± 0.83	31.54 ± 0.75	30.77 ± 0.88
WBS (kg/1.27cmø)	4.14 ± 0.25	4.13 ± 0.25	4.11 ± 0.21	4.15 ± 0.29	4.19 ± 0.25	4.06 ± 0.26

Drip loss and cooking loss

Drip loss is a function of the water-holding capacity (WHC) of meat (Warris, 2000). Some of the eating qualities of meat such as tenderness and juiciness are influenced by the WHC. Physical qualities i.e. drip loss and cooking loss are also affected by the WHC of meat. The WHC is influenced by several factors of which the extent of pH fall post mortem is but one.

Table 4. Least square means (± s.e.) for physical measurements in five different muscles in kudu and impala.

Physical characteristic	**Muscle**				
	LD	**BF**	**SM**	**ST**	**SS**
Drip loss (%)					
Kudu	1.31^{b} ± 0.12	1.15^{a} ± 0.10	1.35^{b} ± 0.19	1.20^{b} ± 0.09	1.09^{a} ± 0.08
Impala	1.22^{a} ± 0.12	1.15^{a} ± 0.10	1.72^{b} ± 0.19	1.16^{a} ± 0.09	1.06^{a} ± 0.08
Cooking loss (%)					
Kudu	30.77^{c} ± 0.55	34.15^{b} ± 0.44	37.56^{a} ± 0.39	38.09^{a} ± 0.41	36.92^{a} ± 0.33
Impala	31.20^{c} ± 0.52	33.65^{b} ± 0.42	37.16^{a} ± 0.37	38.28^{a} ± 0.39	37.07^{a} ± 0.31

^{a,b} Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

The main effects of species, gender and age showed no differences ($P > 0.05$) for drip loss in the present study (Table 3). However, when considering the five muscles, differences ($P \leq 0.05$) were noted (Table 4). Drip loss for impala *M. semimembranosus* was higher ($P \leq 0.05$) (1.72%) than that of all other impala muscles. When considering kudu muscles, *M. semimembranosus* also had the highest value (1.35%), differing ($P \leq 0.05$) from *M. biceps femoris* (1.15%) and *M. supraspinatus* (1.09%) but not from *M. longissimus dorsi* (1.31%) and *M. semitendinosus* (1.20%). These differences between muscles could be attributed to physical (e.g. fibre types) and chemical differences as well as position within the carcass (e.g. subcutaneous and thus chilling more rapidly). Smit (2004) measured drip loss values of 4.49% for *M. longissimus dorsi* in blesbok female and 4.40% for blesbok male. In another study by Van Schalkwyk (2004), the drip loss values for blue wildebeest were 3.63% for female and 4.39% for male animals. The low drip loss values for kudu and impala in the present study could be due to the fact that all of the pH values were above 5.4, the iso-electric point for muscle proteins. Another reason for the low drip loss values could be the efficient cooling techniques used in this study compared to that used for blesbok and blue wildebeest as delayed chilling of carcasses result in higher drip loss. Hoffman (2000a) reported drip loss for impala cropped at night in Zimbabwe

to be 2.66% for female and 2.54% for male animals. In another study, Kritzinger *et al.* (2003) found drip loss of impala cropped at night and therefore being under less stress (2.93 %) to be lower than that of impala cropped during the day (4.15 %).

In terms of cooking loss there were no differences ($P > 0.05$) for the main effects i.e., species, gender and age, between samples (Table 3). However, differences ($P \leq 0.05$) were noted between the different muscles (Table 4). For kudu and impala, the *M. semimembranosus*, *M. semitendinosus* and *M. supraspinatus* did not differ ($P > 0.05$) from each other, but differed ($P \leq 0.05$) from *M. longissimus dorsi* and *M. biceps femoris* (these two muscles also differed ($P \leq 0.05$) from each other) (Figure 2). The highest cooking loss values were measured for *M. semitendinosus* (kudu: 38.09%; impala: 38.28%) with the *M. longissimus dorsi* having the lowest cooking loss values (kudu: 30.77%; impala: 31.20%). The values obtained in the current investigation are higher than that for impala (23.98 ± 0.367%) cropped at night (Hoffman, 2000b). Onyango *et al.* (1998) calculated cooking loss for zebra (*Equus burchelli*) loin samples at 21.9% and for oryx (*Oryx gazella*) leg samples at 36.4%.

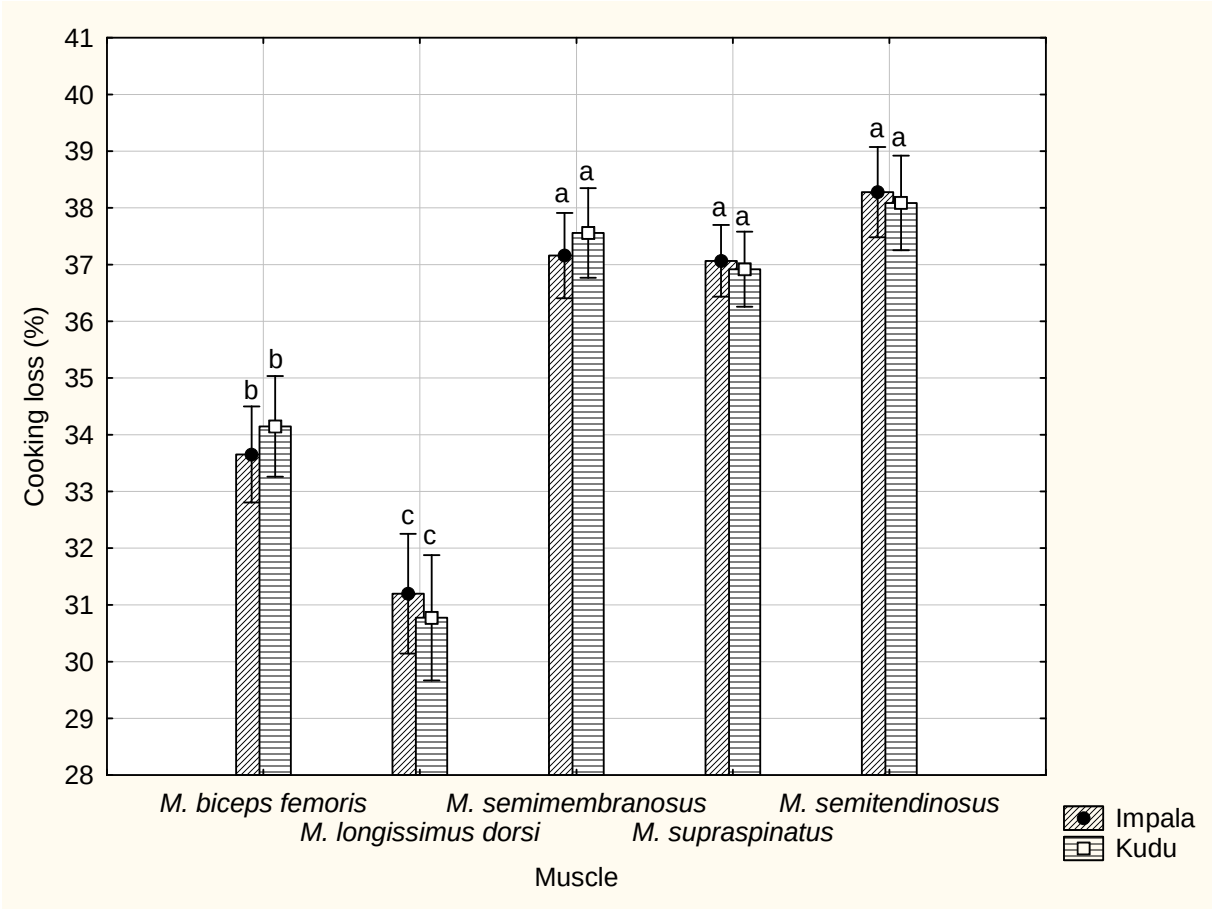

Figure 2. Cooking loss (%) for five different muscles in kudu and impala.

Linear correlation coefficients between the pH_u and the physical measurements of the *M. longissimus dorsi* are presented in Table 5. A low inverse correlation was found between pH_u and cooking loss percentage ($r = -0.277$; $P = 0.0234$) indicating that a higher pH_u resulted in a lower cooking loss. This

corresponds with the findings of Hoffman *et al.* (2007) where springbok *M. longissimus dorsi* correlated inversely with the pH_u ($r = -0.42$; $P < 0.001$).

Tenderness

Consumers consider tenderness to be the most important quality characteristic of meat (Koohmaraie, 1992). Jeremiah (1983) concluded that when consumers found beef to be unacceptable it is mostly because of toughness. In this study no differences ($P > 0.05$) in meat tenderness were detected between gender and age groups. This is consistent with the findings of Van Schalkwyk (2004) who noted no differences ($P > 0.05$) in WBS values for male and female mountain reedbuck (male: 3.00 kg/1.27cmø; female: 2.95 kg/1.27cmø). In the same study, adult and sub-adult black wildebeest showed no differences ($P > 0.05$) in tenderness (adult: 3.13 kg/1.27cmø; sub-adult: 2.77 kg/1.27cmø) either. Hoffman (2000a) noted similar WBS values for impala cropped at night (3.65 kg/1.27cmø). Hoffman *et al.* (2007) also observed no differences ($P > 0.05$) in tenderness of springbok *M. longissimus dorsi* for gender and age groups, however animals from different regions (Rustfontein: 1.67 kg/1.27cmø; Gariep: 2.12 kg/1.27cmø; WP: 2.67 kg/1.27cmø) differed ($P \leq 0.05$) in terms of tenderness.

Table 5. Pearson linear correlation coefficients between pH_u and the physical measurements of *M. longissimus dorsi* of kudu and impala.

	Pearson	
Measurements	**r**	**P**
Drip loss (%)	-0.227	0.0710
Cooking loss (%)	-0.277	0.0234
Shear force (kg/ 1.27cmø)	-0.056	0.654
L*	-0.368	0.0022
a*	-0.433	0.0003
b*	-0.441	0.0002
Hue	-0.180	0.1444
Chroma	-0.533	<0.0001

r = correlation coefficient

The rate of post-mortem pH decline as well as pH_u has a significant influence on meat quality measurements such as tenderness (Sales & Mellett, 1996). In a study by Purchas (1990) an increase in pH_u from about 5.5 to 6.2 resulted in an increase in meat toughness. He explained that this happened as a result of decreased sarcomere length in this pH region. However this is in contradiction with the findings of Tornberg (1996) stating that shorter sarcomere lengths results in more tender meat. Bouton *et al.* (1973) also found that an increase in ultimate pH resulted in an increase in water retention of muscles. However, the pH range from 5.4 to 6.0 as in the present study is small and improbable to have an effect on tenderness. No linear correlation was found between pH_u and shear force values (Table 5).

There is great variation in meat tenderness among different muscles (Purchas & Davies, 1974; Belew *et al.*, 2003). The results in the present study confirm this. An interaction ($P \leq 0.05$) between species and muscle were observed for tenderness. *M. supraspinatus* for kudu (3.79 kg/1.27cm ø) and impala (3.61 kg/1.27cm ø) had the lowest WBS values and differed ($P \leq 0.05$) from all other muscles. Kudu and impala *M. longissimus dorsi*, kudu *M. biceps femoris*, and kudu and impala *M. semitendinosus* did not differ ($P > 0.05$) from each other in terms of WBS tenderness values. Impala *M. biceps femoris* differed ($P \leq 0.05$) from all other muscles. The tenderness of *M. semimembranosus* for both kudu (5.66 kg/1.27cm ø) and impala (5.90 kg/1.27cm ø) had the highest WBS values and differed ($P \leq 0.05$) from all other muscles but not from each other.

Kudu muscles in order of increasing tenderness were: *M. supraspinatus, M. biceps femoris*, *M. semitendinosus, M. longissimus dorsi,* and *M. semimembranosus*. Impala meat could be arranged in order of increasing tenderness as follows: *M. supraspinatus, M. semitendinosus, M. longissimus dorsi, M. biceps femoris* and *M. semimembranosus*. These results are the opposite of that reported by Du Buisson (2006) for five springbok muscles. The springbok muscles in order of decreasing tenderness were: *M. longissimus et lumborum, M. rectus femoris, M. biceps femoris, M. semitendinosus* and *M. supraspinatus*. Shackelford *et al.* (1995) found tenderness in beef muscles to decrease in the order: *M. longissimus dorsi, M. semitendinosus, M. supraspinatus, M. biceps femoris* and *M. semimembranosus*. These differences between muscles could be caused by the activity of these muscles as the abovementioned species all use the different muscles at different frequencies, for different activities, etc. resulting in different ratios of fibre types. For example, the impala is known to jump large heights and distances when frightened whilst the kudu would rather run off (although the kudu has been noted to jump great heights as well).

Table 6. WBS values (kg/1.27cmø) (± s.e.) for five different muscles in kudu and impala compared to beef.

Species	LD	BF	SM	ST	SS	n
Kudu	$4.29^{ab} \pm 0.18$	$4.02^{ab} \pm 0.18$	$5.66^{c} \pm 0.18$	$4.10^{ab} \pm 0.11$	$3.79^{a} \pm 0.10$	32
Impala	$4.15^{ab} \pm 0.17$	$4.58^{b} \pm 0.17$	$5.90^{c} \pm 0.17$	$4.08^{ab} \pm 0.11$	$3.61^{a} \pm 0.10$	35
Beef*	3.40 ± 0.20	-	4.53 ± 0.20	4.10 ± 0.20	3.92 ± 0.20	20

[a,b,c] Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

* *Belew et al., 2003*

A study on beef in the United States showed that WBS values of >4.9 kg/1.27cmø were unacceptable to consumers (Miller *et al.*, 2001). From the five kudu and impala muscles investigated only *M. semimembranosus* was above this threshold indicating that the tenderness may be unacceptable to consumers.

Colour

Consumers use colour as a visual measurement of freshness and quality when purchasing meat (Stevenson *et al.*, 1989; Young & West, 2001; Mancini & Hunt, 2005). The perception is that dark

coloured meat is not fresh, or of inferior quality (Dikeman, 1990). According to Stevenson-Barry *et al.* (1999) venison has poor colour stability when being compared to meat from other species. Viljoen *et al.* (2002) commented that consumers prefer the red colour of raw meat with a normal pH to meat with a slightly higher pH that could be dark, firm and dry (DFD).

The means for L*-, a*- and b*-values, hue-angle and chroma for *M. longissimus dorsi* as affected by species, gender and age are represented in Table 7. The means for a* and b* values, hue-angle and chroma for five different muscles in kudu and impala are represented in Table 8. L* values are not represented in Table 8 since an interaction ($P \leq 0.0001$) between muscle and species was noted for the L*values. This interaction is illustrated in Figure 3. Overall impala meat appeared darker in colour than kudu since L*values were lower ($P \leq 0.0001$) for all impala muscles except for *M. supraspinatus*, which had a higher L*value than that for kudu *M. supraspinatus*.

Table 7. Least square means (± s.e.) for L*-, a*- and b*values, hue-angle and chroma for kudu and impala *M. longissimus dorsi* as affected by gender and age.

		Colour measurements/ determinations				
	Sample	**L***	**a***	**b***	**hue**	**Chroma**
Kudu:	Male	$31.79^{a} \pm 0.49$	$11.04^{ab} \pm 0.36$	8.70 ± 0.41	38.15 ± 1.39	$14.15^{ab} \pm 0.43$
	Female	$31.73^{a} \pm 0.41$	$11.85^{a} \pm 0.30$	8.45 ± 0.34	35.59 ± 1.17	$14.69^{a} \pm 0.36$
Impala:	Male	$29.86^{b} \pm 0.45$	$10.81^{ab} \pm 0.33$	7.57 ± 0.37	34.68 ± 1.28	$13.32^{b} \pm 0.39$
	Female	$28.34^{b} \pm 0.46$	$10.41^{b} \pm 0.34$	7.71 ± 0.38	36.43 ± 1.30	$13.09^{b} \pm 0.40$
Kudu:	Adult	$30.31^{b} \pm 0.41$	11.65 ± 0.30	8.67 ± 0.34	36.67 ± 1.17	$14.60^{a} \pm 0.36$
	Sub-adult	$33.21^{a} \pm 0.49$	11.24 ± 0.36	8.49 ± 0.41	37.06 ± 1.39	$14.24^{ab} \pm 0.43$
Impala:	Adult	$28.33^{c} \pm 0.45$	10.57 ± 0.33	7.50 ± 0.38	35.04 ± 1.28	$13.23^{b} \pm 0.40$
	Sub-adult	$29.87^{ab} \pm 0.48$	10.65 ± 0.34	7.78 ± 0.40	36.07 ± 1.37	$13.27^{b} \pm 0.42$

[a,b,c] Means in the same column, within the same subgroup, with different superscripts are significantly different ($P \leq 0.05$)

The highest reflectance (L*) was measured in kudu *M. semitendinosus* (35.37), while impala *M. longissimus dorsi* had the lowest L* value (29.30) therefore being the darkest in colour (Figure 3). Inverse correlations ($P \leq 0.01$) were found between pH_u and L* ($r = -0.368$), a* ($r = -0.433$) and b* ($r = -0.441$) values (Table 5). Therefore meat with a lower pH_u had a higher reflectance (L*).

With regards to a* values (the red-green range), the mean for kudu (12.79) was higher ($P \leq 0.01$) (more red) than the mean for impala (11.97). When considering the different muscles, fresh *M. supraspinatus* showed a more intense and redder colour, with a higher ($P \leq 0.05$) a* value (13.65) than the other muscles (Table 8). *M. longissimus dorsi* had the lowest a* value (11.08), thus being the least red of the muscles under investigation.

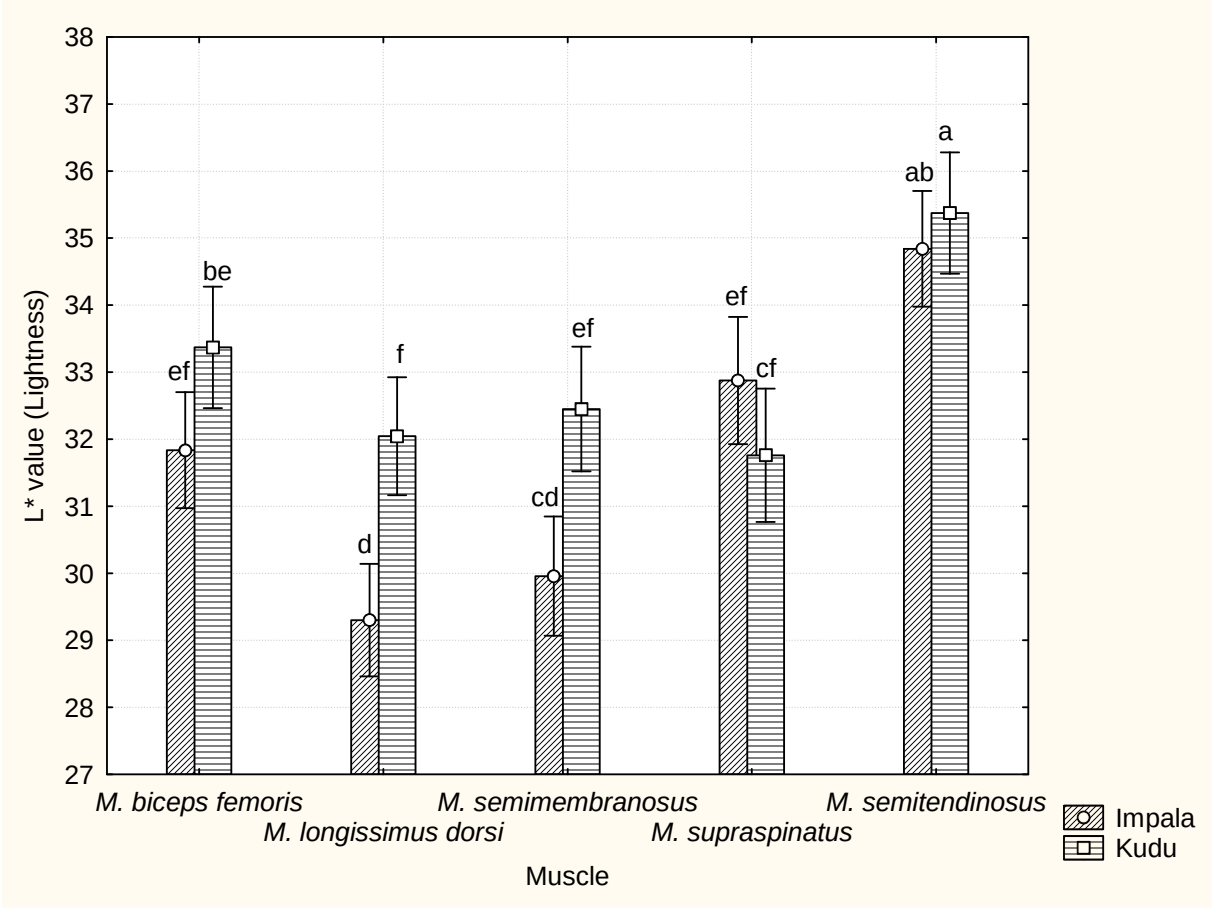

Figure 3. Lightness (L*) values for the muscle and species interaction (Muscle*Species).

