MEAT QUALITY CHARACTERISTICS OF BLESBOK (*Damaliscus dorcas phillipsi)* AND RED HARTEBEEST (*Alcelaphus buselaphus caama)* MEAT

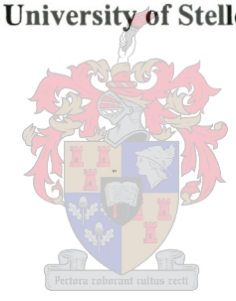
by

KAREN SMIT

Thesis in partial fulfillment for the degree of

MASTER OF CONSUMER SCIENCE

at the University of Stellenbosch



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.

Summary

The purpose of this study was to qualify some of the factors that could influence the meat quality of blesbok *(Damaliscus dorcas phillipsi)* and red hartebeest *(Alcelaphus buselaphus caama)*. The independent variables were the male and female adult, sub-adult and lamb blesbok and male and female adult, sub-adult and calf red hartebeest from different regions in the Free State Province. The dependant variables were the morphological, chemical and physical properties, as well as sensory attributes of the meat. A total of 73 blesbok and 49 red hartebeest were randomly cropped during day and night time harvesting operations.

Regarding the morphological characteristics a mean body weight of 67.38 kg and 126.36 kg was recorded respectively for blesbok and red hartebeest males, compared to the mean body weight of the females, respectively 60.19 kg and 99.31 kg. Within region, blesbok from Qua-Qua (QQ) and red hartebeest from Tussen die Riviere (TDR) had the highest dressout percentages (53.72% and 56.30% respectively).

With regard to the chemical composition, blesbok and red hartebeest meat had a respective fat content of 1.42 g/100 g and 4.49 g/100 g. The blesbok and red hartebeest males had the highest protein (22.39 g/100 g and 23.34 g/100 g meat sample) and total collagen content (1.67% and 0.98%). Red hartebeest meat is an excellent source of iron with values of 11.51 and 7.78 mg/100 g for the males and the adults. For stearic acid (C18:0), there was a significant ($p \leq 0.05$) interaction for blesbok with the females from Rustfontein (RF) having the highest stearic acid value (2.56 mg/100g) and the females from Maria Moroka (MM) the lowest value (1.33 mg/100g). The adult red hartebeest had the highest (1.25 mg/100 g) oleic acid value and the sub-adult animals the lowest value (0.74 mg/100 g). Red hartebeest from TDR had the highest ratio of polyunsaturated:saturated fatty acids (P:S ratio) of 0.87 and MM the lowest ratio of 0.63. There was a significant ($p \leq 0.05$) interaction on the P:S ratio for blesbok with the adult animals from GR having the highest (1.07) and sub-adults from RF the lowest (0.65) ratio. The n-6:n-3 ratio for blesbok ranges between 2.34 for the sub-adult animals and 4.90 for animals from MM. This ratio varies from 3.07 for red hartebeest from MM to 2.36 for red hartebeest from TDR. The female blesbok (54.32 mg/100 g meat sample) and the sub-adult red hartebeest (55.95 mg/100 g meat sample) had the highest cholesterol content.

The physical characteristics indicated that blesbok from QQ had the darkest meat ($L^*=27.94$). The meat of the female red hartebeest from QQ was slightly lighter in colour and not so intensely red ($L^*=37.17$; $b^*=11.9$) than that of the other animals. Although not significant, there was a tendency for the flavour of adult red hartebeest to be stronger than that of the sub-adults. Male sub-adult blesbok had the highest scores for initial and sustained juiciness as well as first bite. The sub-adult red hartebeest from TDR had the highest sustained juiciness and first bite scores. It can thus be concluded that the sex, age and region did not have a significant influence on the overall quality of the meat of the blesbok and the red hartebeest.

Opsomming

Die doel van die studie was om van die faktore wat die vleiskwaliteit van die blesbok *(Damaliscus dorcas phillipsi)* en rooihartebees *(Alcelaphus buselaphus caama)* te bestudeer. Die afhanklike faktore was die manlike en vroulike volwasse, jong en lam blesbokke en die manlike en vroulike volwasse, jong en kalf rooi hartebeeste van verskillende streke in die Vrystaat. Die onafhankilike veranderlikes was die chemiese, fisiese en sensoriese eienskappe van die vleis. 'n Totaal van 73 blesbokke en 49 rooi hartebeeste was willekeurig geoes tydens dag- en nagoes operasies.