For the b* values, differences ($P \leq 0.001$) were observed between species, but neither for age nor gender. Kudu (9.78) had higher b* values than impala (8.75). *M. longissimus dorsi* (8.16) had the lowest b* value which differed ($P \leq 0.05$) from all other muscles. With the highest b* value, *M. semitendinosus* (10.08) differed ($P \leq 0.05$) from all other muscles. For the b* values, *M. semimembranosus*, *M. biceps femoris* and *M. supraspinatus* did not differ ($P > 0.05$) from each other (Table 8).

In the present study, when considering the hue angle, no differences ($P > 0.05$) were found between species and age groups. Males had a higher ($P \leq 0.01$) mean hue angle value than females. Differences ($P \leq 0.05$) were also observed for the different muscles. *M. semimembranosus*, *M. biceps femoris* and *M. semitendinosus* differed ($P \leq 0.05$) from *M. supraspinatus*, but not from each other. *M. longissimus dorsi* did not differ ($P > 0.05$) from either of the two groups of muscles. *M. supraspinatus* had the lowest value (34.43) for hue angle, while the value for *M. semitendinosus* (38.20) was the highest.

Table 8. Least square means (± s.e) for a* and b* values, hue-angle and chroma for kudu and impala as measured in five different muscles (n=46).

	Muscle				
	LD	**BF**	**SM**	**ST**	**SS**
a*	11.08^{d} ± 0.20	12.00^{c} ± 0.17	12.34^{bc} ± 0.19	12.83^{b} ± 0.16	13.65^{a} ± 0.18
b*	8.16^{c} ± 0.22	9.27^{b} ± 0.21	9.44^{b} ± 0.21	10.08^{a} ± 0.15	9.35^{b} ±0.19
Hue	36.24^{ab} ± 0.76	37.45^{a} ± 0.59	37.21^{a} ± 0.67	38.20^{a} ± 0.47	34.43^{b} ±0.66
Chroma	13.89^{c} ± 0.23	15.25^{b} ± 0.21	15.64^{b} ± 0.22	16.37^{a} ± 0.18	16.65^{a} ± 0.18

a* indicates the red-green range and b* indicates the blue-yellow range

$^{a, b, c}$ Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

Higher ($P \leq 0.001$) mean chroma values were recorded for kudu (16.20) compared to that of impala (14.92). Gender and age did not affect chroma values. Chroma was inversely correlated with pH_u ($r = -0.533$, $P \leq 0.0001$) (Table 5), therefore meat with a lower pH_u had a more intense red colour (chroma). *M. longissimus dorsi* differed ($P \leq 0.05$) from all other muscles with the lowest chroma value of 13.89 (Table 8). Higher chroma values signify higher colour saturation levels resulting in the muscles appearing brighter in colour (Stevenson *et al.*, 1989).

Smit (2004) found that gender and age did not have any statistically significant effects on the muscle colour of blesbok. However, the different regions from where the animals were harvested had a significant effect on the L*, a*, b* and chroma values of the meat. Seideman *et al.* (1982) postulated that the meat from male animals is darker in colour due to their greater physical activity. Conversely, in this study no differences ($P > 0.05$) were observed between male and female animals in respect of their meat colour.

Volpelli *et al.* (2003) reported noticeably higher a* and lower b* values (23.71 and 4.26 respectively) for *M. longissimus dorsi* in fallow deer compared to a* and b* values from the present research (11.08 and 8.16 respectively). Colour of meat is also influenced by the concentration of haem pigments present in the muscle, especially myoglobin. According to Lawrie (1998), the concentration of myoglobin increases with age.

Overall, colour measurements were mostly affected by species and muscle with kudu meat being more red and brighter in colour than impala. Colour differences between muscles could be ascribed to differences in myoglobin content between muscles which will be discussed in Chapter 5.

CONCLUSION

The results from this study emphasize the differences between species and muscle type in terms of physical measurements. The respective muscles of kudu and impala investigated in this study differed ($P \leq 0.05$) in terms of drip loss, cooking loss and all colour measurements. An interaction ($P \leq$

0.05) was also noted between muscle and species for tenderness (WBS values). *M. supraspinatus* was found to be the most tender muscle and *M. semimembranosus* the least tender for both kudu and impala. Kudu and impala differed ($P \leq 0.05$) in terms of a*-, b*- and chroma values. Kudu meat, having higher chroma and a* values ($P \leq 0.05$), was found to be more red and brighter in colour than impala meat. In terms of colour, *M. supraspinatus* showed a more intense and redder colour than the other muscles with *M. longissimus dorsi* being the least red in colour. An interaction ($P \leq 0.0001$) between muscle and species was also noted for the L* values. However, no differences ($P \leq 0.05$) in the physical measurements were observed between gender and age groups.

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Chapter 4

Proximate, myoglobin, collagen and mineral contents of kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*) muscle as affected by gender and age

Abstract

Meat and meat products are valuable sources of proteins, minerals and nutrients in the human diet. Research has shown that the proximate composition of meat varies between species. The kudu and impala are two antelope species found in southern Africa and although they are found in the same area, their diet varies to some extent. Kudu are predominantly non-selective browsers, feeding on tree and shrub leaves, while impala are known as mixed feeders as they graze and browse. In the present study, moisture content differed between kudu (76.46%) and impala (75.28%) muscle. Of the five muscles analysed, differences were also noted between muscles for both moisture and fat content. The highest fat content was found in *M. supraspinatus* followed by *M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus* and *M. longissimus dorsi*. Protein content did not differ between the species (kudu -21.66%; impala - 22.26%), nor did gender and age have an effect. Kudu (1.62%) had lower fat content than impala (2.22%) whilst female animals had a higher fat content than male animals. Sub-adults (1.20 ± 0.019%) had higher ash content than adults (1.10 ± 0.032%). The *M. supraspinatus* had the lowest protein and also the highest fat content, with *M. semimembranosus* having the highest protein content but the lowest value for fat. However, no correlation was found between protein and fat content. In terms of myoglobin content no differences were found between kudu and impala meat. Females had a higher mean (6.58 ± 0.20 mg/g) myoglobin content than male (5.11 ± 0.25 mg/g) animals. Glycolitic muscles had the lowest myoglobin content with the highest values found in the oxidative muscle such as *M. supraspinatus.* The myoglobin content of impala *M. longissimus dorsi* was higher than that of kudu *M. longissimus dorsi*; however for all other muscles the myoglobin content was lower in impala. Gender had no effect on mineral content. Potassium levels were highest for kudu while phosphorus was more prevalent in impala meat. Adult and sub-adult groups differed significantly in terms of potassium, calcium and zinc content. Potassium and calcium content were higher for sub-adult animals while zinc content was higher in adult animals. Although the fat content of impala was higher than that of kudu, it was still relatively low and the present findings therefore confirm that kudu and impala meat can be considered a healthy, lean meat.

INTRODUCTION

In recent years the export of game meat from South Africa has increased steadily. It is estimated that deboned meat from 160 000 carcasses was exported during the 2005 season (Hoffman & Wiklund, 2006). Game meat is also gaining popularity as a sought after item on the menus of many restaurants and game lodges. From a group of tourists visiting the Western Cape, 77% of the respondents indicated that they would like to order game meat in a restaurant. In contrast, only 49% of South African consumers indicated that they would like to eat game meat in a restaurant (Hoffman *et al.*,

2003). Radder & Le Roux (2005) concluded that 51% of South Africans ate red meat three or more times a week. However, the fact that only 4% ate game has shown that South African consumers will have to be educated on the nutritional value and health benefits of game meat.

Meat and meat products are valuable sources of proteins, vitamins and minerals in the human diet. As a source of high quality protein and much needed minerals, meat can alleviate many nutritional deficiencies especially in developing countries (Bender, 1992). Therefore the chemical composition of meat is of importance to the consumer. Whether meat is perceived as being healthy or not, particularly with regards to nutrition and fat content, markedly influences meat consumption (Mannion *et al.*, 2000; Jiménez-Colmenero *et al.*, 2001). However, little scientific data exists on the nutritional/chemical value of game meat.

Many factors such as species, diet, gender, age and region can influence the chemical composition of meat. Research has shown that protein content of game meat varies between species, for example Hoffman & Ferreira (2004) found the protein content of duiker (*Sylvicapria grimmia*) to be 25.7%. In contrast, the protein of springbok (*Antidorcas marsupialis*) in four production regions ranged from 18.8 to 21.16% (Hoffman *et al.*, 2007). Fat content and fat composition is also clearly influenced by the diet of the animal (Nuernberg *et al.*, 2005; Wood *et al.*, 1999). Mineral composition has also been found to be influenced by diet and/ or region as noted for example in impala muscle by Hoffman *et al.* (2005).

Myoglobin, one of the two main haem proteins in meat, is important in the determination of meat colour (Kranen *et al.*, 1999) and its quantity is known to be influenced by various extrinsic and intrinsic factors. For example, the myoglobin content of meat is known to vary between species (Warris *et al.*, 1990; Kranen, *et al.*, 1999) and with activity levels (Lawrie, 1998; Vestergaard *et al*., 2000).

This study was undertaken to establish the nutritional content of five muscles from kudu and impala in terms of proximate composition (moisture, protein, lipid and ash), myoglobin, collagen and mineral content and to ascertain the effect of gender and age thereon. These two game species occur over a wide area in southern Africa and are frequently encountered in the same region and their meat is regularly consumed and exported.

MATERIALS AND METHODS

Experimental animals

In this study, 35 kudu (*Tragelaphus strepsiceros*) comprising 14 male (KM) and 21 female (KF), and 32 impala (*Aepyceros melampus*) comprising 17 male (IM) and 15 female (IF), were harvested in the Limpopo Province, Mabula District (S 24 52.611, E 27 56.862). The sample distribution in terms of species, gender and age is shown in Table 1. Harvesting of the animals took place over a period of

128 days (four months), starting in late autumn and extending over the dry winter months. Since animals were expected to lose physical body condition towards the end of winter due to a decline in available food, the day of harvest was used as a co-variant in the statistical analyses.

The area is part of the Savanna Biome and is classified as Central Sandy Bushveld with a mean annual rainfall of 500 – 700 mm (Mucina & Rutherford, 2006). The vegetation varies from broadleaved *Combretum*-woodland on shallow, rocky or gravely soils to open flats and lower slopes with *Acacia*-, *Ziziphus*-, and *Euclea*- species dominating. *Combretum apiculatum*, *Acacia caffra* and *Dichrostachys cinerea* are some of the most prevalent species. Grazing is dominated by *Eragrostis pallens, Eragrostis rigidor* and *Perotis patens*, while *Panicum maximum* is also widely available. The area has summer rainfall with very dry winters and three seasons can be distinguished, namely a cool and dry season from May to mid August, a hot and dry season from mid August to October and a wet and hot season from November to April.

(Refer to Chapter 3 “Materials and Methods” for hunting techniques and age classification of animals.)

Table 1. Sample distribution of kudu (n=35) and impala (n=32) according to age and gender

	Kudu		**Impala**		
	Male	**Female**	**Male**	**Female**	**Total**
Adult	7	14	11	7	39
Sub-adult	7	7	6	8	28
Total	14	21	17	15	67

At 24 h post-mortem, the *M. longissimus dorsi et lumborum* (LD) was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra and the *M. biceps femoris* (BF), *M. semimembranosus* (SM)*, M. semitendinosus* (ST) *and M. supraspinatus* (SS) were also removed. Samples for chemical and sensory analyses were vacuum packed and stored at -20 °C. Prior to chemical analyses all visible fat and connective tissue were removed from the meat samples. The meat was then homogenised and used as required.

Chemical analyses

Proximate composition

The moisture and protein contents (g/100 g meat) of all the samples were determined according to the Association of Official Analytical Chemist’s Standard Techniques (A.O.A.C., 1997). The accuracy and repeatability of all the techniques are controlled on a bi-monthly basis by means of a National Inter-laboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa) wherein blind

samples are analysed. The moisture content was determined by drying at 105°C for 24 hours. After drying samples were weighed and put in the ashing oven at 500˚C for 6 hours to determine ash content. To determine the protein content, dried and defatted meat were ground with a pestle in a mortar to a fine powder. Samples of 0.100 mg were inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Ave., St Joseph, HI 49085-2396, USA, Part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. The fat content was determined by homogenising the samples in a blender, followed by chloroform:methanol (2:1) extraction (Lee *et al.*, 1996).

Myoglobin content

For determination of the myoglobin content a 5 g sample was homogenised with a phosphate buffer (pH 6.8). After cooling for 1 hour on an ice bed, the sample was centrifuged at 9000 rpm for 45 minutes and poured through filter paper (Whatman 4). Spectrophotometer readings of the supernatant were taken at 580 and 725 nm respectively (Warris, 1979).

Hydroxyproline content

The *M. Longissimus dorsi* samples were analysed for hydroxyproline content as a means of estimating collagen content (Kolar, 1990). Samples (8 g) with 1% NaCl were cooked at 78˚C (60 min), cooled down and centrifuged at 6000 RCF for 10 minutes. The supernatant and residue fractions were individually hydrolysed in 6M HCl at 110˚C for 12 - 16 hours. The hydrolysate was filtrated and diluted. Hydroxyproline was oxidised with chloramine-T, the excess chloramine-T was destroyed with perchloric acid and the hydroxyproline chromagen then reacted with 4-dimethylaminobenzaldehyde to develop a pink colour. After heating to 60°C the absorption was measured at 560 nm on a spectrophotometer. Total collagen was calculated by multiplying the hydroxyproline content by 7.25 and 7.52 for the insoluble and soluble fractions respectively (Cross *et al.*, 1973). The percentage solubility was calculated by dividing the soluble collagen content by the total collagen content and expressing it as a percentage.

Mineral composition

The mineral composition of the meat was determined after ashing of the defatted meat samples using the method described by Giron (1973). The fat-free meat samples (1–3 g) were air dried and ground to pass through a 0.5 mm sieve. The samples were ashed overnight in a muffle furnace at 550 °C. A 6 M HCl solution was prepared by diluting 500 cm^3 of a 36% (m/m) HCl solution to 1 dm^3. After ashing, 5 cm^3 of 6 M HCl was added to dissolve the cooled sample. The samples were subsequently dried on a waterbath. After cooling, 5 cm^3 6 M nitric acid (HNO_3) solution was added to the samples. The 6 M

HNO_3 solution was prepared by diluting 429 cm^3 of a 65% (m/m) solution to 1 dm^3. After adding the latter solution, the samples were heated in a water bath and removed after boiling point was reached. The solution was subsequently filtered through filter paper into a 100 cm^3 volumetric flask and diluted to volume with deionised water. Element concentrations were measured on a Varian (Victoria, Australia) Liberty Series II sequential inductively coupled plasma atomic emission spectrophotometer.

Statistical analyses

The data was analysed using repeated measures ANOVA as five muscles from each carcass were analysed. This was done with Statistica (version 7) statistical software. The full model was analysed (2 species x 2 genders x 2 age groups x 5 muscles), however, due to missing data the design was unbalanced and higher order interactions (4^{th} order) could not be estimated. In some cases lower order interaction results were also suspect due to the unbalanced design and it was therefore decided to conduct further analyses as follows:

- Analysis on the *M. Longissimus dorsi* only (2 species x 2 genders x 2 age groups as main effects)
- Analysis without gender (2 species x 2 age groups x 5 muscles as main effects)
- Analysis with only females included (2 species x 2 age groups x 5 muscles as main effects)
- Analysis without age (2 species x 2 genders x 5 muscles as main effects)
- Analysis with only sub-adults included (2 species x 2 genders x 5 muscles as main effects)

This was done in order to test the validity of significant differences noted in the unbalanced, full model. When a significant difference or interaction was noted throughout these different models, it was concluded to be of significant value and was therefore reported. In all cases harvest (day of culling) was added to the model as a covariate. Post hoc differences between treatments were tested for by means of the Tukey HSD test. Pearson correlation coefficients were determined when relevant using the linear regression procedure.

RESULTS AND DISCUSSION

Proximate composition

As differences ($P \leq 0.0001$) were noted between the five muscles investigated (Table 3), the data could not be pooled for muscles. An analysis of the main effects of species, gender and age on the proximate composition of the *M. longissimus dorsi* are summarised in Table 2. The moisture content of meat usually varies between 70 and 77%, depending on the fat content of the meat. Meat with a high fat content has a lower moisture content and visa versa (Young *et al.*, 2001).

In the present study, the moisture content differed ($P \leq 0.05$) between species. Kudu *M. longissimus dorsi* had a higher mean moisture content (75.52%) than that of impala (74.52%). As expected, the fat

content measured in kudu *M. longissimus dorsi* (1.62 ± 0.10%) was lower (P ≤ 0.0001) than impala *M. longissimus dorsi* (2.22 ± 0.10%).

Table 2. Least square means (± s.e.) for proximate chemical composition (%) and myoglobin content (mg/g) for kudu and impala *M. longissimus dorsi*.

Chemical component	Species		Gender		Age	
	Kudu	Impala	Male	Female	Adult	Sub-adult
Moisture (%)	75.52 [a] ± 0.15	74.52 [b] ± 0.15	76.19 ± 0.23	75.55 ± 0.13	76.11 ± 0.25	75.62 ± 0.15
Protein (%)	21.66 ± 0.28	22.26 ± 0.18	21.98 ± 0.29	21.95 ± 0.16	21.74 ± 0.32	22.18 ± 0.19
Fat (%)	1.62 [a] ± 0.10	2.22 [b] ± 0.10	1.74 [c] ± 0.10	2.10 [d] ± 0.09	2.04 ± 0.13	2.06 ± 0.08
Ash (%)	1.14 ± 0.03	1.16 ± 0.02	1.15 ± 0.03	1.15 ± 0.02	1.10 [c] ± 0.03	1.20 [d] ± 0.02
Myoglobin (mg/g)	6.17 ± 0.35	5.75 ± 0.22	5.11 [a] ± 0.25	6.58 [b] ± 0.20	6.11 ± 0.40	5.81 ± 0.24

[a,b] Means in the same row within the same subgroup, with different superscripts are significantly different (P < 0.0001)

[c,d] Means in the same row within the same subgroup, with different superscripts are significantly different (P ≤ 0.05)

No differences (P > 0.05) for protein content were found between species, gender or age groups (Table 2). The values obtained for protein in this study are lower than that of *M. longissimus dorsi* from kudu harvested in the Orange Free State where female kudu was reported to have a protein content of 24.29% and kudu male 23.58% protein (Mostert & Hoffman, 2007). Hoffman *et al*. (2007) found the protein content of springbok from four different regions to vary from 18.80 to 21.16%, whilst the protein content of impala was found to vary between 23.6 and 24.1% (Hoffman, 2000), values slightly higher than that reported for the present investigation (Table 2).