Betreffende die morfologiese eienskappe was 'n gemiddelde liggaamsmassa van 67.38 kg en 126.36 kg gemeet vir manlike blesbokke en rooi hartebeeste en onderskeidelik 60.19 kg en 99.31 kg vir die vroulike bokke. In area, het blesbokke van QQ (53.72%) en rooi hartebeeste van Tussen die Riviere (TDR) (56.30%) die grootste opbrengs gelewer.

Die chemiese ontleding het getoon dat die hoogste vetinhoud van die blesbok en rooi hartebees onderkeidelik 1.42g/ 100 g en 4.49 g/100 g was. Die blesbokramme en rooi hartebees bulle het die hoogste proteininhoud (22.39 g/100 g en 23.34 g/100 g onderskeidelik) en totale kollageeninhoud (1.67% en 0.98%) gehad. Rooi hartebees vleis is 'n uitstekende bron van yster met waardes van 11.51 mg/100 g en 7.78 mg/100 g vir die manlike en die volwasse diere. Daar was 'n betekenisvolle interaksie ($p \leq 0.05$) vir steariensuur, waar die blesbok ooie van Rustfontein (RF) met 2.56 mg/100g die hoogste waarde en die ooie van Maria Moroka (MM) die laagste waarde van 1.33 mg/100 g gehad het. Die jong blesbokke het ook 'n betekenisvolle hoër waarde vir steariensuur (2.19 mg/100 g) gehad, maar die laasgenoemde resultaat kan bevooroordeeld wees aangesien die sub-monster uit slegs vier jong diere bestaan het. Die volwasse rooi hartebeeste het die hoogste (1.25 mg/100 g) oleïenesuur waarde gehad en die jong diere die laagste (0.74 mg/100 g). Wat betref die ratio van poli-onversadigde:versadigde vetsure (P:V) ratio het rooi hartebeeste van TDR die hoogste waarde (0.87) en MM die laagste waarde (0.63) gehad. Daar was 'n betekenisvolle P:V ratio interaksie ($p \leq 0.05$) tussen die blesbokke met die volwasse diere wat die hoogste (1.07) en die jong diere van RF wat die laagste (0.65) ratio gehad het. Die n-6:n-3 verhouding vir blesbokke wissel tussen 2.34 vir die jong diere en 4.90 vir die diere van MM. Die waarde wisssel van 3.07 vir die rooi hartebeeste van MM tot 2.36 vir die rooi hartebeeste van TDR. Die blesbok ooie (54.32 mg/100 g vleismonster) en die jong rooi hartebeeste (55.95 mg/100 g vleismonster) het die hoogste cholesterol waarde.

Die fisiese eienskappe wys dat blesbokke van QQ die donkerste vleis ($L^*=27.94$) gehad het. Die rooi hartebees koeie van QQ se vleis was effens ligter van kleur en nie so dieprooi ($L^*=37.17$; $b^*=11.9$) soos die ander rooi hartebeeste s'n nie. Alhoewel nie betekenisvol nie, was daar 'n tendens vir die geur van volwasse rooi hartebeeste om sterker te wees as dié van die jong diere. Volgens die proepaneel het die jong blesbokramme die hoogste sappigheid, sowel as taaiheid gehad. Die jong rooi hartebeeste van TDR het die hoogste sappigheid en taaiheid gehad. Daar kan dus opsommend gesê word dat geslag, ouderdom en streke nie 'n betekenisvolle invloed op die algemene kwaliteit van blesbok en rooi hartebees vleis gehad het nie.

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CONTENTS

LIST OF ABBREVIATIONS

QQ	Qua-Qua
TDR	Tussen die Riviere
RF	Rustfontein
MM	Maria Moroka
GR	Gariep
MLD	*M. longissimus dorsi*
Anon.	Anonymous
WHC	Water-holding capacity
ATP	Adenosine triphosphate
ADP	Adenosine diphosphate
pH_u	Ultimate pH
DFD	Dark, Firm and Dry
RDA	Recommended Dietary Allowance
AI	Adequate Intake
EAR	Estimated Average Requirement
EAA	Essential Amino Acids
P:S	Polyunsaturated:Saturated
P:V	Poli-onversadig:Versadig
PUFA	Polyunsaturated Fatty Acids
MUFA	Monounsaturated Fatty Acids
SFA	Saturated Fatty Acids
TUFA	Total Unsaturated Fatty Acids
DFA	Desirable Fatty Acids
$Temp_{45}$	Temperature measured at 45 min post-mortem
$Temp_{24}$	Temperature measured 24 h post-mortem

NOTES

The language and style used in this thesis are in accordance with the requirements of the scientific journal, *Meat Science*. This dissertation represents a compilation of manuscripts where each chapter is an individual entity and some repetition between the chapters has, therefore, been unavoidable.