As mentioned before, female animals had (P ≤ 0.05) higher fat contents than male animals. This is in keeping with the findings of Hoffman (2000) where impala females had statistically higher (P = 0.0197) fat content (3.4 ± 0.2%) than impala males (2.5 ± 0.3%). Hoffman *et al.* (2007) investigated the meat quality of springbok and also noted significantly higher fat in females (3.13 ± 0.28%) compared to that of male animals (1.35 ± 0.08%). In the same study, an inverse linear correlation was observed between fat and moisture content for springbok *M. longissimus dorsi* (r = -0.49, P < 0.0001). In beef and lamb a similar trend was noticed (Doornenbal & Murray, 1981; Rowe *et al.*, 1999). Aidoo & Haworth (1995) speculated that this trend is possibly a result of the fact that water and protein are mainly contained within the lean portion of meat. In the present study inverse linear correlations were also found between the fat and moisture contents for all five muscles investigated (Table 4).

The fat content of kudu in the present study is similar to that of kudu harvested in the Orange Free State (female: 1.56 ± 0.093%, male: 1.58 ± 0.056%), although differences between genders were not significant in that investigation (Mostert & Hoffman, 2007).

For the five muscles analysed, differences (P ≤ 0.0001) were noted for the mean protein content (Table 3). Protein content was the highest for the *M. semimembranosus* (22.60 ± 0.20%), followed by *M. semitendinosus* (22.56 ± 0.51%) and *M. longissimus dorsi* (22.54 ± 0.18%), then *M. biceps femoris* (21.64 ± 0.21%) whilst the *M. supraspinatus* had the lowest protein at 20.48 ± 0.14%. The *M.*

supraspinatus not only had the lowest protein but also the highest fat content, whilst the *M. semimembranosus* had the lowest fat content and the highest value for protein. However, no significant correlation was found between protein and fat content. Du Buisson (2006) could not detect any differences (P > 0.05) between the same five springbok muscles in terms of protein content, although she did note that in another antelope species, blesbok (*Damaliscus dorcas phillipsi*) the protein content of the *M. longissimus dorsi* differed (P ≤ 0.05) from *M. biceps femoris*, *M. semitendinosus* and *M. supraspinatus*.

Table 3. Least square means (± s.e.) for proximate chemical composition (%) of five different kudu and impala muscles.

Chemical component	LD	BF	SM	ST	SS
Moisture (%)	$75.18^{d} \pm 0.15$	$75.88^{c} \pm 0.17$	$75.17^{d} \pm 0.18$	$76.36^{b} \pm 0.16$	$76.75^{a} \pm 0.13$
Protein (%)	$22.54^{ab} \pm 0.18$	$21.64^{b} \pm 0.21$	$22.60^{a} \pm 0.20$	$22.56^{ab} \pm 0.51$	$20.48^{c} \pm 0.14$
Fat (%)	$1.89^{b} \pm 0.12$	$2.06^{b} \pm 0.08$	$1.93^{b} \pm 0.06$	$1.97^{b} \pm 0.08$	$2.41^{a} \pm 0.07$
Ash (%)	1.20 ± 0.04	1.18 ± 0.03	1.22 ± 0.03	1.19 ± 0.02	1.11 ± 0.01

^{a,b,c,d} Means in the same row, with different superscripts are significantly different (P ≤ 0.05)

Table 4. Pearson linear correlation coefficients between fat content (%) and moisture content (%) for five muscles in kudu and impala.

Muscle	Pearson	
	r	P
M. longissimus dorsi	-0.525	< 0.0001
M. biceps femoris	-0.516	< 0.001
M. semimembranosus	-0.603	< 0.0001
M. semitendinosus	-0.604	< 0.0001
M. supraspinatus	-0.742	< 0.0001

r = correlation coefficient

Significant differences were noted between muscles for moisture and fat content (Table 3) for the five muscles analysed. In terms of fat content, *M. supraspinatus* (differing (P < 0.0001) from all other muscles) had the highest fat, followed by *M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus* and *M. longissimus dorsi* (these four muscles did not differ (P > 0.05) from each other). This differs from what has been noted in other species, for example, beef muscles in order of decreasing fat content were: *M. longissimus dorsi* (7.74%), *M. biceps femoris* (6.86%), *M. supraspinatus* (4.95%), *M. semimembranosus* (4.36%) and *M. semitendinosus* (4.08%) (Von Seggern *et al.*, 2005). Species and gender had no effect on ash content; however, sub-adults (1.20 ± 0.02%) had a higher (P ≤ 0.05) ash content than adults (1.10 ± 0.03%).

Myoglobin content

In the present study no differences ($P \leq 0.05$) were found between kudu and impala myoglobin content (Table 2). However, differences ($P \leq 0.0001$) in myoglobin content were noted between genders with females having higher (6.58 ± 0.20 mg/g) concentrations than males (5.11 ± 0.25 mg/g). In contrast, Hoffman *et al.* (2005) found no differences in myoglobin content for male (7.249 mg/g) and female (7.254 mg/g) impala from the Musina region, South Africa. Their values for impala were higher than the values obtained in the present study. According to Lawrie (1998), myoglobin content in muscle is known to increase with age. Therefore young animals are expected to have lighter coloured muscles. However in the present study no difference was noted in myoglobin content for the two age groups. This is also confirmed by the absence of differences ($P > 0.05$) between the two age groups for colour measurements (L*-, a*- and b*-values, hue-angle and chroma) (Chapter 4).

A significant ($P \leq 0.05$) interaction was noted between muscle and species for myoglobin concentration (Figure 1). The myoglobin content of impala *M. longissimus dorsi* was higher than that of kudu *M. longissimus dorsi*; however for all other muscles the myoglobin content was lower in the impala. However, only the *M. semitendinosus* in impala (4.46 mg/g) had a statistically significant lower ($P \leq 0.05$) myoglobin content than that in kudu (5.79 mg/g). For all other muscles differences between the two species were not significant. A possible explanation for this difference in myoglobin content between the *M. semitendinosus* of the two species could be the flight reaction of the impala. The flight reaction of the impala is more rapid than that of the kudu as the impala can jump up and sideways in one swift motion whilst kudu tend to run away. This could explain why the *M. semitendinosus* is probably used more often in the kudu than in the impala and hence the higher myoglobin content. However, further research is required into the size and proportion of the *M. semitendinosus* in relation to the other muscles in the buttock for both impala and kudu in order to fully understand the difference in myoglobin content. The myoglobin levels found in kudu and impala *M. semitendinosus* are higher than that for bovine *M. semitendinosus* (2.10 mg/g) (Rickansrud & Henrickson, 1967). As game is physically more active than most domesticated animals, their meat also tends to be darker in colour. In contrast to the findings of the present study is that found by Rickansrud & Henrickson (1967) for myoglobin concentrations in bovine muscles, where *M. semitendinosus* had the lowest concentrations followed by the *M. longissimus dorsi* and the highest concentrations were in the *M. biceps femoris*.

The myoglobin content of *M. supraspinatus* for both kudu (8.53 mg/g) and impala (8.09 mg/g) were higher ($P \leq 0.05$) than all of the other muscles, although they did not differ from each other (Figure 1). The *M. supraspinatus* is a foreleg muscle which is used when the animals are running. The high physical activity causes the amount of myoglobin to increase in the muscle in order to increase its oxygen carrying capacity. These findings are confirmed by the observation of Kranen *et al.* (1999) who noted that haem protein levels, especially myoglobin, in chicken muscles correlate with muscle

fibre composition. Glycolitic muscles had the lowest myoglobin content with the highest values found in oxidative muscle such as *M. supraspinatus*.

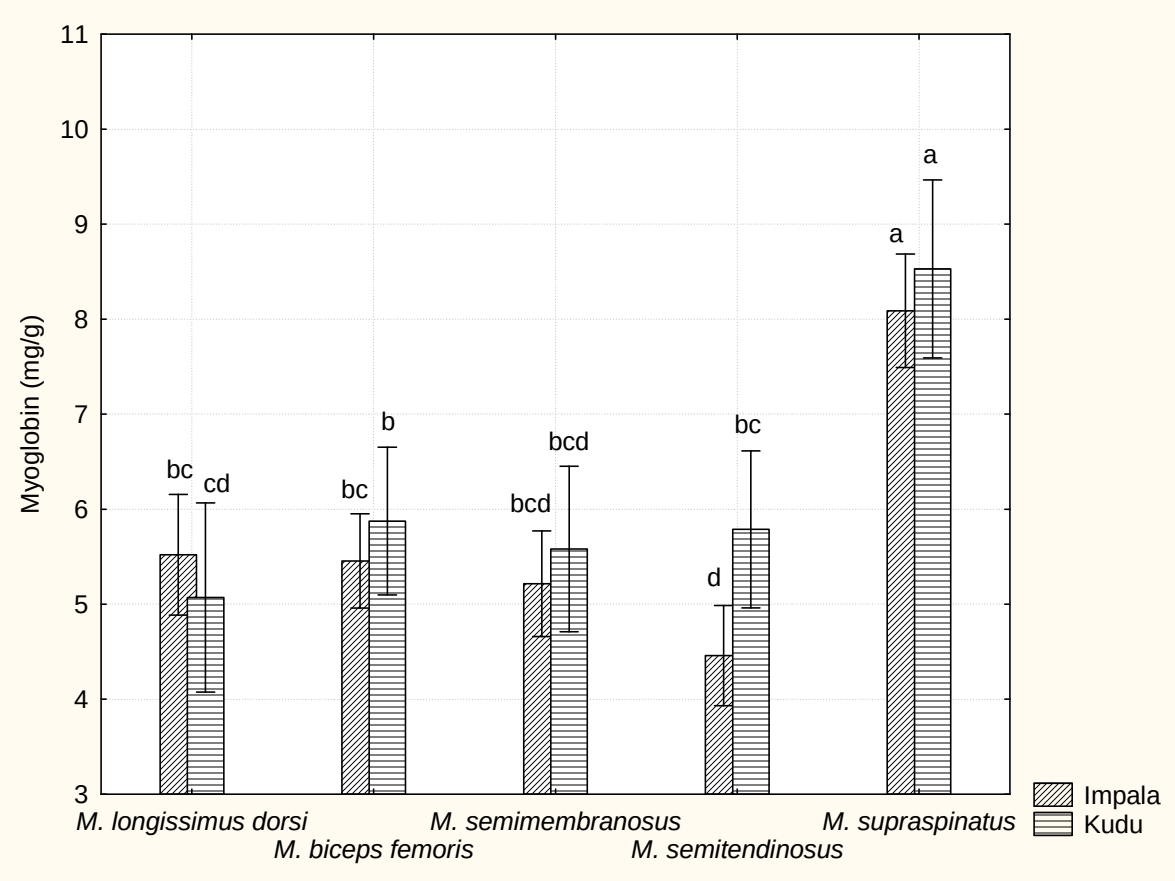

Figure 1. Myoglobin content (mg/g) for five muscles found in kudu and impala

Colour measurement values (L*-, a*-, b*-, hue-angle and chroma) for kudu and impala *M. longissimus dorsi* as affected by age and gender are shown in Table 5. Overall, impala *M. longissimus dorsi* appeared darker in colour than kudu hence the lower L* values.

Table 5. Least square means (± s.e.) for L*-, a*-, b*-values, hue-angle and chroma for kudu and impala *M. longissimus dorsi* as affected by gender and age.

		Colour measurements				
	Sample	**L***	**a***	**b***	**hue**	**Chroma**
Kudu:	Male	31.79^{a} ± 0.49	11.04^{ab} ± 0.36	8.70 ± 0.41	38.15 ± 1.39	14.15^{ab} ± 0.43
	Female	31.73^{a} ± 0.41	11.85^{a} ± 0.30	8.45 ± 0.34	35.59 ± 1.17	14.69^{a} ± 0.36
Impala:	Male	29.86^{b} ± 0.45	10.81^{ab} ± 0.33	7.57 ± 0.37	34.68 ± 1.28	13.32^{b} ± 0.39
	Female	28.34^{b} ± 0.46	10.41^{b} ± 0.34	7.71 ± 0.38	36.43 ± 1.30	13.09^{b} ± 0.40
Kudu:	Adult	30.31^{b} ± 0.41	11.65 ± 0.30	8.67 ± 0.34	36.67 ± 1.17	14.60^{a} ± 0.36
	Sub-adult	33.21^{a} ± 0.49	11.24 ± 0.36	8.49 ± 0.41	37.06 ± 1.39	14.24^{ab} ± 0.43
Impala:	Adult	28.33^{c} ± 0.45	10.57 ± 0.33	7.50 ± 0.38	35.04 ± 1.28	13.23^{b} ± 0.40
	Sub-adult	29.87^{ab} ± 0.48	10.65 ± 0.34	7.78 ± 0.40	36.07 ± 1.37	13.27^{b} ± 0.42

$^{a, b}$ Means in the same column, within the same subgroup, with different superscripts, are significantly different ($P \leq 0.05$)

Strong inverse correlations were calculated between myoglobin content and L* values for *M. longissimus dorsi* (r = -0.474; P < 0.0001) and *M. supraspinatus* (r = -0.783; P < 0.0001) (Table 6). Meat with higher myoglobin content (impala *M. longissimus dorsi*) had lower L* values, and appeared darker in colour. Correlations were also noted for myoglobin content and a* values (the red-green range) from *M. biceps femoris* (r = 0.366; P < 0.05), *M. semitendinosus* (r = 0.346; P < 0.05) and *M. supraspinatus* (r = 0.363; P < 0.05). Overall the mean a* value for kudu (12.79) was higher (P < 0.01) (more red) than that of impala (11.97) (Chapter 4). Fresh *M. supraspinatus* showed a more intense and redder colour, with a higher (P ≤ 0.05) a* value (13.65) than the other muscles, and it is also the muscle with the highest myoglobin content.

Table 6. Pearson linear correlation coefficients between myoglobin content (mg/g) and the colour measurements for kudu and impala

Muscle		Colour measurements				
		L*	**a***	**b***	**Hue angle**	**Chroma**
M. longissimus dorsi	r	-0.474	-0.076	-0.301	-0.263	-0.209
	P	< 0.0001	0.541	0.013	0.032	0.090
M. biceps femoris	r	-0.429	0.366	-0.045	-0.314	0.182
	P	0.003	0.013	0.767	0.034	0.225
M. semimembranosus	r	-0.398	0.213	-0.205	-0.342	0.030
	P	0.006	0.150	0.167	0.019	0.840
M. semitendinosus	r	-0.266	0.346	-0.050	-0.394	0.226
	P	0.071	0.017	0.737	0.006	0.127
M. supraspinatus	r	-0.783	0.363	-0.159	-0.363	0.183
	P	<0.0001	0.013	0.292	0.013	0.223

r = correlation coefficient

Collagen content

Values for hydroxyproline, soluble collagen, insoluble collagen and total collagen content as well as percentage solubility are represented in Table 7. Only the *M. longissimus dorsi* from sub-adult animals were chemically analysed. Impala and kudu differed (P ≤ 0.0001) in terms of all the collagen values except for the percentage solubility. Impala had higher (P ≤ 0.0001) values than kudu for hydroxyproline content, and therefore also for soluble collagen, insoluble collagen and total collagen content. The percentage solubility was higher (P > 0.05) in impala than kudu. Gender did not have an effect (P > 0.05) on any of the collagen and hydroxyproline values. This may be attributed to the fact that the analysis were conducted on young animals where the characteristics of sexual maturity with increasing age has not yet had opportunity to manifest themselves. This phenomenon is in keeping with the findings of Hoffman *et al.* (2005) where no significant differences were observed between gender for collagen and hydroxyproline content in impala.

Table 7. Least square means (± s.e.) for hydroxyproline content, soluble collagen, insoluble collagen, total collagen content and % solubility for *M. longissimus dorsi* in sub-adult male and female kudu and impala

	Species		Gender	
	Kudu	**Impala**	**Male**	**Female**
Hydroxyproline (g/100g)	0.331 [b] ± 0.015	0.453 [a] ± 0.016	0.392 ± 0.016	0.392 ± 0.015
Soluble collagen (mg/g)	0.936 [b] ± 0.022	1.308 [a] ± 0.022	1.116 ± 0.023	1.129 ± 0.022
Insoluble collagen (mg/g)	1.257 [b] ± 0.068	1.732 [a] ± 0.071	1.453 ± 0.071	1.535 ± 0.068
Total collagen (mg/g)	2.246 [b] ± 0.103	3.071 [a] ± 0.107	2.660 ± 0.108	2.657 ± 0.103
% Solubility	41.07	41.58	41.10	41.55

[a,b] Means in the same row, within the same subgroup, with different superscripts are significantly different (P > 0.05)

In ovine *M. semimembranosus* it was found that collagen content were more related to eating quality, while WBS force values were closely related to solubility of collagen (Young *et al.*, 2001). In the current investigation no correlations were found between hydroxyproline content, soluble collagen, insoluble collagen or total collagen content when correlated with WBS values (Chapter 4). A weak correlation (r = -0.267; P = 0.178) was noted between percentage solubility and tenderness (WBS values). Boleman *et al.* (1996) reported a total collagen content of 3.78 mg/g for mature cows and Riley *et al.* (2005) reported collagen content for Brahman to be 3.49 mg/g muscle, which are slightly higher than the values from the present study.

Mineral content

The mean mineral compositions (± standard error) for the pooled data of the five muscles investigated as affected by the main effects of species, gender and age, are represented in Table 8. In terms of phosphorus and zinc content there were no differences (P > 0.05) between species, gender or age groups, although some of the samples analysed were outliers. Means were recalculated without outliers and this resulted in differences (P ≤ 0.05) between species for both phosphorus and zinc content (Table 8). A difference (P ≤ 0.05) was also noted between adult and sub-adult animals in terms of zinc content. For the sake of this discussion data without the outliers will be considered. The mineral concentrations differed (P ≤ 0.05) between species for all of the minerals except for calcium. The variation in diet of the two species could be the reason for these differences. In impala, phosphorus was present in the highest concentration followed by potassium and magnesium. Conversely, potassium was present in the highest concentration in kudu, followed by phosphorus and magnesium. No differences (P > 0.05) were observed between genders for any of the minerals investigated. This is in keeping with the findings for male and female kudu harvested in the Orange Free State (Mostert & Hoffman, 2007). Hoffman *et al.* (2007) also noted no significant differences in mineral content for male and female springbok. Adult and sub-adult groups differed (P ≤ 0.05) in terms of potassium, calcium and zinc content. Potassium and calcium contents were higher in the sub-adult animals while the zinc content was higher in the adult animals.

Table 8 Mean mineral composition (mg/100gmuscle) (± s.e.) of the five muscles of kudu and impala with gender and age as main effects.