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

1. Smit, K., Hoffman, L. C., & Muller, M. (2003). Health attributes of blesbok *(Damaliscus dorcas phillipsi)* meat. Annual Congress of the South African Wildlife Management Association, September 2003. Ganzekraal, Melbosstrand.

2. Smit, K., Hoffman, L. C., & Muller, M. (2003). Morphological characteristics of blesbok *(Damaliscus dorcas phillipsi)* meat. Annual Congress of the South African Wildlife Management Association, September 2003. Ganzekraal, Melkbosstrand.

3. Smit, K., Hoffman, L. C., & Muller, M. (2003). Morphological characteristics of red hartebeest *(Alcelaphus buselaphus caama)* meat. Annual Congress of the South African Wildlife Management Association, September 2003. Ganzekraal, Melkbosstrand.

Chapter 1

Introduction

Due to various reasons the South African meat market and export industry are experiencing an increase in the demand for game meat. The diverse tastes of game meat (Pauw, 1993), the decrease in the per capita supply of high quality meat (Onyango, Izumimoto & Kutima, 1998) and its lower fat content (Schönfeldt, 1993) all contribute to this increasing demand. Despite the higher demand, there is a tendency for the game meat to be sold under the generic name of "venison", and not by the name of the specific species of game that the meat is derived from. It is assumed that one of the reasons for generic marketing might lie in the unavailability of nutritional information on the meat of most game species.

The prevalent animal fat in red meat is associated with health risks, and therefore contributes to the negative health image associated with it. As a result the per capita consumption of red meat, both in South Africa and overseas, is declining when compared to the consumption of white meat and other non-meat proteins (Schönfeldt, 1993). Game meat, however, has a lower fat content (2 to 3 g per 100 g meat) than domestic meat species, and therefore provides a healthy alternative for health-conscious consumers, who are aware of the nutritional content of food (Schönfeldt, 1993).

In South Africa game meat is considered to be an organic product, due to the fact that no fertilizers or growth hormones are used in the production system (Pauw, 1993). In the marketing of game meat this is an important attribute to focus on.

The tourist industry in South Africa is growing fast. More and more overseas visitors are willing to pay to see game in its natural habitat. A strict management program is required for game parks to maintain the illusion of wild animals in an un-spoilt habitat. As in North America where sport hunting of game is a popular recreational activity (Novakowski & Solman, 1975), hunting is also fast becoming a popular activity in South Africa. Only a very small proportion of the potential supply of game meat is, however, obtained from trophy hunting (Pietersen, 1993).

The regular cropping of surplus animals could increase the availability of game meat on a more organized and larger scale (Hoffman & Bigalke, 1999). However, inefficient cropping methods result in significant losses. Information on factors such as ante-mortem stress, bullet damage and the effect thereof on meat quality are very limited (Von La Chevallerie & Van Zyl, 1971).

The main aim of this study was to characterize game meat with the potential of being harvested regularly on a sustainable basis. For the purpose of this study the blesbok and red hartebeest were chosen. This study was done in collaboration with the Departments of Consumer Science and Animal Sciences of the University of Stellenbosch.

As a primary objective it was necessary to qualify some of the factors that could influence the meat quality of the *M. longissimus dorsi* of blesbok (*Damaliscus dorcas phillipsi)* and red hartebeest (*Alcelaphus buselaphus caama)*. The independent variables were the samples of male and female adult, sub-adult and lamb/calf blesbok and red rartebeest.

The samples were obtained from different areas in the Free State Province. The dependant variables were the chemical and physical properties, as well as the sensory properties of the meat.

The study consisted of two experiments. Male and female adult blesbok samples for Experiment 1 (Figure 1) were collected in the region if Qua-Qua in 2001. In 2002 male and female, adult, sub-adult and lamb blesbok samples (Figure 1) were collected in the regions of Maria Moroka, Gariep and Rustfontein. The male and female, adult and sub-adult red hartebeest samples for Experiment 2 (Figure 2) were collected in nature reserves in the regions of the Sandveld and Qua-Qua in 2001. In 2002 the male and female, adult, sub-adult and calf red hartebeest samples (Figure 2) were collected at nature reserves in the regions of Tussen die Riviere, Sandveld and Maria Moroka.