	Species		Gender		Age	
Mineral (mg/100g)	**Kudu**	**Impala**	**Male**	**Female**	**Adult**	**Sub-adult**
[#]Phosphorus	165.812[a] ± 1.628	149.584[b] ± 1.673	156.077 ± 1.876	158.303 ± 1.435	157.605 ± 2.022	157.791 ± 1.567
Potassium	192.566[a] ± 6.939	127.578[b] ± 7.530	168.419 ± 9.140	160.039 ± 6.599	146.707[a] ± 8.798	173.437[b] ± 7.137
Calcium	7.309 ± 0.412	7.482 ± 0.379	7.582 ± 0.474	7.468 ± 0.348	6.738[a] ± 0.455	8.053[b] ± 0.357
Magnesium	21.689[a] ± 0.659	24.349[b] ± 0.692	22.646 ± 0.805	23.033 ± 0.591	23.549 ± 0.829	22.488 ± 0.650
Sodium	9.717[a] ± 0.435	12.940[b] ± 0.456	11.979 ±0.535	11.207 ± 0.393	10.636 ± 0.547	12.021 ± 0.429
Iron	1.889[a] ± 0.082	2.307[b] ± 0.086	1.811 ± 0.086	2.213 ± 0.063	2.210 ± 0.103	1.986 ± 0.081
Copper	0.014[a] ± 0.004	0.061[b] ± 0.004	0.041 ± 0.005	0.036 ± 0.003	0.039 ± 0.005	0.037 ± 0.004
[#] Zinc	2.375[a] ± 0.066	2.633[b] ± 0.070	2.551 ± 0.090	2.451 ± (0.007	2.634[a] ±0.081	2.374[b] ± 0.067
Manganese	0.009[a] ± 0.001	0.001[b] ± 0.001	0.003 ± 0.001	0.005 ± 0.001	0.005 ± 0.001	0.004 ± 0.001

[a,b] Means in the same row, with different superscripts within the same subgroup, are significantly different

[#] Means calculated without outliers

The mean mineral compositions (± standard error) for each of the five muscles analysed for kudu and impala meat is summarised in Table 9. In terms of the five muscles examined, outliers were removed for phosphorus, calcium and sodium and the means recalculated. Differences ($P \leq 0.05$) were then detected between muscles for phosphorus and sodium. An interaction ($P \leq 0.001$) between muscle and species was observed for sodium content. The highest sodium content was measured in impala *M. supraspinatus* (16.225 mg/100g) and the lowest content in kudu *M. semimembranosus* (8.806 mg/100g). An interaction ($P \leq 0.0001$) between muscle and species was also noted for zinc content. Zinc content for *M. supraspinatus* in both kudu (5.096 mg/100g) and impala (6.404 mg/100g) was noted to be considerably higher ($P \leq 0.05$) than that measured in all other muscles. It is not clear why the zinc concentration is so high in the *M. supraspinatus* and further investigations are required to explain this phenomenon. However, this is in keeping with the high zinc content noted in *M. supraspinatus* from springbok (5.58 mg/100g) and blesbok (6.03 mg/100g) (Du Buisson, 2006). Differences ($P \leq 0.05$) were noted between muscles for all minerals except for calcium and magnesium.

CONCLUSION

Species, gender and age did not influence the muscle protein content, although the protein content varied between the different muscles. Kudu were also noted to have a lower fat content than impala whilst the male animals also had less fat than females, irrespective of the species. As with many other game species, the low fat content of kudu and impala meat makes it a preferable choice for the health-conscious consumer. Although the myoglobin content did not differ between the two species, gender had an effect on myoglobin content, with females having higher concentrations. Myoglobin concentration also varied between muscles with the oxidative muscles such as the *M. supraspinatus* having the highest levels. Impala had significantly higher insoluble collagen, soluble collagen, total collagen and hydroxyproline content than kudu. Mineral content differed between kudu and impala and these differences could be attributed to the variation in diet of the two species. Gender had no effect on mineral content. Potassium levels were highest for kudu while phosphorus was the highest in the impala meat. The chemical composition of meat was also significantly affected by muscle as differences ($P \leq 0.05$) were noted between muscles for all minerals except for calcium and magnesium. From this study it can be concluded that although kudu and impala habituate the same geographical area, there are significant differences in chemical composition between the two species.

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Table 9. Mean mineral composition (mg/100g muscle) (± SE) of five muscles for kudu and impala meat.

Mineral (mg/100g)	Species	LD	BF	SM	ST	SS
#Phosphorus:	*Kudu*	170.357^{cd} ± 4.030	171.703^{d} ± 2.477	173.163^{d} ± 3.873	167.302^{bcd} ± 3.074	146.536^{ae} ± 2.123
	Impala	152.496^{abc} ± 4.142	152.055^{ab} ± 2.546	152.275^{abc} ± 3.980	153.070^{abc} ± 3.159	138.021^{e} ± 2.182
Potassium:	*Kudu*	183.909^{a} ± 9.020	193.815^{a} ± 6.272	202.647^{a} ± 23.625	195.732^{a} ± 7.108	186.728^{a} ± 5.533
	Impala	118.392^{b} ± 9.787	125.210^{b} ± 6.806	145.055^{ab} ± 25.634	121.819^{b} ± 7.712	127.412^{b} ± 6.004
#Calcium:	*Kudu*	7.496 ± 1.177	7.449 ± 0.463	7.544 ± 0.359	7.317 ± 0.385	6.901 ± 0.291
	Impala	9.288 ± 1.389	5.896 ± 0.546	6.006 ± 0.423	6.424 ± 0.454	6.199 ± 0.343
Magnesium:	*Kudu*	20.989 ± 1.062	22.655 ± 0.848	22.398 ± 2.081	21.924 ± 1.092	20.477 ± 0.702
	Impala	21.380 ± 1.115	25.070 ± 0.889	25.731 ± 2.184	25.447 ± 1.146	24.117 ± 0.737
#Sodium:	*Kudu*	8.825^{b} ± 0.307	9.439^{bc} ± 0.259	8.806^{b} ± 0.322	9.783^{bc} ± 0.304	11.742^{a} ± 0.526
	Impala	10.790^{ac} ± 0.336	11.798^{a} ± 0.283	10.808^{ac} ± 0.352	11.867^{a} ± 0.332	16.225^{d} ± 0.575
Iron:	*Kudu*	1.718^{ab} ± 0.144	1.960^{abc} ± 0.096	1.759^{ab} ± 0.221	1.538^{a} ± 0.119	2.471^{cde} ± 0.109
	Impala	2.237^{bcde} ± 0.151	2.079^{abcd} ± 0.101	2.476^{de} ± 0.232	1.984^{abc} ± 0.125	2.760^{e} ± 0.115
Copper:	*Kudu*	0.013^{a} ± 0.012	0.013^{a} ± 0.010	0.017^{a} ± 0.014	0.014^{a} ± 0.009	0.016^{a} ± 0.011
	Impala	0.061^{ab} ± 0.013	0.056^{ab} ± 0.011	0.075^{b} ± 0.015	0.041^{ab} ± 0.009	0.074^{b} ± 0.012
Zinc:	*Kudu*	1.083^{d} ± 0.061	1.822^{abc} ± 0.081	1.652^{abd} ± 0.130	2.146^{bc} ± 0.140	5.096^{e} ± 0.198
	Impala	1.293^{ad} ± 0.064	1.780^{abc} ± 0.085	1.650^{abc} ± 0.136	2.143^{bc} ± 0.146	6.404^{f} ± 0.208
Manganese:	*Kudu*	0.848^{ab} ± 0.097	1.090^{b} ± 0.104	0.877^{ab} ± 0.107	0.663^{a} ± 0.089	0.853^{ab} ± 0.105
	Impala	0.018^{a} ± 0.102	0.007^{a} ± 0.109	0.033^{a} ± 0.113	0.021^{a} ± 0.094	0.020^{a} ± 0.110

$^{a, b, c, d}$ Means for the same mineral within species with different superscripts, are significantly different

$^{\#}$ Means calculated without outliers

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Chapter 5

Fatty acid profile and cholesterol content of kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*) as affected by gender and age

Abstract

Consumption of red meat has been associated with an increase in cardiovascular diseases, diabetes and even cancer. The perception exists that red meat has a high fat content and an undesirable fatty acid ratio. However, previous studies on game meat have proved that it can be a healthy alternative due to its favourable fatty acid profile. In impala meat, stearic acid (22.67%) was found to be the major fatty acid, followed by palmitic acid (16.66%), oleic acid (12.22%) and linoleic acid (14.70%). In contrast, oleic acid (24.35%) was the most profuse fatty acid in kudu, followed by linoleic acid (22.95%), stearic acid (15.53%) and then palmitic acid (11.85%). Males (0.35%) had higher levels of arachidic acid than females (0.24%). The SFA's as a percentage of the total fatty acids differed between impala (51.12%) and kudu meat (34.87%). Oleic acid (C18:1 *n*-9c) was the only MUFA that differed between the two species with kudu having a higher quantity. Females (0.24%) had lower levels of gondoic acid than males (0.55%). In terms of PUFA's, kudu had higher levels of linoleic acid, C20:3 *n*-6 and C22:6 *n*-3. Levels of C20:4 *n*-6 (arachidonic acid), C20:5 *n*-3 (eicosapentaenoic acid) and C22:5 *n*-3 (docosapentaenoic acid) were higher in impala than in kudu. Kudu meat had a higher concentration of total PUFA (38.88%) compared to impala (34.06%). The PUFA: SFA ratio for kudu meat (1.22) was more favourable than that for impala meat (0.73). The ratio of *n*-6 PUFA's to *n*-3 PUFA's for kudu and impala were determined as 2.20 and 3.76 respectively. Kudu meat (72.62 ± 1.86 mg/100g muscle) had higher cholesterol levels than impala meat (55.35 ± 1.84 mg/100g muscle). From the current findings it is evident that kudu and impala meat have fatty acid profiles such that the meat from these species can be a healthy substitute for other red meats. However, the cholesterol content of kudu meat is high compared to other game species and further studies are necessary to confirm this.

Introduction

Early men were hunter-gatherers and their diet consisted mainly of wild animal tissue. It is estimated that on average 68% of their diet were from meat and animal-derived foods (Cordain *et al.*, 2000). Thus, their primary lipid source was from wild game animals. In recent years meat has widely been criticised on the basis of its fat content and fatty acid profile (Wood & Enser, 1997). Consumers have also become more aware of the health aspects as pertaining to the food they eat. However, consumers mostly overestimate the fat content of meat (Peterson *et al.*, 2001). The perception exists that red meat has a high fat content as well as an undesirable fatty acid ratio.

As the modern Western diet is characterised by animal fats containing high amounts of saturated fatty acids (SFA), the World Health Organisation (WHO, 2003) has drawn up guidelines as pertaining to fat

intake. They suggest that fat intake be restricted to providing between 15 and 30% of the calories in the human diet and not more than 10% of this should be from SFA's. Another point of concern regarding the modern diet is the unbalanced *n*-6: *n*-3 ratio.

There is great variation in the fat content of meat depending on the species, age of the animal, gender and also the cut of meat (Miller *et al.*, 1986; Wood & Enser, 1997; Hoffman, 2000; Jiménez-Colmenero *et al.*, 2001; Rule *et al.*, 2002). It has been shown that fat content and fatty acid composition of meat can be altered by manipulating the feed intake of animals (Larick & Turner, 1990; Wood & Enser, 1997; Wiklund *et al.*, 2003; Phillip *et al.*, 2007). When compared to monogastric animals, the fat tissue of ruminant animals contains higher proportions of SFA and lower proportions of PUFA (Wood & Enser, 1997) due to the hydrogenating effect of the rumen. However, previous studies on muscle tissue from wild ruminant animals show that the amount of polyunsaturated fatty acids (PUFA) in game meat is substantially higher than in meat from domesticated animals (Crawford *et al.*, 1970; Miller *et al.*, 1986; Mostert & Hoffman, 2007).

Although kudu and impala occupy the same ecological region, their diets differ to a great extent. The kudu is predominantly a non-selective browser and feeds on tree and shrub leaves, woody branches, and seeds. In the savannah bushveld (the area under investigation) the kudu's diet consists of 18% grass, 21% forbs and 61% browse (Furstenburg, 2005a). The impala on the other hand, grazes and browses and is known as a mixed or intermediate feeder. The graze to browse ratio of the impala changes according to habitat, season and availability of food. During winter (the period during which samples were collected), the impala will adapt its diet with browse and protein-rich fruit or pods constituting a higher proportion of the diet (Furstenburg, 2005b). The present research was conducted in order to determine the fatty acid profile of meat from kudu and impala from the same geographical region and to investigate possible differences in fatty acid and cholesterol content between genders, age groups and muscles between these two species.

MATERIALS AND METHODS

The 35 kudu (*Tragelaphus strepsiceros*) and 32 impala (*Aepyceros melampus*) for this study were harvested in the Limpopo Province, Mabula District (S 24 52.611, E 27 56.862). The kudu comprised 14 male (KM) and 21 female (KF), and the impala comprised 17 male (IM) and 15 female (IF) (Table 1). Harvesting of the animals took place over a period of 128 days (four months), starting in late autumn and extending over the dry winter months. Since animals were expected to lose physical body condition towards the end of winter due to a decline in available food, the day of harvest was used as a co-variant in the statistical analyses. (Refer to Chapter 3 "Materials and Methods" for hunting techniques and age classification of animals.)

At 24 h post-mortem the *M. longissimus dorsi* (LD) was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra. *M. biceps femoris* (BF), *M. semimembranosus* (SM), *M. semitendinosus* (ST) *and M. supraspinatus* (SS) were also removed. Samples for chemical and sensory analyses were vacuum packed and stored at -20 °C until analysed.

Table 1. Sample distribution of kudu (n=35) and impala (n=32) according to age and gender.

	Kudu		Impala		
	Male	**Female**	**Male**	**Female**	**Total**
Adult	7	14	11	7	39
Sub-adult	7	7	6	8	28
Total	14	21	17	15	67

Chemical analyses

Fatty acid content

The fatty acid content was determined by using the method of Tichelaar *et al*. (1998). After thawing the meat, the lipids in a 2 g sample were extracted with chloroform/methanol (2:1) and 0.01% (v/v) butylated hydroxytoluene (BHT) as antioxidant. The samples were homogenised for 30 seconds in a polytron mixer (Kinematica, type PT 10-35, Switzerland) and transmethylated for two hours at 70°C with methanol/sulphuric acid (19:1; v/v). After cooling to room temperature, the fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. The FAME were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300, equipped with a flame ionisation detector), using a 60 m BPX70 capillary column of 0.25 mm internal diameter (SGE, Australia). The hydrogen gas flow rate was 25 ml/min; and the hydrogen carrier gas rate 2-4 ml/min. Temperature programming was linear at 3°C/min, with an initial temperature of 150°C, a final temperature of 220°C, an injector temperature of 240°C and a detector temperature of 250°C. The FAME in the total lipids was identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue number 18919-1AMP, Lot number, LB-16064. Sigma Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

Cholesterol content

From the same lipid extraction used for the fatty acid determination, a sub-sample was used for cholesterol determination. After drying the sub-sample under nitrogen, Stigmasterol (3-B-hydroxy-24-ethyl-5.22-cholestadiene; Sigma Chemical Co., St Louis, MO, USA) was added as internal standard and 6% ethanol KOH used to saponify the extraction for 2 h at 70°C in a heating block. After cooling, distilled water and hexane were added and the resultant extraction was analysed by GLC (Varian

Model 3700, equipped with flame ionization detection). A 1.2 m glass column of 2 mm internal diameter packed with 3% SP2401 on 100/120 mesh Supelcoport (Supelco Inc., Bllefonte, PA, USA) was used. Gas flow rates were: hydrogen, 20 ml/min; air, 200 ml/min and nitrogen (carrier gas), 25 ml/min. Temperatures were: injector temperature 280°C; column temperature 255°C and detector temperature 290°C.

Statistical analyses

The data was analysed using repeated measures ANOVA as five muscles from each carcass were analysed. This was done with Statistica (version 7) statistical software. The full model was analysed (2 species x 2 genders x 2 age groups x 5 muscles), however, due to missing data the design was unbalanced and higher order interactions (4^{th} order) could not be estimated. In some cases lower order interaction results were also suspect due to the unbalanced design and it was therefore decided to conduct further analyses as follows:

- Analysis on the *M. longissimus dorsi* only (2 species x 2 genders x 2 age groups as main effects)
- Analysis without gender (2 species x 2 age groups x 5 muscles as main effects)
- Analysis with only females included (2 species x 2 age groups x 5 muscles as main effects)
- Analysis without age (2 species x 2 genders x 5 muscles as main effects)
- Analysis with only sub-adults included (2 species x 2 genders x 5 muscles as main effects)

This was done in order to test the validity of significant differences noted in the unbalanced full model. When a significant difference or interaction was noted throughout these different models, it was concluded to be of significant value and was therefore reported. In all cases harvest (day of culling) was added to the model as a covariate. Post hoc differences between treatments were tested for by means of the Tukey HSD test. Pearson correlation coefficients were determined using the linear regression procedure.

RESULTS AND DISCUSSION

Fatty acid profile

The results for the fatty acid composition (percentage of total identified fatty acids) of kudu and impala *M. longissimus dorsi* are represented in Table 2. Palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1) and linoleic acid (C18:2 n-6c) were the major fatty acids present in both species. For impala, stearic acid (22.67%) was present in the highest quantity, followed by palmitic acid (16.66%), linoleic acid (14.70%) and oleic acid (12.22%). This corresponds with the results for springbok muscle where stearic acid (26.56%) were the major fatty acid followed by palmitic acid (14.90%) (Hoffman *et al.*, 2007). Conversely, oleic acid (24.35%) was the most prolific fatty acid in kudu, followed by linoleic acid (22.95%), stearic acid (15.53%) and then palmitic acid (11.85%). These results are similar to the

Table 2. The mean fatty acid composition (% of total fatty acids) (±s.e.) of *M. Longissimus dorsi* in kudu (n=35) and impala (n=32) as affected by age and gender.