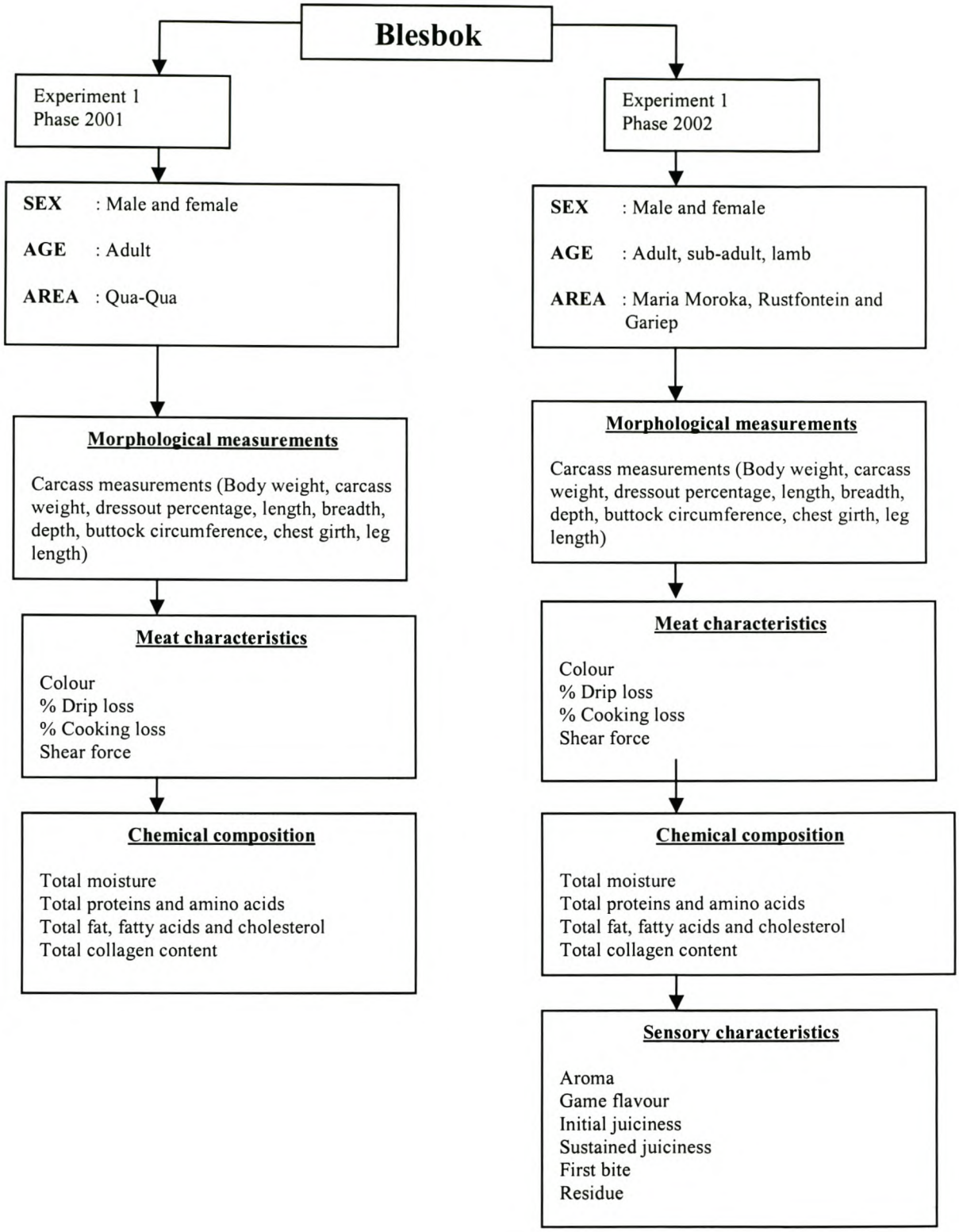

Fig. 1. Measurements executed on the *M. longissimus dorsi* of the blesbok

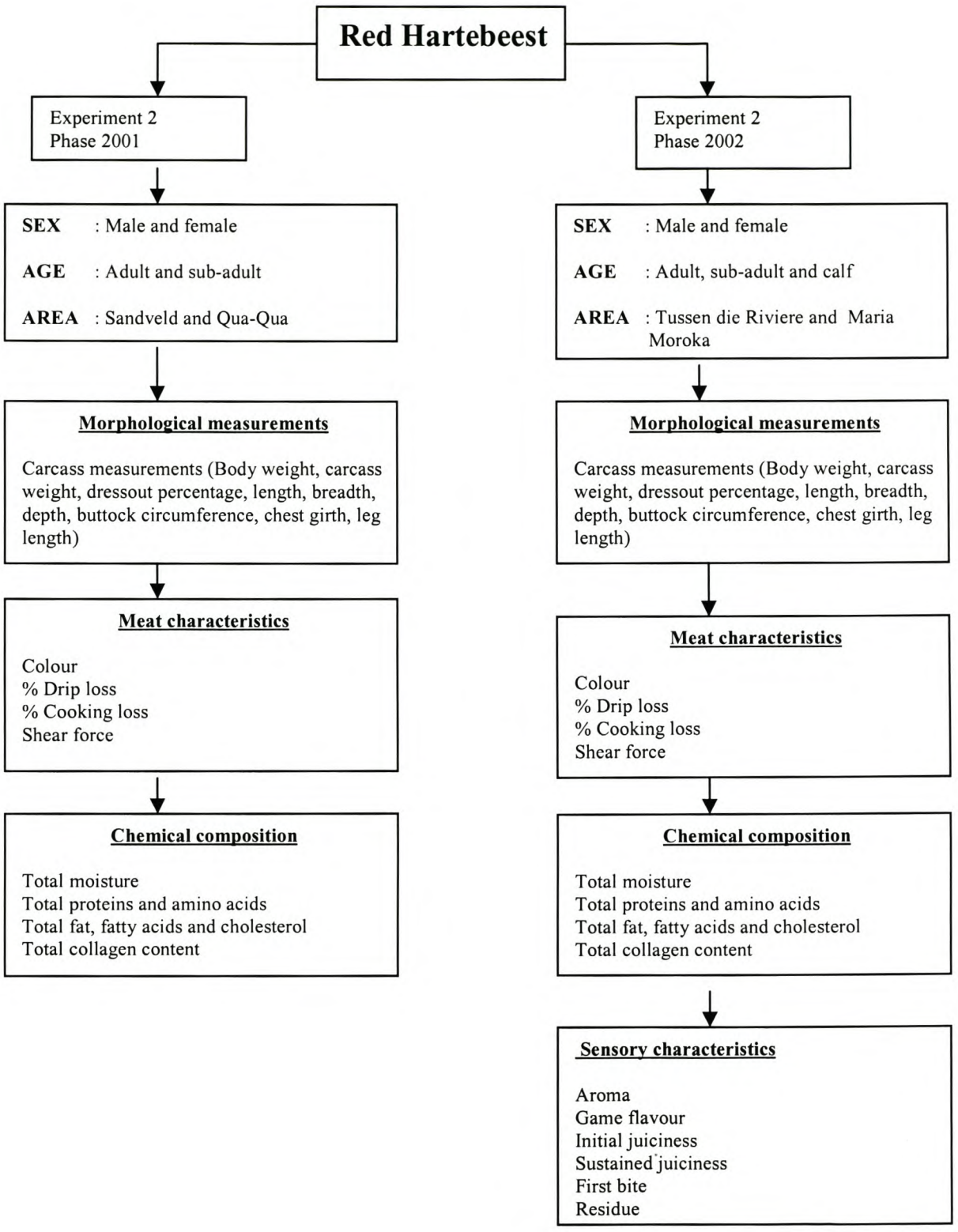

Fig. 2. Measurements executed on the *M. longissimus dorsi* of the red hartebeest

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Chapter 2

Literature Review

In 1972 Von La Chevallerie found the total fat content of blesbok and red hartebeest muscle to be 1.7% and 2% respectively. Compared to this mutton has a fat content of 20 to 25% (Schönfeldt, 1993). The low fat content of game meat contributes to making it a suitable form of protein in a healthy diet. As no growth stimulators or fertilisers are used in the production system (Pauw, 1993), South African game meat are marketed as organic produce.