Fatty Acid (%)	Kudu	Impala	Male	Female	Adult	Sub-adult
C14:0 (Myristic Acid)	0.69 ± 0.17	1.10 ± 0.17	1.04 ± 0.17	0.75 ± 0.16	0.92 ± 0.16	0.87 ± 0.19
C16:0 (Palmitic Acid)	11.85 [c] ± 1.17	16.66 [d] ± 1.16	13.15 ± 1.19	15.36 ± 1.11	15.57 ± 1.08	12.94 ± 1.27
C18:0 (Stearic Acid)	15.53 [e] ± 0.84	22.67 [f] ± 0.83	18.90 ± 0.85	19.30 ± 0.79	19.67 ± 0.78	18.52 ± 0.91
C20:0 (Arachidic Acid)	0.38 [c] ± 0.04	0.21 [d] ± 0.04	0.35 [a] ± 0.04	0.24 [b] ± 0.04	0.29 ± 0.04	0.30 ± 0.04
TOTAL SFA (%)	**34.87 [e]**	**51.12 [f]**	**43.06**	**42.93**	**44.54**	**41.45**
C16:1 (Palmitoleic Acid)	0.43 ± 0.04	0.35 ± 0.04	0.36 ± 0.04	0.42 ± 0.04	0.45 [a] ± 0.04	0.33 [b] ± 0.05
C18:1 *n*-9t (Elaidic Acid)	0.57 ± 0.06	0.69 ± 0.06	0.58 ± 0.06	0.68 ± 0.06	0.61 ± 0.06	0.65 ± 0.07
C18:1 *n*-9c (Oleic Acid)	24.35 [e] ± 1.22	12.22 [f] ± 1.21	17.73 ± 1.23	18.83 ± 1.15	19.19 ± 1.12	17.38 ± 1.32
C20:1 (Gondoic Acid)	0.27 ± 0.09	0.52 ± 0.09	0.55[a] ± 0.09	0.24 [b] ± 0.09	0.22 [c] ± 0.08	0.57 [d] ± 0.10
C22:1 *n*-9 (Erucic Acid)	0.14 ± 0.06	0.30 ± 0.06	0.20 ± 0.06	0.24 ± 0.06	0.28 ± 0.06	0.16 ± 0.07
TOTAL MUFA (%)	**26.25 [e]**	**14.82 [f]**	**20.08**	**20.99**	**21.40**	**19.67**
C18:2 *n*-6t	0.22 ± 0.03	0.20 ± 0.03	0.26 [a] ± 0.03	0.17 [b] ± 0.03	0.20 ± 0.03	0.22 ± 0.03
C18:2 *n*-6c (Linoleic Acid)	22.95 [e] ± 0.87	14.70 [f] ± 0.87	18.58 ± 0.86	19.07 ± 0.82	16.86 [c] ± 0.80	20.79 [d] ± 0.94
C18:3 *n*-3 (α-Linolenic Acid)	2.12 ± 0.17	1.92 ± 0.17	2.06 ± 0.17	1.97 ± 0.0.16	1.89 ± 0.16	2.14 ± 0.19
C18:3 *n*-6 (γ-Linolenic Acid)	0.26 ± 0.10	0.28 ± 0.09	0.35 ± 0.10	0.19 ± 0.09	0.33 ± 0.09	0.20 ± 0.10
C20:2	0.40 ± 0.07	0.49 ± 0.07	0.39 ± 0.07	0.50 ± 0.07	0.38 ± 0.06	0.50±0.08
C20:3 *n*-6	0.96 [a] ± 0.08	0.72 [b] ± 0.082	0.88 ± 0.08	0.80 ± 0.08	0.85 ± 0.08	0.83±0.09
C20:4 *n*-6 (Arachidonic Acid)	7.81 ± 1.19	9.80 ± 1.18	9.31 ± 1.21	8.30 ± 1.12	8.13 ± 1.10	9.48 ± 1.29
C20:5 *n*-3 (EPA)	0.90 [a] ± 0.14	1.37 [b] ± 0.13	1.08 ± 0.14	1.20 ± 0.13	1.18 ± 0.12	1.10 ± 0.15
C22:5 *n*-3 (DPA)	0.32 [c] ± 0.18	1.94 [d] ± 0.18	1.01 ± 0.18	1.25 ± 0.17	1.18 ± 0.16	1.08 ± 0.19
C22:6 *n*-3 (DHA)	1.92 [c] ± 0.18	1.05 [d] ± 0.18	1.55 ± 0.18	1.42 ± 0.17	1.40 ± 0.17	1.58 ± 0.20
TOTAL PUFA (%)	**38.88[a]**	**34.06[b]**	**36.86**	**36.09**	**34.06[a]**	**38.88[b]**
PUFA: SFA	1.22 [c] ± 0.07	0.73 [d] ± 0.07	0.99 [a] ± 0.07	0.96 [b] ± 0.07	0.87 [a] ± 0.06	1.08 [b] ± 0.08
n-6: *n*-3	2.22 [a] ± 0.47	3.76 [b] ± 0.46	2.90 ± 0.47	3.07 ± 0.44	2.48 ± 0.43	3.50 ± 0.51

[a,b] Means in rows with different superscripts are significantly different, $P \leq 0.05$.

[c,d] Means in rows with different superscripts are significantly different, $P < 0.01$

[e,f] Means in rows with different superscripts are significantly different, $P < 0.0001$

findings of Mostert & Hoffman (2007) where oleic acid and linoleic acid also constituted the largest proportion of fatty acids in kudu meat harvested in the Orange Free State, South Africa.

Differences between kudu and impala *M. longissimus dorsi* were observed for palmitic acid (C16:0) ($P \leq 0.01$), stearic acid (C18:0) ($P \leq 0.0001$) and arachidic acid (C20:0) ($P \leq 0.01$). The high quantities of C16:0 and C18:0 in impala meat resulted in impala having a higher ($P \leq 0.0001$) total SFA content (51.12%) when compared to that of kudu meat (34.87%). The high SFA content in impala, specifically stearic acid, corresponds with the higher ($P \leq 0.0001$) intramuscular fat content measured in impala (2.22%) (Chapter 4). Marmer *et al.*, (1984) found that at higher levels of total fat the triacylglycerols contribute proportionally more to the total fat than the more unsaturated phospholipids.

Hoffman *et al.* (2005) determined the total SFA concentration for impala male (41.26%) from the Musina area (Limpopo province, South Africa) to be lower ($P > 0.05$) than that for impala female (45.13%) from the same area. When considering the SFA's in the present investigation, differences between genders were only noted for arachidic acid (C20:0) with males having a higher ($P \leq 0.05$) mean concentration than females. Age did not have an effect on the individual SFA's.

Of the monounsaturated fatty acids (MUFA's), differences were only noted between kudu and impala for oleic acid (C18:1 *n*-9c). Oleic acid was higher ($P \leq 0.01$) in kudu (24.35%) than in impala (12.22%). Gender differences were only noted for gondoic acid (C20:1) with females (0.24%) having lower concentrations ($P \leq 0.05$) than males (0.55%). With regards to age groups, differences were noted for palmitoleic acid (C16:1) ($P \leq 0.05$) and gondoic acid (C20:1) ($P \leq 0.01$) between adult and sub-adult animals. The MUFA's as a percentage of the total fatty acids were substantially higher ($P \leq 0.0001$) in kudu (26.25%) compared to impala (14.82%), mainly due to the differences in oleic acid.

Linoleic acid, an omega-6 PUFA and α-linolenic acid (C18:3 *n*-3) an omega-3 PUFA are both essential fatty acids as they cannot be synthesised in the human body. Linoleic acid is found in many seeds and this could be an explanation for the high ($P \leq 0.01$) quantity found in kudu meat (22.95%) compared to impala meat (14.70%) as kudu will eat fallen fruits and pods in the dry season (during which time this study was conducted) when browse is less available.

When considering the other PUFA's**,** kudu had higher levels of C20:3 *n*-6 (0.96%) ($P \leq 0.05$), and C22:6 *n*-3 (1.92%) ($P \leq 0.01$) than impala. On the other hand, levels of eicosapentaenoic acid (C20:5 *n*-3) ($P \leq 0.05$) and docosapentaenoic acid (C22:5 *n*-3) ($P \leq 0.01$) were higher in impala than in kudu (Table 2). Arachidonic acid (C20:4 *n*-6) was the second most abundant PUFA for both kudu (7.81%) and impala (9.80%). Arachidonic acid is a major thrombogenic fatty acid and meat is considered to be an important source of this fatty acid (Berner, 1993). The current values obtained are in keeping with the arachidonic acid concentrations for impala male (7.79–7.87%) and female (5.87–6.12%) as reported by Hoffman *et al.* (2005). Kudu from the Orange Free State had a mean arachidonic acid content of 8.44% for male and 7.74% for female animals (Mostert & Hoffman, 2007).

Of the total PUFA's, kudu (38.88%) had a higher ($P \leq 0.05$) concentration than impala (34.06%). Since grass contain high quantities of α -linolenic acid (C18:3 *n* -3), and the impala is mostly a grazer, high levels of α-linolenic acid would be expected in impala meat. However, kudu had more (although not significantly) α-linolenic acid (2.12%) than impala (1.92%). α -Linolenic acid values ranging between 3.33% and 4.00% were obtained for another southern African ungulate, springbok, and no differences were noted between genders, ages or regions (Hoffman *et al.*, 2007). In the present investigation, gender differences were observed only for C18:2 *n*-6t with males (0.26%) having higher ($P \leq 0.05$) concentrations than females (0.17%). With regards to age, higher ($P \leq 0.01$) concentrations of linoleic acid were found in sub-adults (20.79%) compared to adults (16.86%).

Diets rich in fat are known to cause obesity in humans, but are also associated with colon cancer and cardiovascular diseases. In lieu of this, the World Health Organisation (WHO, 2003) recommends that animal fat should provide between 15 and 30% of the calories in the diet. Of this, not more than 10% should be from saturated fat. Not only should the amount of fat be considered, but also the fatty acid composition (Jiménez-Colmenero *et al*., 2001) as this varies greatly among different fat sources. In the present study kudu had a lower ($P \leq 0.0001$) concentration of total SFA (34.87%) compared to impala (51.12%) resulting in kudu meat having a higher ($P \leq 0.05$) concentration of total PUFA (38.88%) than impala (34.06%) meat. This caused kudu *M. longissimus dorsi* to have a more favourable PUFA: SFA ratio (1.22) than impala (0.73). However, the PUFA: SFA ratios for both species are above the recommended minimum value of 0.45 prescribed by the British Department of Health (1994). The typical PUFA: SFA ratio for beef and lamb is 0.11 and 0.15 respectively (Enser *et al.*, 1998).

Harris (1997) concluded that consumption of sufficient levels of *n*-3 fatty acids can reduce serum triacylglycerols in humans. The British Department of Health recommended a maximum *n*-6:*n*-3 ratio of 4, while Lee *et al.* (1989) proposed a *n*-6:*n*-3 ratio of between 2.5 to 5 to be optimal. The *n*-6:*n*-3 ratio for kudu and impala in the present study were below this maximum although the ratio was higher ($P \leq 0.05$) for impala (3.76) than for kudu (2.22). The *n*-6:*n*-3 ratio for kudu compares well to the values obtained by Mostert & Hoffman (2007) where the ratio for kudu females was 2.42 and for kudu males it was 2.29. Du Buisson (2006) reported an *n*-6:*n*-3 ratio of 1.98 for springbok and 1.57 for blesbok.

Despite the hydrogenating effect of rumen microbes on dietary lipids, diet can modify the fatty acid profile of meat. Rule *et al.* (2002) calculated *n*-6:*n*-3 ratios of 1.94 (range-raised bison), 5.73 (feedlot raised bison), 1.95 (range-raised beef), 6.38 (feedlot raised beef) and 2.84 for elk. The values for elk and range-raised bison and beef are in line with values obtained for game animals. Several studies have indicated that forage or grass diets resulted in higher concentrations of *n*-3 PUFA in body tissues and grain or concentrate diets resulted in higher concentrations of *n*-6 PUFA (Marmer *et al.*, 1984; Wood & Enser, 1997; Wood *et al.*, 1999; Wiklund *et al.*, 2001). The fatty acid profile of reindeer has also been manipulated by feeding commercial pellets to the animals and comparing the data to that

from grazing animals. The most obvious difference was the higher *n*-3 fatty acid content in grazing reindeer, resulting in a lower *n*-6:*n*-3 ratio (Wiklund *et al.*, 2001). Reindeer raised on pellets had an increase in the amount of C18:2 *n*-6 resulting in a higher *n*-6:*n*-3 ratio. The effect of diet manipulation on South African game species has not yet been studied although Hoffman *et al*. (2005) noted differences in the fatty acid profile of impala originating from two regions and ascribed these differences to diet.

The mean fatty acid composition (percentage by weight of total identified fatty acids) for the five different muscles analysed for kudu and impala is represented in Tables 3 and 4 respectively. When comparing the five kudu muscles, differences ($P \leq 0.05$) were noted for myristic acid, palmitic acid, stearic acid, elaidic acid and gondoic acid. The total PUFA concentration also differed ($P \leq 0.05$) between the five muscles. *M. biceps femoris* and *M. semimembranosus* did not differ from each other, but had higher ($P \leq 0.05$) concentrations of PUFA's than *M. longissimus dorsi, M. semitendinosus* and *M. supraspinatus.*

When comparing the five impala muscles for the individual SFA's, differences ($P \leq 0.05$) were noted for myristic acid, palmitic acid and stearic acid. The SFA's as a percentage of the total fatty acids did not differ ($P > 0.05$) between the impala muscles. When comparing the MUFA's as a percentage of the total fatty acids, *M. longissimus dorsi* had the lowest value (15.21%) and *M. supraspinatus* had the highest value (19.87%). The total MUFA's for *M. longissimus dorsi* differed ($P \leq 0.05$) from *M. biceps femoris* and *M. semimembranosus* (which did not differ from each other), and they differed ($P \leq 0.05$) from *M. semitendinosus* and *M. supraspinatus* (these two did not differ from each other). When considering the individual MUFA's, differences were noted in elaidic acid, oleic acid and gondoic acid concentrations between impala muscles. Of the PUFA's, differences ($P \leq 0.05$) between the five impala muscles were observed for linoleic acid. The PUFA's as a percentage of the total fatty acids differed ($P \leq 0.05$) between the impala muscles with *M. longissimus dorsi* (34.02%) and *M. semimembranosus* (34.30%) (these two did not differ ($P > 0.05$) from each other) having the highest values and *M. supraspinatus* (24.05%) having the lowest value.

Wood *et al.* (2003) stated that the differences in muscle fibre types were reflected in their fatty acid composition. Higher proportions of phospholipids were said to be present in red oxidative muscles thus resulting in higher PUFA contents than in "white" muscles. Enser *et al*. (1998) found few differences in fatty acid content between muscles; however *M. longissimus dorsi* tended to have the lowest PUFA concentration when compared to *M. gluteobiceps* and *M. triceps brachii*. They ascribed this phenomenon to its metabolic status as a "whiter" muscle. Conversely, in the present study the PUFA: SFA ratio was lower in the "redder" *M. supraspinatus* (0.54) compared to the *M. longissimus dorsi* (0.68) for impala, although not significantly. The mean PUFA: SFA ratio for the five kudu

Table 3. The mean fatty acid composition (% of total fatty acids) (±s.e.) of five kudu muscles.

Fatty Acid (%)	*Longissimus dorsi*	*Biceps femoris*	*Semimembranosus*	*Semitendinosus*	*Supraspinatus*
C14:0 (Myristic Acid)	0.83^{abc} ± 0.34	0.29^{bc} ± 0.18	0.50^{bc} ± 0.17	0.12^{b} ± 0.14	0.30^{bc} ± 0.15
C16:0 (Palmitic Acid)	13.10^{ab} ± 2.24	11.86^{a} ± 1.33	13.71^{ab} ± 1.53	14.85^{abc} ± 1.65	12.37^{abc} ± 1.52
C18:0 (Stearic Acid)	18.55^{a} ± 1.43	16.83^{a} ±.81	18.51^{a} ± 1.77	21.59^{ab} ± 1.38	20.86^{ab} ± 1.42
C20:0 (Arachidic Acid)	0.38 ± 0.05	0.22 ± 0.06	0.28 ± 0.05	0.18 ± 0.08	0.26 ± 0.04
TOTAL SFA (%)	**34.31**	**34.08**	**34.92**	**37.00**	**37.91**
C16:1 (Palmitoleic Acid)	0.43 ± 0.08	0.35 ± 0.05	0.41 ± 0.05	0.39 ± 0.06	0.40 ± 0.05
C18:1 *n*-9t (Elaidic Acid)	0.59^{a} ± 0.12	0.51^{a} ± 0.15	0.67^{a} ± 0.11	0.73^{a} ± 0.11	0.88^{b} ± 0.18
C18:1 *n*-9c (Oleic Acid)	29.49 ± 2.31	27.51 ± 2.22	26.91 ± 2.01	28.61 ± 1.97	28.64 ± 1.80
C20:1 (Gondoic Acid)	0.28^{ab} ± 0.19	0.17^{ab} ± 0.04	0.28^{a} ± 0.15	0.12^{a} ± 0.06	0.10^{a} ± 0.04
C22:1 *n*-9 (Erucic Acid)	0.03 ± 0.12	0.02 ± 0.06	0.14 ± 0.10	0.06 ± 0.14	0.12 ± 0.15
TOTAL MUFA (%)	**30.24**	**28.56**	**28.81**	**29.71**	**30.49**
C18:2 *n*-6t	0.17 ± 0.04	0.18 ± 0.02	0.21 ± 0.07	0.10 ± 0.05	0.28 ± 0.03
C18:2 *n*-6c (Linoleic Acid)	21.99 ± 1.77	24.59 ± 1.43	24.07 ± 1.34	23.14 ± 1.36	23.58 ± 1.27
C18:3 *n*-3 (α-Linolenic Acid)	2.04 ± 0.30	1.99 ± 0.45	2.30 ± 0.36	1.70 ± 0.39	1.90 ± 0.31
C18:3 *n*-6 (γ-Linolenic Acid)	0.26 ± 0.08	0.31 ± 0.13	0.34 ± 0.12	0.20 ± 0.14	0.15 ± 0.03
C20:3 *n*-6	0.81 ± 0.14	0.75 ± 0.16	1.25 ± 0.28	0.69 ± 0.14	0.52 ± 0.19
C20:4 *n*-6 (Arachidonic Acid)	7.08 ± 1.44	6.35 ± 2.09	7.75 ± 1.27	6.73 ± 1.54	6.38 ± 1.24
C20:5 *n*-3 (EPA)	0.20 ± 0.20	0.90 ± 0.64	0.47 ± 0.24	0.26 ± 0.29	0.28 ± 0.30
C22:5 *n*-3 (DPA)	0.20 ± 0.26	0.10 ± 0.31	0.18 ± 0.24	0.25 ± 0.32	0.07 ± 0.18
C22:6 *n*-3 (DHA)	1.26±0.33	1.48 ± 0.24	1.36 ± 0.47	1.11 ± 0.35	0.60 ± 0.47
TOTAL PUFA (%)	**35.45^{ab}**	**38.22^{a}**	**36.27^{a}**	**33.29^{ab}**	**34.41^{ab}**
PUFA: SFA	1.23^{a} ± 0.13	1.22^{a} ± 0.19	1.19^{a} ± 0.10	1.00^{ab} ± 0.12	1.00^{ab} ± 0.12
n-6: *n*-3	3.30 ± 1.00	1.76 ± 1.40	1.99 ± 0.44	2.72 ± 1.04	3.17 ± 0.51

^{a,b,c,d} Means in rows with different superscripts are significantly different, $P \leq 0.05$.