The continued growth in the human population necessitates the gaining of knowledge on the meat production potential from wild ungulates. From a meat production point of view it is essential to obtain knowledge on the edible tissue available for human consumption (Von La Chevallerie, 1970).

Only by regularly cropping surplus animals can game parks maintain the illusion of wild animals in an un-spoilt habitat. It is predicted that the demand for hunting opportunities and stocking animals will decrease in the years to come. The surplus game meat could be marketed on a bigger scale, specifically on the export market (Hoffman & Bigalke, 1999). The blesbok and red hartebeest species should be considered for sustainable harvest and export, because they are found in large enough quantities to be cropped regularly.

This study was conducted on two species, namely blesbok (*Damaliscus dorcas phillipsi)* and red hartebeest (*Alcelaphus buselaphus)*. Blesbok and red hartebeest are found in open grasslands throughout South Africa. According to Veary (1991), the majority of game meat produced in 1987 was from blesbok (13.3%) and springbok (69.9%). These percentages give justification to the assumption that blesbok is an important species for meat production. In 1994 the estimated numbers of blesbok and red hartebeest in the Limpopo Province (formerly known as Northern Province), were 11 000 and 15 000 respectively (Van der Waal & Dekker, 2000). These numbers indicate a large enough population of these species to justify cropping.

Blesbok ewes start breeding at the age of three years, and produce a single calf early in the summer after a gestation period of eight months (Anon, 1993). It is logical that rams rather than mature ewes should be croped, as the cropping of ewes will drastically affect the reproduction rate (Du Plessis, 1972). The natural decrease in the blesbok numbers due to predators should also be taken into account.

The gestation period of the red hartebeest is also eight months. Heifers become sexually mature in their second year (Kok, 1975). In the absence of predators, the main cause of early death in the red hartebeest is due to inter-species aggression.

As a first aim the literature study gives a detailed review of each species, whereafter the factors that influence the quality of game meat will be discussed. Table 1 summarises the factors and the properties.

Table 1

Factors that may affect the quality of meat

Pre-slaughter factors	Age Sex Season Shooting procedures
Physical characteristics	Colour Water- holding capacity Rigor mortis pH/ temperature Shear force
Chemical composition	Total moisture Protein and amino acids Fat and fatty acids Cholesterol Mineral content Total collagen content
Sensory characteristics	Aroma Initial juiciness Sustained juiciness Tenderness Residue Game flavour

1. REVIEW OF SPECIES

This review includes a general discussion of the characteristics of the blesbok and red hartebeest. Relevant aspects pertaining to the cropping of the specific species will also be discussed briefly.

1.1 Blesbok (*Damaliscus dorcas phillipsi)*

Although not found in great numbers, blesbok is in no danger of becoming extinct (Osterhoff, Ward-Cox & Emslie, 1972). This species is inhabitants of the open grassland (Rowe-Rowe, 1983) and are distributed in the areas of Gauteng, Free State and north-eastern Karoo (Skead, 1958). It has also been introduced to other areas in South Africa, such as southern Cape Province, Kwa-Zulu Natal and the northern savannah regions of the Limpopo, where it is not naturally found (Kettlitz, 1967). Being particularly hardy blesbok is popular on farms in the highveld. They can be fenced in by ordinary stock fences and as the animals can easily be observed in open grasslands, this habitat is beneficial for the practice of cropping (Du Plessis, 1972).

Blesbok are morphologicaly similar to bontebok and are frequently mistaken for the latter. Although both species are white, brown and purple-brown in colour, the blesbok's colours are not as striking as that of the bontebok. Blesbok are also a smaller antelope than the bontebok and have a broken bald spot in the middle of the forehead (Steele, 1974).

When cropping game, it is important to be able to judge the age of the animal, so that sorting of animals in different age categories can be done effectively. The weight difference between the sexes is only significant when animals are cropped as adults (Von La Chevallerie, 1970). The sex ratios of other game species, including adult impala, do not differ between areas (Gallivan, Culverwell & Girdwood, 1995). Only an experienced observer can determine the sex of a herd from a distance, because animals from both sexes have horns, and have other similar characteristics (Du Plessis, 1972). The horn, tooth and cranial development can be used to determine the age of blesbok, and the shape, length and base circumference of the horns are useful parameters in animals younger than 18 months (Watson, Skinner, Erasmus & Dott, 1991). The base circumference of the horn is about one inch more in the ram than in the ewe (Kettlitz, 1967). The ridges on the horns of the ram are more prominent and the tuft on his tail longer with more white hair than that of the female (Du Plessis, 1972). The teeth of the animals can also be used as a gauge during cropping, but as it is not possible to see the teeth of the animal at night, croppers must rely on the horn size when determining the age of an animal.