Table 4. The mean fatty acid composition (% of total fatty acids) (±s.e.) of five impala muscles**.**

Fatty Acid (%)	*Longissimus dorsi*	*Biceps femoris*	*Semimembranosus*	*Semitendinosus*	*Supraspinatus*
C14:0 (Myristic Acid)	1.12 ^{a} ± 0.22	1.13 ^{a} ± 0.11	0.92 ^{ab} ± 0.11	1.08 ^{a} ± 0.09	0.96 ^{ab} ± 0.09
C16:0 (Palmitic Acid)	18.10 ^{a} ± 1.44	16.77 ^{abc} ± 0.86	14.28 ^{bcd} ± 0.98	15.73 ^{abcd} ± 1.07	17.29 ^{ab} ± 0.98
C18:0 (Stearic Acid)	22.87 ^{ab} ± 0.92	22.55 ± 1.16	21.16 ^{abc} ± 1.14	20.63 ^{bc} ± 0.89	24.02 ^{a} ± 0.91
C20:0 (Arachidic Acid)	0.19 ± 0.03	0.25 ± 0.04	0.26 ± 0.03	0.29 ± 0.05	0.20 ± 0.02
TOTAL SFA (%)	**50.78**	**45.65**	**48.42**	**49.21**	**51.40**
C16:1 (Palmitoleic Acid)	0.39 ± 0.05	0.38 ± 0.03	0.28 ± 0.03	0.37 ± 0.04	0.39 ± 0.03
C18:1 *n*-9t (Elaidic Acid)	0.71^{b} ± 0.08	0.77^{ab} ± 0.09	0.63 ^{b} ± 0.07	0.68 ^{b} ± 0.07	1.10 ^{a} ± 0.11
C18:1 *n*-9c (Oleic Acid)	13.06 ^{a} ± 1.48	15.66 ^{ab} ± 1.43	14.73 ^{ab} ± 1.29	16.66 ^{ab} ± 1.27	17.69 ^{bc} ± 1.16
C20:1 (Gondoic Acid)	0.54 ^{a} ± 0.13	0.19 ^{b} ± 0.03	0.29 ^{ab} ± 0.10	0.26 ^{ab} ± 0.04	0.22 ^{ab} ± 0.03
C22:1 *n*-9 (Erucic Acid)	0.30 ± 0.08	0.22 ± 0.04	0.31 ± 0.06	0.34 ± 0.09	0.31±0.10
TOTAL MUFA	**15.21^{c}**	**16.66^{b}**	**17.28^{b}**	**19.36^{a}**	**19.87^{a}**
C18:2 *n*-6t	0.17 ± 0.03	0.16 ± 0.01	0.26 ± 0.05	0.27 ± 0.03	0.21 ± 0.02
C18:2 *n*-6c (Linoleic Acid)	14.59^{ab} ± 1.14	13.08^{abc} ± 0.92	14.76^{a} ± 0.86	11.80^{bc} ± 0.88	10.96^{c} ± 0.82
C18:3 *n*-3 (α-Linolenic Acid)	2.10 ± 0.19	1.87 ± 0.29	2.40 ± 0.23	1.78 ± 0.25	1.52 ± 0.20
C18:3 *n*-6 (γ-Linolenic Acid)	0.20 ± 0.05	0.17 ± 0.09	0.12 ± 0.08	0.20 ± 0.09	0.11 ± 0.02
C20:3 *n*-6	0.67 ± 0.09	0.73 ± 0.10	1.17 ± 0.18	0.80 ± 0.09	0.77 ± 0.12
C20:4 *n*-6 (Arachidonic Acid)	9.14 ± 1.33	11.42 ± 1.93	8.00 ± 1.18	6.73 ± 1.54	6.38 ± 1.24
C20:5 *n*-3 (EPA)	1.18 ± 0.13	1.07 ± 0.41	1.21 ± 0.16	1.12 ± 0.19	1.12±0.19
C22:5 *n*-3 (DPA)	1.65 ± 0.17	1.69 ± 0.20	1.86 ± 0.15	2.11 ± 0.21	1.50±0.11
C22:6 *n*-3 (DHA)	0.92 ± 0.21	0.87 ± 0.16	1.58 ± 0.30	1.04 ± 0.22	1.35±0.30
TOTAL PUFA	**34.02^{abc}**	**30.06^{cd}**	**34.30^{abc}**	**31.43^{bcd}**	**24.05^{d}**
PUFA: SFA	0.68 ^{a} ± 0.8	0.80^{ab} ± 0.12	0.73 ^{ab} ± 0.06	0.70 ^{a} ± 0.08	0.54 ^{a} ± 0.08
n-6: *n*-3	3.94 ± 0.65	4.60 ± 0.90	2.90 ± 0.28	3.71 ± 0.67	3.06 ± 0.33

^{a,b,c,d} Means in rows with different superscripts are significantly different, $P \leq 0.05$.

muscles was 1.13 (*M. longissimus dorsi* highest and *M. semitendinosus* and *M. supraspinatus* lowest values). For the five impala muscles the mean PUFA: SFA ratio was 0.69 with *M. biceps femoris* having the highest value and *M. supraspinatus* the lowest value.

Cholesterol content

Cholesterol is another meat component of nutritional value due to its connection to cardiovascular diseases. The World Health Organisation's nutritional guideline for cholesterol intake is 300 mg per day (Jiménez-Colmenero *et al*., 2001). Lauric acid (C12:0), myristic acid and palmitic acid are known to increase plasma cholesterol levels. In contrast, stearic acid has no effect on cholesterol levels (Grundy & Denke, 1990). Cholesterol content varies in meat and meat products, but is on average below 75 mg/100g (Jiménez-Colmenero *et al*., 2001).

In the present study kudu meat were found to have a higher ($P \leq 0.0001$) (72.62 ± 1.86 mg/100g) cholesterol content than impala (55.35 ± 1.84 mg/100g) (Figure 1). No differences ($P > 0.05$) were noted between age or gender groups. When considering the muscles, no differences were found in the cholesterol content between the five muscles investigated. Cholesterol content of impala compares well to that of springbok (54.45-59.34 mg/100g) (Hoffman *et al.*, 2007), mountain reedbuck (51.56 mg/100g) (Hoffman & Wiklund, 2006) and black wildebeest (47 mg/100 g), another African ruminant game species (Hoffman & Wiklund, 2006). On the other hand, cholesterol content of kudu is higher than that reported for grazed lambs (62.03 ± 4.46 mg/100g) (Rowe *et al.*, 1999), but lower than the average for South African beef (89.58 mg/100g) (Schönfeldt, 1993). The cholesterol content of kudu seems high when compared to other game species. The reason for this is unknown and as far as could be ascertained no other data on kudu cholesterol is available. Further research would have to be conducted to corroborate these results.

Conclusion

The results obtained from this study are proof that kudu and impala meat differ significantly in terms of fatty acid profile and cholesterol content. The SFA content of impala meat was high compared to kudu and other game species. This could be linked to the high level of intramuscular fat observed in impala. However, the PUFA: SFA ratio was still above the recommended minimum of 0.45 for both species. Kudu and impala meat differed significantly in terms of many of the fatty acids. These differences can mainly be ascribed to the differences in diet between the two species as the kudu is primarily a browser in contrast to the impala being a mixed, concentrate feeder. The ratio of *n*-6 to *n*-3 PUFA's for both species are below the recommendation of 4.0 set by the British Department of Health. Some of the fatty acids showed significant differences between gender and age groups. However, when taken as a whole, gender and age did not have a significant effect on the fatty acid profile and cholesterol content from these two species. Significant differences were noted between the five muscles investigated for both species, resulting in the muscles differing in terms of their PUFA: SFA

ratio. Overall, kudu and impala meat were found to have favourable fatty acid profiles and can be considered healthy.

The cholesterol content of impala meat compared well to other game species and was markedly lower than that of domesticated species. However, the cholesterol content of kudu meat was found to be high when compared to other game species. It is advised that further research be done in order to substantiate these values.

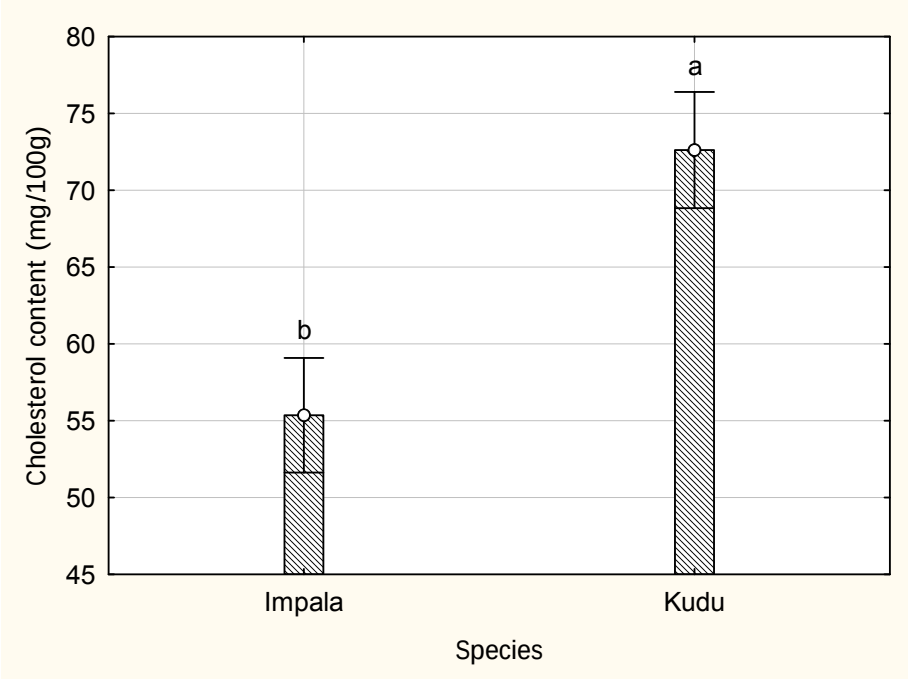

Figure 1. Cholesterol content (mg/100g) for kudu and impala.

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Chapter 6

Sensory characteristics of kudu (*Tragelaphus strepsiceros*) and impala (*Aepyceros melampus*) meat as affected by gender

Abstract

Game meat is a unique product and meat from each species has its own distinct flavour and other sensory characteristics. In this study kudu and impala meat from male and female animals derived from the same region and season were evaluated in seven tasting sessions, serving four samples in each session (kudu male, kudu female, impala male and impala female). Within species, the panel (n=10) found no gender differences for any of the sensory characteristics tested. The impala meat had a more intense game aroma than the kudu meat. The initial juiciness of the cooked samples differed with the kudu meat being more juicy than impala meat. However, the impala had a more intense game flavour than the kudu meat. These significant differences in the flavour and aroma of kudu and impala meat indicate that the marketing of game meat should be species-specific.

INTRODUCTION

Game farming is a rapid growing industry in southern Africa. Van Zyl (2000) estimated that between 17 and 18 million hectares is being used for game farming purposes. Although biltong and trophy hunting is still the biggest earner in gross income in the game industry (Kieser, 2001; Samuelsson & Stage, 2007), the sale of game meat can provide a welcome additional income for the game farmer or ranch owner. De-boned game meat from an estimated 160 000 carcasses were exported from South Africa during the 2005 harvesting season. These were mostly springbok (*Antidorcas marsupialis*) (>80%), blesbok (*Damaliscus pygargus phillipsi*) and kudu (Hoffman & Wiklund, 2006).

Bakula & Kêdzior (2001) found that sensory characteristics are the most important quality aspect of meat and meat products. This is confirmed by Hernández & Seehawer (2002), who found that consumers evaluate food quality based on aspects of hygiene, safety, sensory quality and origin of food. Juiciness, tenderness and flavour seem to be key indicators of taste and quality of meat according to South African consumers (Radder & Le Roux, 2005). South African game meat can still be considered an organic product as these ungulates are not farmed intensively as is the case with venison from other countries (Hoffman & Wiklund, 2006). Another positive health aspect is the low fat content of game meat. Schönfeldt (1993) and Hoffman (2000) reported fat contents ranging between two and three percent, which is lower than that of many domestic species. Hoffman *et al.* (2003) found that the health aspect of food were imperative to 82% of a group of tourists visiting South Africa that were questioned regarding their perceptions and consumption of game meat. Of the respondents 80% said that they were of the opinion that game meat is healthy.

Some supermarkets and butcheries in South Africa are not aware of the species of game meat they buy. The meat is simply marketed as venison or game without any reference to the specific species (Hoffman *et al.*, 2004). The question that arises is whether this is the way to go or should the consumer be given the choice to buy game meat from a specific species. Pauw (1993) stated that game meat is a unique product and that meat from each species has its own distinct flavour.

It is well known that diet has an influence on the sensory characteristics of meat (Melton, 1990; Muir *et al.*, 1998, Wiklund *et al.*, 2003a). Amino acids, fatty acids and carbohydrates undergo chemical reactions during cooking, which produces compounds that contribute to meat flavour. Although kudu and impala are found in the same area, they have different diets. Kudu are predominantly non-selective browsers and feed on tree and shrub leaves, woody branches, pods, seeds, broad-leaved forbs and succulents (Furstenburg, 2006). The diet of kudu in the savanna bushveld consists of 18% grass, 21% forbs and 61% browse while kudu in the valley bushveld of the Eastern Cape will consume 5-12% grass, 15-18% broad-leaved forbs and 70-80% browse (Furstenburg, 2005). Impala, on the other hand are intermediate feeders. Meissner & Pieterse (1996) found that 90% of the impala's diet consisted of grass during the rainy season with browse increasing to 35% during the dry season. Hoffman *et al.* (2007) observed that the regional effect was greater on the sensory characteristics of springbok than either gender or age. Production region influenced the game meat aroma, initial juiciness, sustained juiciness and residual tissue ratings of the meat, whilst gender and age only had a significant effect on the residual tissue rating of the meat.

No data is available on the sensory characteristics of kudu or impala meat. Therefore, the present study was undertaken to determine whether there are differences in sensory characteristics of kudu and impala meat from both genders within the same geographical region.

MATERIALS AND METHODS

In this study, 14 kudu (*Tragelaphus strepsiceros*) (seven female (KF) and seven male (KM)) and 13 impala (*Aepyceros melampus*) (seven female (IF) and six male (IM)) were harvested in the Limpopo Province, Mabula District (S 24 52.611, E 27 56.862). After inspection of tooth eruption and horn development (where relevant), animals were divided into sub-adult and adult groups. For this sensory evaluation, only sub-adults were used. The impala in the sub-adult group were all younger than 30 months whilst the kudu were younger than 34 months. (Refer to Chapter 3 "Materials and Methods" for age classification of animals.)

All animals were harvested using standard techniques (Hoffman & Wiklund, 2006). The animals were killed instantaneously with head shots using a .243 calibre rifle. Carcasses were bled immediately after being shot. Evisceration and skinning were done at the slaughter facilities (within 1 h post mortem), after which they were moved to a cold room (<4ºC). At 24 h post-mortem the *M. longissimus*

dorsi was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra. Samples were taken for physical measurements (Chapter 3) and chemical composition analysis (Chapters 4 and 5). Another sample was vacuum packed and stored at -20 °C for sensory analysis.

The *M. longissimus dorsi* samples were defrosted at 3-4°C for a 24 h period prior to cooking. The samples were placed on foil covered metal racks. Each metal rack was placed in a coded cooking bag with a thermocouple inserted into the centre of each piece of meat. The samples were roasted in a Defy 835 oven connected to a computerised temperature control system (Viljoen *et al.*, 2001) at 160°C to an internal temperature of 68°C. After cooking the meat were left to rest for 5 minutes, in which time an internal temperature of 72°C were reached. The samples were then cut into 1x1x1 cm cubes, wrapped individually in aluminium foil and placed in labelled ramekins and kept in a pre-heated oven (100°C). The samples were tasted by a trained panel within 10 minutes from being placed back into the oven.

The tasting panel consisted of ten members, who were trained in accordance with the guidelines for the sensory evaluation of meat of the American Meat Science Association (AMSA, 1995). Panel members were further trained using the consensus method as described by Lawless & Heymann (1999). The meat was evaluated for the following sensory characteristics: intensity of aroma, texture, initial and sustained juiciness, tenderness and flavour. The judges rated the samples on a 100 mm unstructured line scale with the left side of the scale resultant to the lowest rating (zero) and the right side of the scale resultant to the highest rating. Table 1 gives the verbal definitions of the characteristics used in the sensory analyses. The meat was evaluated in seven sessions, serving four samples in each session (kudu male, kudu female, impala male and impala female). As there were only six samples of impala male available, the last tasting session was incomplete.

Statistical analyses

The experimental design consisted of a randomised complete block design with four treatments (kudu male, kudu female, impala male and impala female). The factors tested were two species (kudu and impala) and two genders (male and female). With each tasting session the four treatments were evaluated by the ten trained panel members for the different variables. For each session different carcasses were used and sessions were considered as the block effect. The variables were recorded on an unstructured line scale as interval data and subjected to an appropriate analysis of variance using SAS (version 9.1) statistical software. The ANOVA were setup to test internal consistency and stability of judges. The Shapiro-Wilk test was used to test for normality (Shapiro & Wilk, 1965). Student's t-LSD (Least significant differences) was calculated at a 5% significance level to compare treatment means.

Table 1. Definition of characteristics for sensory analyses of game meat.

Characteristic and scale	Definition
Game meat aroma intensity 0 = Low; 100 = High	The intensity of a typical game meat aroma
Initial juiciness 0 = Dry; 100 = Juicy	The amount of fluid exuded on the cut surface when pressed between forefinger and thumb
Sustained juiciness 0 = Dry; 100 = Juicy	The impression of juiciness after the first two to three chews
Tenderness 0 = Tough; 100 = Tender	The impression of tenderness after the first two to three chews between the molar teeth
Residue 0 =Abundant; 100 = None	The amount of residue left after 15 chews
Game meat flavour 0 = Low; 100 = High	The intensity of the game meat flavour (combination of taste and swallowing)

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) results from the sensory analyses are represented in Table 2. The effects of species (kudu and impala), gender (male and female) and the interactions between the two factors (species x gender) were investigated. A judge interaction was noted for aroma, flavour, initial juiciness and sustained juiciness (Table 2). Even though the sensory analyses were done by a trained panel, this can be expected as people perceive flavours and aromas differently. To test for internal consistency of judges, the ANOVA for judge x treatment (species x gender) was done and the results showed that judges ranked the treatments consistently in the same order.

Flavour and aroma

Jansen van Rensburg (1997) describes meat flavour as a combination of aroma, taste and overall mouth-feel during mastication. The flavour of cooked *M. longissimus dorsi* differed ($P \leq 0.05$) between kudu and impala (Tables 2 & 3). The impala meat had a more intense game flavour than the kudu meat. Mottram (1998) explains that the differences in flavour from different meat species can be ascribed to its lipid components. During thermal degradation of the lipids, the specific flavours are released. In this investigation, differences were noted between the fatty acid profiles of these two species (Chapter 5); especially the kudu had a higher PUFA: SFA ratio. Various studies have shown that the fatty acid composition of meat changes in response to the diet of the animal (Wood & Enser, 1997; Wiklund *et al.*, 2001; Wiklund *et.al.*, 2003a). Hoffman *et al.* (2005) also found significant differences in fatty acid concentrations between impala from two different regions where these animals consumed different diets. Impala from the region that fed on a more grass-based diet had increased levels of stearic and α-linolenic acid.

Table 2. Analysis of variance (ANOVA) of sensory characteristics for kudu and impala *M. longissimus dorsi.*

	Aroma			Initial Juiciness			Tenderness			Residue			Sustained Juiciness			Flavour		
Source	DF	MS	P	DF	MS	P	DF	MS	P	DF	MS	P	DF	MS	P	DF	MS	P
Judge	9	3337.40	<0.001	9	2071.29	< 0.001	9	2002.72	0.07	9	6511.74	0.01	9	3314.88	< 0.001	9	4331.60	<0.001
Session	6	423.33	0.03	6	1436.26	0.01	6	1582.01	0.17	6	2264.17	0.24	6	669.63	0.29	6	470.18	0.001
Judge x Session	54	193.96	0.21	54	206.40	0.85	54	341.98	0.99	54	610.30	0.99	54	161.43	0.99	54	155.20	0.007
Species	1	805.60	0.03	1	2273.71	0.01	1	29.04	0.86	1	21.28	0.91	1	1013.88	0.17	1	705.25	0.01
Gender	1	15.54	0.74	1	15.21	0.82	1	262.81	0.60	1	660.32	0.52	1	1.41	0.96	1	94.62	0.19
Species x Gender	1	0.01	0.99	1	1539.56	0.04	1	478.62	0.48	1	137.76	0.77	1	879.58	0.20	1	57.03	0.31
Judge x Treat	27	64.74	0.96	27	77.51	0.99	27	204.59	0.99	27	343.06	0.99	27	104.85	0.99	27	50.32	0.53
Experimental error	17	136.21	-	17	299.26	-	17	900.39	-	17	1530.74	-	17	496.86	-	17	51.14	-
Sample error	152	55.81	-	153	91.51	-	153	180.01	-	153	270.93	-	152	102.08	-	153	46.83	-
Corrected Total	268	-	-	269	-	-	269	-	-	269	-	-	268	-	-	269	-	-

DF Degree of freedom

MS Mean Square

P Probability value of F-ratio test

In a study on reindeer, a trained sensory panel found significant differences in flavour between animals fed commercial diets and animals grazing on natural pasture (Wiklund *et al.*, 2003a). In another study, grazing reindeer had a significant more "grassy" flavour than reindeer fed on pellets (Wiklund *et al*., 2003b). The variation in the diet of the kudu and impala can therefore be responsible for the difference in flavour between the two species. Although both species habituate the same area, the kudu consumes only about 18% grass and up to 60% leaves, while the impala's diet consists of 65-90% grass and only 10-35% leaves. For kudu meat, a positive correlation ($r = 0.569$, $P = 0.034$) was noted between sensory flavour and oleic acid (C18:1 *n*-9c), a monounsaturated fatty acid (MUFA). Oleic acid (24.35%) was also the major fatty acid found in kudu meat followed by linoleic acid (22.95%) (Chapter 5). Combined these two fatty acids constitute nearly 50% of the fatty acids present in kudu meat. Conversely, two saturated fatty acids, stearic acid (22.67%) and palmitic acid (16.66%) were the most plentiful fatty acids in impala meat. These two fatty acids compose 40% of the fatty acids in impala meat. Weak correlations ($P \leq 0.10$) were noted between sensory flavour in kudu meat and palmitic acid (C16:0) ($r = -0.459$; $P = 0.099$), linoleic acid (C18:2 n-6c) ($r = 0.5189$; $P = 0.057$) and eicosapentaenoic acid (C20:5 n-3) ($r = -4786$; $P = 0.078$). For impala meat no correlations ($P > 0.10$) were noted between sensory flavour and any of the fatty acids.

Age was not investigated in this study as all the animals were sub-adult; although an increase in flavour intensity is associated with an increase in animal age (Ford & Park, 1980). For example; Schönfeldt *et al.* (1993) found the species flavour of goat and sheep meat to be less typical in young animals compared to that of older animals.

Although a low fat content is desirable in meat, some fat is necessary to convey flavour and juiciness in meat (Melton, 1990), for example; Tshabalala *et al.* (2003) found a positive correlation between fat content and flavour intensity in goat and sheep meat. In this study, the impala which had a stronger game flavour, also had significantly more fat (2.22%) than the kudu (1.62%) (Chapter 4). A positive correlation ($r = 0.412$, $P < 0.05$) was also calculated between fat content and sensory flavour for the kudu and impala meat.

The aroma of meat is described as the sensory quality experienced by the olfactory organ due to the presence of specific volatile substances (Meilgaard *et al.*, 1987). Over 1000 volatile compounds have been isolated in meat (Mottram, 1998). In the present study, the panel found significant differences ($P \leq 0.05$) in the aroma of kudu and impala meat (Tables 2 & 3). The impala meat had a more intense ($P \leq 0.05$) game aroma than the kudu meat. According to Mottram (1998), lipid sources are responsible for the characteristic odours of different species. For instance, certain methyl-branched saturated fatty acids which give mutton its characteristic odour have not been identified in other meats. In impala meat from the present study, myristic acid (C14:0) and arachidic acid (C20:1) were weakly correlated ($P < 0.10$) with sensory aroma. Further studies are required to identify the specific volatile compounds associated with kudu and/or impala meat.

No significant differences in aroma were detected between the two genders within species. This is consistent with the findings of Smit (2004) for red hartebeest and Van Schalkwyk (2004) for mountain reedbuck where gender had no effect on aroma of the meat. It could be speculated that gender differences in aroma could be apparent in sexually mature animals due to hormones after the animals have reached sexual maturity. Therefore the lack of differences in aroma could be due to all the animals in this study being sub-adult. Ford & Park (1980) stated that the natural flavour of meat from a particular species is not fully developed until the animal reaches maturity.

Initial juiciness

Initial juiciness can be described as the impression of wetness perceived after the first few chews which is due to the rapid release of meat fluids. The amount of water in the muscle as well as intramuscular fat of the meat sample is in part accountable for the juiciness of meat (Cross *et al.*, 1986). It is not only the amount of water, but also the extent to which the water is bound in the meat, also referred to as the water holding capacity (WHC), that adds to the initial juiciness of meat. For instance, a low water holding capacity (Honikel, 1998), may lead to a decrease in the perceived juiciness of the meat. The ability of meat to retain water is influenced by the ultimate pH (pH_u). A low pH_u results in meat proteins having decreased WHC and thus being less juicy. Conversely, meat with a higher pH_u will have less drip loss and thus keep more juice after cooking of the meat. The result is a more favourable eating experience due to the juiciness of the meat. However, an ultimate pH above 6.0 could result in dark, firm and dry (DFD) where the WHC is so strong that the meat is perceived to be dry. In this study there was a positive correlation ($r = 0.4815$, $P < 0.05$) between moisture content and initial juiciness. No correlation was found between cooking loss and initial juiciness.

Table 3. Mean panel scores for sensory characteristics of kudu and impala *M. longissimus dorsi* as influenced by species and gender.

Sensory characteristic	Species			Gender		
	Kudu	Impala	LSD	Female	Male	LSD
Aroma	57.6[b]	61.2[a]	3.0	59.5	59.1	NS
Initial Juiciness	66.4[a]	60.8[b]	4.4	63.6	63.7	NS
Sustained juiciness	62.7	58.6	NS	60.8	60.7	NS
Tenderness	63.0	63.8	NS	62.4	64.4	NS
Residue	49.4	49.0	NS	50.6	47.7	NS
Flavour	58.4[b]	61.6[a]	1.7	60.6	59.1	NS

[a-b]Means, in rows, with different superscript letters are significantly different, $P \leq 0.05$

LSD=Least Significant Difference ($P = 0.05$)

NS=Not significant ($P > 0.05$)

Initial juiciness showed an interaction between species and gender ($P = 0.04$, Table 4). For initial juiciness, the kudu females differed significantly from the impala females, but not from the kudu males or impala males. Similarly, the latter two did not differ significantly from the impala females. This

higher value for the kudu females (KF) also resulted in the initial juiciness of the cooked samples differing (P ≤ 0.05) between kudu and impala meat with the kudu having a significantly higher score for initial juiciness (Table 3).

Table 4. Mean panel scores for the sensory characteristics of kudu and impala *M. longissimus dorsi.*

Sensory characteristic	KF	KM	IF	IM	LSD
Aroma	57.8	57.3	61.3	61.1	NS
Initial Juiciness	68.9[a]	63.8[ab]	58.4[b]	63.6[ab]	6.3
Sustained juiciness	64.5	60.9	57.1	60.5	NS
Tenderness	63.3	62.8	61.5	66.4	NS
Residue	49.6	51.5	49.1	53.2	NS
Flavour	58.7[b]	58.1[b]	62.6[a]	60.4[ab]	2.4

[a-b]Means in rows with different superscript letters are significantly different (P≤0.05)

LSD=Least Significant Difference (P=0.05)

NS=Not significant (P>0.05)

Sustained juiciness

Sustained juiciness is described as the impression formed after the first two to three chews using the molar teeth. As fat has an effect of stimulating saliva production in the mouth, it is expected that fatter animals would seem to have a higher sustained juiciness. Although impala (2.22 ± 0.10%) and all female animals (2.10 ± 0.09%) had a higher fat content than kudu (1.62 ± 0.10%) and male animals (1.74 ± 0.10%) (Chapter 4), no differences (P > 0.05) in sustained juiciness were found for any of the treatments (Tables 2 & 3).

A study on 471 lamb and sheep carcasses indicated that juiciness declined as age increased, and as intramuscular fat percentage decreased (Hopkins *et al.*, 2006). However, in the present study no correlation (r = -0.1112, P = 0.5887) was observed between sustained juiciness and fat percentage. This is most probably caused by the fact that the kudu and impala muscles have a low intramuscular fat (IMF) content (kudu: 1.62%; impala: 2.22%; Chapter 4) compared to that of the sheep (7.00%). Wood (1990) confirmed the fact that the level of IMF has a significant effect on juiciness as well as tenderness.

Tenderness and residue

Tenderness, followed by flavour and juiciness is rated the most important criterion in consumer sensory surveys (Tornberg, 1996). The panel could not detect any differences (P > 0.05) in the tenderness and residue for any of the treatments. Although tenderness decreases with age as there is an increase in collagen cross-linkages to form insoluble heat-resistant structures (Miller *et al.*, 1983), only sub-adult animals were used in this study and therefore very little cross-linking would have formed. Hydroxyproline content and total collagen content was determined (Chapter 4) on the *M.*

longissimus dorsi for the same carcasses used in the sensory evaluation. However, no correlations were noted between both sensory tenderness and hydroxyproline content or sensory tenderness and total collagen content. There were also no significant differences between species, gender and age when meat tenderness was measured with the WBS technique (Chapter 3). When comparing sensory panel scores for meat tenderness the best correlation is achieved with the WBS technique (Tornberg, 1996). Nevertheless, in this study a weak correlation ($r = -0.230$, $P = 0.248$) was found between sensory tenderness and WBS values. This phenomenon has also been noted elsewhere; when reindeer, caribou and beef were compared for sensory tenderness, the trained panel found beef to be less tender than the other two species, a result that contrasted to the WBS values which did not differ significantly between reindeer, caribou and beef (Rincker *et al.*, 2006).

CONCLUSION

Significant sensory differences were found between kudu and impala *M. longissimus dorsi* meat from sub-adult animals. Impala meat had a more intense game aroma and also a more intense flavour than kudu meat. The differences in flavour and aroma for kudu and impala meat could be due to the difference in the diet of the two species. These differences indicate that the marketing of game meat should be species-specific and not under the collective term of "game meat". Kudu had a significantly higher initial juiciness than impala. No significant differences were found for sustained juiciness, tenderness and residue. The fact that no significant differences were detected between meat from male and female animals, suggest that the consumer would not be able to tell the difference between the genders when the animals are young.

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Chapter 7

CONCLUSIONS

During the past two decades the game ranching industry in South Africa has grown considerably. This has led to game ranch owners/ managers looking for alternative ways of dealing with surplus animals. As a result the export of game meat from South Africa to European countries has increased as game meat is regarded as exotic in these countries. The growing demand for game meat both locally and internationally resulted in the need for base line data on the quality of the meat from species utilised for game meat production. Also, consumers have become more aware of the health implications of the food they eat and therefore nutritional data on the meat from African game species has become essential.

The main effects of species, gender and age showed no differences in physical measurements (drip loss, cooking loss and tenderness). This could largely be ascribed to minimum pre-mortem stress experienced by the animals due to correct harvesting procedures being followed. Kudu and impala meat differed in terms of colour measurements with kudu meat being more red and brighter in colour than impala meat. Colour measurements were correlated with myoglobin concentration.

The results from the present study emphasize the differences in the chemical composition of meat from different African game species. Kudu had a lower fat content than impala and male animals also had less fat than females. As with many other game species, the low fat content of kudu and impala meat makes it a preferable choice for the health-conscious consumer. Species, gender and age did not affect the protein content. Mineral content differed between kudu and impala and this could be attributed to the variation in diet of the two species. The impala grazes and browses and is therefore known as a mixed or intermediate feeder. The graze to browse ratio varies depending on the season, rainfall conditions and habitat. The impala also has a preference for high quality food and can thus be considered a concentrate feeder, whereas the kudu is considered a bulk feeder as it eats browse with a high crude fibre content throughout the year. The results from this study show that kudu and impala meat can be regarded as a lean, healthy meat due to the low lipid and high protein content.

Impala had significantly higher insoluble collagen, soluble collagen, total collagen and hydroxyproline content than kudu. However, these differences were not reflected in WBS measurements.

Furthermore, kudu and impala meat differed significantly in terms of several of the fatty acids and these differences could also be ascribed to the differences in diet between the two species. As

noted before, the kudu is primarily a browser whereas the impala is a grazer that will also browse to some extent. No other data is available on chemical meat quality from a browser and therefore this research will help to explain the effect of diet on meat quality and the fatty acid profile from different species. Although there were differences in the fatty acid profiles of the two species, the PUFA: SFA ratio was above the recommended minimum of 0.45 for both species. Also the ratio of *n*-6 to *n*-3 PUFA's for both species are below the recommendation of 4.0 set by the British Department of Health. Impala meat can be considered a healthy choice when comparing its cholesterol content with other domestic species. However, the cholesterol content of kudu meat was found to be high when compared to other game species and it is advised that further research be done in order to substantiate these values. The results obtained from this study are proof that kudu and impala meat have favourable fatty acid profiles and can be considered healthy meat.

This study has provided some insight into the differences between different muscles from the same carcass. The five muscles of kudu and impala investigated in this study (*M. longissimus dorsi, M. biceps femoris, M. semimembranosus, M. semitendinosus* and *M. supraspinatus*) differed in terms of physical measurements (drip loss, cooking loss and colour), as well as chemical composition (moisture, protein, fat, myoglobin concentration and mineral content). Differences in physical measurements between muscles can be ascribed to the location and the activity of the muscles. Myoglobin concentration also varied between muscles with the oxidative muscles like the *M. supraspinatus* having the highest levels. Differences in the fatty acid profiles of the five muscles investigated were also noted. The five muscles from kudu and impala also differed in terms of their PUFA: SFA ratio.

Differences were evident in the sensory characteristics of meat from the two species investigated. Impala meat had a more intense game aroma and also a more intense flavour than kudu meat. The differences in flavour and aroma for kudu and impala meat could be due to the difference in the diet of the two species. The fact that no significant differences were detected between meat from male and female animals, suggest that the consumer would not be able to tell the difference between the genders when the animals are young.

It can therefore be concluded that although kudu and impala habituate the same geographical area, there are significant differences in chemical composition between the two species, resulting in sensory differences being noted. These differences indicate that the marketing of game meat should be species-specific and not under the collective term of "game meat".

Addendum 1

Effect of gender on the meat quality characteristics and chemical composition of kudu (*Tragelaphus strepsiceros*), an African antelope species[1]

Abstract

The kudu (*Tragelaphus strepsiceros*), one of Africa's most majestic antelope species, shows strong sexual dimorphism. The male reaches a larger size (≈250 kg live weight) than the female (≈180 kg live weight). Kudu occur throughout the savannah regions in central Africa south of the equatorial forests, through East Africa to Ethiopia, Sudan and Chad down to the Eastern Cape, South Africa. Kudu are predominantly browsers, but will occasionally graze. Within South Africa, this species is hunted regularly for local consumption, and kudu meat is also a regular item in most restaurants that serve game meat and is also frequently exported. However, very little data has been published as pertaining to the muscle chemical composition and other quality attributes of its meat. In the present investigation, the proximate, amino acid and fatty acid composition, and mineral content of the *Longissimus dorsi et lumborum* muscle of eighteen animals were determined, and the effect of gender on meat quality characteristics investigated. Kudu meat was found to have a high protein and low fat content. Only two of the longer chained polyunsaturated fatty acids, i.e. C20:3 *n*-6 and C20:5 *n*-3, were found in higher concentrations ($P \leq 0.05$) in meat samples obtained from male kudu. Of the kudu muscle's fatty acids, 37% were saturated, 22% monounsaturated and 41% polyunsaturated. The mean PUFA to SFA ratio (1.12) were well above the recommended 0.45 prescribed by the British Department of Health. The *n*-6:*n*-3 PUFA ratio (2.34) was also well below the British department of Health's recommended figure of 4. Histidine and valine had significantly higher levels ($P \leq 0.05$) in female kudu meat than in male kudu meat. Of the minerals analysed, phosphorous was found to be the mineral with the highest concentrations in both female and male meat samples. Overall, the chemical composition of kudu meat is not significantly affected by gender.

INTRODUCTION

During the past 20-25 years the commercial utilisation of wildlife has grown tremendously in South Africa (Hoffman & Bigalke, 1999). Berry (1986) compared the different aspects of utilisation on a wildlife farming enterprise and noted that wildlife can be utilised in either a consumptive or a non-consumptive way. Consumptive utilisation includes trophy hunting, recreational hunting, live capture and sales and game meat production. Non-consumptive utilisation is the provision of services to tourists such as game viewing, bird watching and wildlife photography. Non-consumptive utilisation is also better known as eco-tourism. When comparing the four pillars of consumptive utilisation, trophy hunting gives the highest net return on capital. This was followed by biltong or recreational hunting, live sales and lastly game meat production. However, when one considers the low percentage of

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trophy animals on a particular game ranch, trophy hunting gives the lowest return per unit area. Live sales of game are a good option, but in recent years auction prices for the more common wildlife species have reached a plateau (Eloff, 2002). In Limpopo Province, the heads of game sold increased from 6802 in 2003 to 9163 in 2004. However, the monetary value decreased from 39 million Rand in 2003 to 35 million Rand in 2004 (Eloff, 2005).

The time has come where the wildlife industry can no longer depend on hunting and live sales alone. Diversification into other areas for profitable production has to be considered. Although game meat is already marketed locally and internationally, there is great potential for expansion of target markets. In 2000, a survey in the Northern Province, South Africa showed that game meat production attributed only 4% to the wildlife industry in that Province (Van Der Waal & Dekker, 2000).

In order to conserve wildlife and wildlife habitats, game ranches and/or nature reserves need to be managed from a sustainable utilisation viewpoint. The consequence is that surplus animals have to be removed every year either by hunting or capture for live sales.

The driving force behind game meat for export is the demand for meat derived from species such as springbok (*Antidorcas marsupialis*), kudu, gemsbok (*Oryx gazelle*) and impala (*Aepyceros melampus*) by European countries (Olivier & Van Zyl, 2002). There is also a definite growth in game meat consumption through the local South African hotel and restaurant trade (Hoffman *et al.*, 2003). A survey of European tourists found that 92% had eaten game meat in South African restaurants. Kudu, springbok and warthog (*Phacochoerus africanus*) are the species commonly consumed by tourists (Hoffman, 2003). Jansen van Rensburg (2001) stated that the demand for game meat is expected to grow both locally and internationally as game meat meets the modern consumer's demand for lean meat.

To compete with existing meat products, scientifically based information on the quality and characteristics of game meat is needed. The same criteria that applies to meat production from domestic stock, applies to game meat production. These criteria include factors such as dress out percentages, chemical composition and meat quality. Factors affecting the meat quality, such as species, age, sex, geographical region and cropping method need to be evaluated.

The kudu is considered by many to be one of the most beautiful and majestic antelope species in Africa. With shoulder heights ranging from 100 – 150 cm the greater kudu is also one of the tallest of the antelope species. There is definite sexual dimorphism between male and female kudu; the female has a mean body weight of 170 kg (120 -215 kg) whereas the mean body weight for the male is 257 kg (120-315 kg) (Estes, 1991). The male kudu has the largest horns in the genus *Tragelaphus*, with a mean length of 120 cm, but also known to reach lengths of up to 180 cm (Estes, 1991). Kudu are browsers, feeding on shrubs, fruit and seed pods and will raid crops where available (Walker, 1996).

All over eastern and southern Africa, kudu have been hunted for many years and the meat utilised as a food source. However, little is known about the chemical composition and quality of its meat. The question of whether gender plays a role in the quality of kudu meat has also not been answered.

MATERIALS AND METHODS

Experimental animals

In this study, eighteen kudu were harvested in the Tussen die Riviere Nature Reserve in the Free State Province. A total of ten (10) female and eight (8) male animals were culled. The aimals were harvested using standard techniques. The animals were killed instantaneously with head shots using a .270 calibre rifle. Carcasses were bled, eviscerated, skinned and cleaned after which they were moved to a cooling facility. The next morning (≈12 h post-mortem) the *M. longissimus dorsi* (LD) was removed from between the 12^{th} and 13^{th} rib to between the 4^{th} and 5^{th} lumber vertebrae. Physical quality characteristics and chemical composition of the *M. longissimus dorsi* were analysed and the data subjected to the Student's t-test.

Physical analyses

Drip loss was determined by taking a freshly cut sample of 80-100 g meat, weighing it and then suspending it in an inflated plastic bag (Honikel, 1998). The sample bags were then left in a cold room at 1-5°C for 24 hours and then weighed again. The drip loss is expressed as a percentage of the weight of the fresh sample. Cooking loss was determined by using freshly cut samples of ± 80 g, weighing it and placing it in separate plastic bags. The sealed plastic bags were cooked in a water bath at 80°C for 1 hour. The samples were then cooled under running water; the liquid decanted and the samples weighed. The cooking loss is expressed as a percentage of the initial weight (Honikel, 1998). The cooked samples were then used to determine the tenderness by measuring Warner-Bratzler shear force values. A minimum of three cores of 1.27 cm were taken from each sample steak with a hand-coring device (Byrne *et al.*, 2000). A Warner-Bratzler shear device with a V-shaped blade that is attached to an Instron Universal Testing machine was used to take the shear force measurements (Byrne *et al.,* 2000).

Chemical analysis

Proximate composition

The moisture and protein contents (g/100 g meat) of all the samples were determined according to the Association of Official Analytical Chemist's Standard Techniques (AOAC, 1997). The accuracy and repeatability of all the techniques are controlled on a bi-monthly basis by means of a National Inter-

laboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa) wherein blind samples are analysed. The moisture content was determined by drying at 105°C for 24 hours. To determine the protein content, dried and defatted meat were ground with a pestle in a mortar to a fine powder. Samples of 0.100 mg were inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Ave., St Joseph, HI 49085-2396, USA, Part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. The fat content was determined by homogenising the samples in a blender, followed by chloroform:methanol (2:1) extraction (Lee *et al.*, 1996).

Amino acid composition

The amino acid composition was determined by using a modification of the HPLC method described by Bidlingmeyer *et al.* (1984). The meat was defatted by solvent extraction, according to the method of Lee *et al.* (1996) and then hydrolysed with 6 N HCl in a vacuum-sealed tube for 24 hours at 110°C, centrifuged and dried under vacuum for at least 1.5 hours. The pH was adjusted by adding 20 µl ethanol:water:triethylamine (2:2:1) and the sample dried as before. The samples were derivatised by adding 20 µl ethanol:water:triethylamine:phenylisothiocyanate (7:1:1:1) at room temperature (26°C) for 10 min and then dried under vacuum for at least 3 hours. The sample was re-suspended in 200 µl Picotag (Waters, Millford, MA, USA), from which 8 µl was then injected into an HPLC (Waters HPLC column, Novapak C18. 60 Angstrom, 4 micron, 3.9x150mm). Separation was by using buffers A (sodium acetate, pH 6.4, 5 000 ppm EDTA, triethylamine (1:2000) and 6%, v/v, acetonitrile) and B (60%, v/v, acetonitrile and 5 000 ppm EDTA). A 1525 HPLC with a binary gradient delivery, 717 auto-sampler and injector, 1500 column heater and 2487 dual wavelength UV detector were the equipment used in the analysis by Breeze software Z (Waters, Milford, MA, USA). Accuracy and repeatability of this analysis is ensured by inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

Mineral composition

The mineral composition of the meat was determined after ashing the defatted meat samples. The defatted meat samples (1-3 g) were air dried and ground to pass through a 0.5 to 1.0 mm sieve. Thereafter, the samples were ashed overnight in a muffle furnace at 550°C. A 6 M hydrocloric acid (HCl) solution was prepared by diluting 500 cm^3 of a 36% (m/m) HCl solution to 1 dm^3. After ashing, 5 cm^3 of a 6 M HCl was added to dissolve the cooled sample. Thereafter, the samples were dried on a waterbath. After cooling, a 5 cm^3 6 M nitric acid (HNO_3) solution was added to the samples. The 6 M HNO_3 solution was prepared by diluting 429 cm^3 of a 65% (m/m) solution to 1 dm^3. After adding the latter solution, the samples were heated on a waterbath and removed after boiling point was reached. The solution was subsequently filtered through filter paper into a 100 cm^3 volumetric flask and diluted

to volume with deionized water (Giron, 1973). Element concentrations were then measured on an ICP-Thermo Jarrel Ash, IRIS (AP).

Fatty acid composition

The fatty acid content was determined by using the method of Tichelaar *et al*. (1998). After thawing the meat, the lipids in a 2 g sample were extracted with chloroform/methanol (2:1) and 0.01% (v/v) butylated hydroxytoluene (BHT) as antioxidant. The samples were homogenised for 30 seconds in a polytron mixer (Kinematica, type PT 10-35, Switzerland) and transmethylated for two hours at 70°C with methanol/sulphuric acid (19:1; v/v). After cooling to room temperature, the fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. The FAME were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300, equipped with a flame ionisation detector), using a 60 m BPX70 capillary column of 0.25 mm internal diameter (SGE, Australia). The hydrogen gas flow rate was 25 ml/min; and the hydrogen carrier gas rate 2-4 ml/min. Temperature programming was linear at 3°C/min, with an initial temperature of 150°C, a final temperature of 220°C, an injector temperature of 240°C and a detector temperature of 250°C. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma Aldrich Inc. 595 North Harrison Road, Bellefonte, PA 16823-0048, USA). The FAME in the total lipids was identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue number 18919-1AMP, Lot number, LB-16064. Sigma Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

RESULTS AND DISCUSSION

Physical characteristics

No significant differences in the live weight (120.80 ± 10.36 vs. 134.13 ± 4.81 kg) and the carcass weight (72.40 ± 6.68 vs. 79.25 ± 4.21 kg) of female and male kudus were detected. The lack of differences in weights between female and male kudu is due to the fact that no heavy trophy bulls were culled. Dress out percentages for female and male kudu was 59.75 ± 0.99% and 58.86 ± 1.46%, respectively. This compares favourably to the dress out percentage for kudu (56.6%) in a study by Huntley (1971) on 18 kudu in the Northern Transvaal (now Limpopo Province), South Africa. The slightly lower dress out percentage of the bulls could be attributed to the weight of their horns.

The physical characteristics of female and male kudu meat (Table 1) showed no significant differences ($P > 0.05$). The mean drip loss was 4.48 ± 0.53% for female and 3.71 ± 0.15% for male kudu. The drip loss values from this study were higher than those obtained for night-cropped impala (Hoffman, 2000). The drip loss values for female and male impala were found to be similar (2.66 ± 1.097% and 2.45 ± 1.362% respectively; Hoffman, 2000). Cooking loss values for female (23.48 ± 1.449%) and

male (24.48 ± 1.388%) impala (Hoffman, 2000) were also lower than the values for female (38.36 ± 1.21%) and male (41.17 ± 1.21%) kudu from the present study. Shear force values showed no significant differences (P > 0.05) between male (136.63 ± 11.24 kg/1.27cmø) and female (140.01 ± 7.33 kg/1.27cmø) animals.

Table 1. The physical measurements of *Longissimus dorsi et lumborum* muscle in female and male kudu.

Physical measurements	Female (n=10)	Male (n=8)	P > |t|
Drip loss (%)	4.48 ± 0.53	3.71 ± 0.15	0.226
Cooking loss (%)	38.36 ± 1.21	41.17 ± 1.21	0.140
Shear force (kg/1.27cmø)	140.01 ± 7.33	136.63 ± 11.24	0.810

Proximate composition

The proximate composition of the *M. longissimus dorsi* muscle of female and male kudu is represented in Table 2. No significant differences (P > 0.05) were detected between female and male proximate composition. The high protein content in both female (24.29 ± 0.278%) and male (23.58 ± 0.181%) kudu meat is of importance from a health point of view. Although it seems that protein content differs significantly between female and male kudu, this can be due to the cumulative effect of the percentages. The fat content is also very low (female: 1.56 ± 0.093%, male: 1.58 ± 0.056%), which indicates that kudu meat can be considered as a healthy, lean meat. In contrast, intensively reared livestock have ≈15% lipids, while lean domesticated cattle fed on supplemented diets have ≈5% lipids (Crawford, 1975).

Table 2. Proximate composition of *M. longissimus dorsi* in female and male kudu.

Chemical constituents	Female (n=10)	Male (n=8)	Pr > |t|
Moisture (%)	74.14 ± 0.285	74.49 ± 0.162	0.342
Protein (%)	24.29 ± 0.278	23.58 ± 0.181	0.059
Fat (%)	1.56 ± 0.093	1.58 ± 0.056	0.880
Ash (%)	1.29 ± 0.021	1.23 ± 0.032	0.090

Fatty acid composition

The fatty acid content (%) of kudu *M. Longissimus dorsi* is shown in Table 3. Fatty acids not detected were C22:0 (docosanoic acid), C22:4 *n*-6, C24:0 (tetracosanoic acid) and C24:1 *n*-9 (15-tetracosenoic acid). Oleic acid (C18:1), a monounsaturated fatty acid (MUFA) was found to be most abundant in the female (21.94 ± 1.455%) while linoleic acid (C18:2 *n*-6), a polyunsaturated fatty acid (PUFA), made out the biggest proportion of fatty acids in the male kudu (20.53 ± 0.786%). The fatty acids present in the highest proportions are oleic, stearic, linoleic and palmitic acid in that order.

The fatty acid content of *M. longissimus dorsi* in female and male kudu differed significantly only in two of the polyunsaturated fatty acids (C20:5 *n*-3 and C20:3 *n*-6). In both cases male carcasses were characterised by a higher concentration of the polyunsaturated fatty acids (PUFA). Eicosapentaenoic acid (C20:5 *n*-3) and dihomo-γ-linolenic acid (C20:3 *n*-6) are both long chain PUFA's known to play an important role in human health. C20:5*n*-3 is known to be beneficial in protection against cardiovascular diseases because of lipid-lowering effects and reduction of platelet aggregation (Sayanova & Napier, 2004).

Eicosapentaenoic acid (EPA) is also the precursor of docosahexaenoic acid (DHA) and together they are important for normal cognitive and behavioural function. Other polyunsaturated fatty acids present in high quantities are linoleic acid, arachidonic acid and α-linolenic acid.

Table 3. The mean fatty acid content (%) of *M. longissimus dorsi et lumborum* muscle in female and male kudu.

Fatty Acid (%)	Female (n=10)	Male (n=8)	P > |t|
C16:0	17.52 ± 0.688	16.10 ± 0.343	0.106
C18:0	20.00 ± 1.157	19.72 ± 1.086	0.864
C20:0	0.20 ± 0.035	0.11 ± 0.042	0.115
TOTAL SFA (%)	**37.73**	**35.93**	0.433
C16:1 *n*-7	0.69 ± 0.129	0.52 ± 0.054	0.264
C18:1 *n*-9	21.94 ± 1.455	19.91 ± 0.967	0.287
C20:1 *n*-9	0.10 ± 0.030	0.06 ± 0.033	0.331
TOTAL MUFA (%)	**22.74**	**20.48**	0.270
C18:2 *n*-6	19.03 ± 1.313	20.53 ± 0.786	0.370
C18:3 *n*-3	4.67 ± 0.383	4.85 ± 0.395	0.746
C18:3 *n*-6	0.08 ± 0.028	0.05 ± 0.026	0.477
C20:2 *n*-6	0.12 ± 0.032	0.15 ± 0.083	0.723
C20:3 *n*-6	0.92 ± 0.049	1.14 ± 0.050	0.008
C20:4 *n*-6	7.74 ± 0.455	8.44 ± 0.376	0.270
C20:5 *n*-3	2.50 ± 0.256	3.17 ± 0.147	0.049
C22:5 *n*-3	2.42 ± 0.150	2.75 ± 0.139	0.135
C22:6 *n*-3	2.06 ± 0.239	2.50 ± 0.227	0.202
TOTAL PUFA (%)	**39.53**	**43.59**	0.175
PUFA: SFA	1.09	1.23	0.344
n-6: *n*-3	2.42	2.29	0.228

Myristic (C14:0) and palmitic (C16:0) acids are said to be the principal fatty acids that cause an increase in blood cholesterol levels. Stearic acid (C18:0) is considered a desirable fatty acid as it is converted to oleic acid in the human body (Bender, 1992). An individual's receptiveness to cardiovascular diseases might also be lowered with a high ratio of unsaturated fatty acids (UFA) to saturated fatty acids (SFA) in the diet (Lawrie, 1998). In the male kudu's muscle, 64.1% were UFA's and 35.9% were SFA's. The ratio for female kudu was 62.3% unsaturated to 37.7% saturated fatty acids. The British Department of Health recommends a PUFA:SFA ratio of over 0.4. The PUFA:SFA ratio in kudu meat was calculated to be 1.05 for female and 1.21 for male animals. In a study by Enser *et al.* (1996) the PUFA:SFA concentrations for beef, lamb and pork was 0.11, 0.15 and 0.58 respectively. When compared to the domesticated animals in the study by Enser *et al.* (1996), the female and male kudu has a more favourable PUFA:SFA ratio. In the present study PUFA's represent the highest proportion of fatty acids in both female (39.53%) and male (43.59%) kudu *M. Longissimus dorsi*. The high levels of PUFA's can be attributed to the fact that the kudu is a browser, feeding on trees and shrubs. Wiklund *et al*. (2001) studied reindeer fed on different commercial feeds compared to grazing animals. The meat from the grazing reindeer had higher *n*-3 PUFA content.

The recommended maximum *n*-6:*n*-3 ratio according to the British Department of Health is 4. In the kudu muscle analysed, the *n*-6:*n*-3 ratio was found to be 2.42 for females and 2.29 for males. The mean for female and male kudu is 2.34 which is well below the maximum of 4. However, the *n*-6:*n*-3 ratio between female and male kudu did not differ significantly ($P > 0.05$). Due to the desirable *n*-6:*n*-3 and PUFA:SFA ratios, kudu meat can be seen as a favourable meat for human consumption. Also, the mean desirable fatty acid (stearic acid plus all unsaturated fatty acids) content of kudu meat is very high at 83%. Wood *et al*. (2003) found that the feeding of grass or roughage had the effect of producing higher concentrations of *n*-3 PUFA's, whereas feeding of concentrates led to higher *n*-6 PUFA production. Wiklund *et al.* (2001) showed that the fatty acid composition of reindeer grazing on natural pastures had higher *n*-3 PUFA content than reindeer fed on pellets. The kudu, being a browser and therefore consuming mostly roughage will have a high *n*-3 PUFA concentration in its muscles as was found in this study.

Amino acid composition

The amino acid composition of the *M. longissimus dorsi* of the kudu is represented in Table 4. All essential amino acids were present in higher concentrations in female muscle than in male muscle. However, only two of the essential amino acids showed significant differences ($P \leq 0.05$) between the female and the male. Histidine, the precursor of histamine, was found to be present at a concentration of 0.93 ± 0.016 g/100 g muscle in female compared to the concentration of 0.86 ± 0.012 g/100 g muscle in the male. Valine was found to be present at 1.43 ± 0.019 g/100 g muscle in female compared to 1.37 ± 0.015 g/100 g muscle in male kudu *M. longissimus dorsi*.

Leucine (female: 1.95 ± 0.023 g/100 g, male: 1.91 ± 0.014 g/100 g muscle) and lysine (female: 1.57 ± 0.040 g/100 g, male: 1.57 ± 0.037 g/100 g muscle) are the essential amino acids with the highest concentrations. In a study of the *M. Longissimus dorsi* of impala, leucine and lysine were also found to be the essential amino acids with the highest concentrations (Hoffman *et al.*, 2005).

Table 4. Amino acid composition (g/100g muscle) of *M. longissimus dorsi et lumborum* muscle in female and male kudu.

Amino acid	Female (n=10)	Male (n=8)	Pr > |t|
Essential			
Arginine	1.18 ± 0.012	1.16 ± 0.009	0.189
Histidine	0.93 ± 0.016	0.86 ± 0.012	0.003
Isoleucine	1.17 ± 0.016	1.13 ± 0.010	0.052
Leucine	1.95 ± 0.023	1.91 ± 0.014	0.119
Lysine	1.57 ± 0.040	1.57 ± 0.037	0.917
Methionine	0.61 ± 0.007	0.60 ± 0.004	0.290
Phenylalanine	0.75 ± 0.013	0.73 ± 0.007	0.214
Threonine	1.30 ± 0.020	1.27 ± 0.014	0.161
Valine	1.43 ± 0.019	1.37 ± 0.015	0.030
Non-essential			
Alanine	2.06 ± 0.025	1.98 ± 0.023	0.040
Aspartic acid	2.23 ± 0.031	2.15 ± 0.024	0.068
Cystine	0.13 ± 0.002	0.13 ± 0.002	0.277
Glutamine	3.14 ± 0.033	3.08 ± 0.030	0.219
Glysine	1.72 ± 0.028	1.65 ± 0.022	0.077
Proline	1.12 ± 0.012	1.10 ± 0.011	0.173
Serine	1.16 ± 0.016	1.13 ± 0.008	0.091
Tyrosine	0.62 ± 0.007	0.60 ± 0.006	0.105

Mineral content

The mineral content of kudu meat compared to that of antelope (*Antilocapra americana* and *Bosephalus tragocamelus*), deer (*Odocoileus* spp) and elk (*Cervus elaphyus*) are shown in Table 5. Potassium and sodium levels in both male and female kudu are considerably lower than the levels found in antelope, deer and elk (USDA, 1989). Variations in the mineral composition of meat can be caused by various factors, such as the concentration of minerals in the diet, hormones, age, gender, species and region (Doyle, 1980). Gender made no significant difference ($P < 0.05$) in the mineral

composition of kudu *M. longissimus dorsi*. This is consistent with the findings of Hoffman *et al*. (2005) with impala meat and Kroucamp (2004) with springbok meat where no significant differences between genders were noted.

Table 5. The mineral content (mg/100g muscle) in female and male kudu, antelope, deer and elk.

Mineral (mg/100g)	Kudu		Antelope[a]	Deer[a]	Elk[a]
	Female (n=10)	Male (n=8)			
Phosphorus	172.88 ± 2.706	171.74 ± 5.818	188.0	202.0	161.0
Potassium	118.45 ± 1.577	119.93 ± 2.444	353.0	318.0	312.0
Magnesium	24.29 ± 0.377	23.94 ± 0.673	27.0	23.0	23.0
Sodium	7.41 ± 0.120	7.59 ± 0.302	51.0	51.0	58.0
Calcium	4.62 ± 0.423	6.01 ± 2.285	3.0	5.0	4.0
Iron	2.79 ± 0.173	2.85 ± 0.230	3.19	3.4	2.76
Copper	0.01 ± 0.002	0.02 ± 0.004	0.18	0.25	0.12
Zinc	1.19 ± 0.090	1.37 ± 0.111	1.28	2.09	2.40
Manganese	0.04 ± 0.001	0.05 ± 0.007	0.02	0.04	0.012

[a] *USDA Agricultural Handbook (1989): 8-17*

In kudu *M. longissimus dorsi* phosphorus was present in the highest concentration (female: 172.88 ± 2.706 mg/100 g, male: 171.74 ± 5.818 mg/100 g muscle), followed by potassium and sodium (Table 5). In springbok *M. Longissimus dorsi* phosphorus was also found to be the most abundant mineral followed by potassium and calcium (Kroucamp, 2004). In a study on ostrich meat, potassium was quantitatively the most important mineral followed by phosphorus (Sales & Hayes, 1996).

CONCLUSIONS

The results from this study show that kudu meat can be regarded as a lean, healthy meat due to the low lipid content (≈1.5 g/100g meat) and high protein content (≈24 g/100g meat). However, no significant differences between sexes were found in the physical characteristics and proximate composition. Only two of the longer chained polyunsaturated fatty acids (C20:3*n*-6 and C20:5*n*-3) differed significantly between the females and males, with males having the higher concentrations. Kudu meat contains a high concentration of PUFA's. The mean desirable fatty acid (stearic acid plus all unsaturated fatty acids) content of 83% is very high. The ratio of *n*-6 to *n*-3 PUFA's is balanced and well below the British Department of Health's recommended figure of 4, which further promotes the health benefits of kudu meat. All essential amino acids were found to be present in kudu meat. However, only histidine and valine content differed significantly between sexes. The most abundant mineral in kudu meat was phosphorous followed by potassium.

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