According to Kettlitz (1967) blesbok ewes are sexually mature at 18 months of age, and males normally mature later, although males as young as 18 months are known to mate. Du Plessis (1976) stated that blesbok ewes are successfully mature at 28 months, although there is evidence of somes ewes maturing as early as 16 months.

At the onset of the mating season the rams start chasing each other. This leads to an increase in the number of solitary males. Chasing subsides during daytime while herds are resting and apparently reaches a peak in late afternoon as they disperse to graze (Du Plessis, 1976). As grazing takes place in the early evening, it would provide the ideal time of day for cropping of these animals.

The most successful time of year for the cropping of these animals should occur at the beginning of the dry season – normally from March to the end of April. Mating occurs at the end of the rainy season, when the animals are in peak condition. Most mature ewes are pregnant in early November and lambing starts in the middle of November when the grass is well sprouted (Du Plessis, 1976). Ewes give birth in the herd, usually in the forenoon. To strengthen the legs a newborn lamb sprints across the veld shortly after birth. The bleats of lambs may rise to a chorus in search of their mothers after a disturbance has caused them to run for some distance (Du Plessis, 1976). These bleats can contribute in leading the croppers to the animals. Walther (1966) established that the bond between the lamb and his mother is maintained by smell and by recognition of each other's voices. The interdigital glands on the forefeet could be important in this connection (Walther, 1966). These glands occur in both sexes and secrete a yellow substance, which adheres to the long hair sticking out between the hoofs (Du Plessis, 1976).

The alarmed snort of the free-ranging blesbok appears to be made by forcing air through the nose. Apart from the vocal communication between lamb and ewe, this is the only other sound audible (Du Plessis, 1976). These bleats may lead the croppers to the specific area where the animals find themselves. Blesbok are not very vocal, although bleats are often heard, particularly in solitary males, whom appear more alert than the rest of the population (Du Plessis, 1976). The individual blesbok that utters a snort at short intervals, will stare in the direction of the disturbance with pricked ears and alerts all the other blesbok in the vicinity (Du Plessis, 1976). The function of the marking of objects with the secretion of the preorbital gland in blesbok is not known, but could be indicate a means of communication.

The daily routine of blesbok is most visible during the winter months, and thus provides an ideal time for cropping, as it is a time when minimal activity occurs, mainly because of the fact that the food intake is low. According to Du Plessis (1976) the whole herd seldomly lies down at the same time, however, there are always individual animals that rise to scratch or lick their bodies or to change position. Blesbok sleep on their feet or lie down during daytime. On a hot day they stand or lie in the shade of trees. A blesbok may lower its head, or it may bend its neck so that the horns point forward when sleeping on its feet. On a particularly hot day the animal will fall into a very deep sleep (Du Plessis, 1976). As not all animals sleep at the same time, the herd is always alert. At night, blesbok lie down to sleep or rest (Du Plessis, 1976). The fact that they lie down will make night cropping more difficult. In hot weather a blesbok will always nod its head several times upon awakening (Du Plessis, 1976). It was stated by Walther (1966) that blesbok and related species nod their heads when beginning to walk and this will be an indication to the croppers that the animal is about to move.

Blesbok are exclusively grazers, feeding only on grass. There seems to be no evidence of any preference for certain plant communities, but the blesbok graze less eagerly on unburnt areas (Du Plessis, 1976). Close grazing is possible because food is gathered with the lips (Du Plessis, 1976). Blesbok are attracted to a fresh burn in early summer and they will graze on it a day after the fire, before any grass sprouts are visible (Du Plessis, 1976). After the first heavy frost, which is usually in May, blesbok enter a period of minimal activity, which lasts until the spring when the grass starts to sprout.

In most species the mature males are heavier than the mature female (Von La Chevallerie, 1970). The mean live weight for blesbok males is 62.7 to 95.3 kg, and for females is 59.5 to 86.3 kg. The carcass weight for blesbok males is 38.6 kg and 35.0 kg for females (Von La Chevallerie & Van Zyl, 1971). The annual weight fluctuation of the population is evident from a decline in weight between the months of March and September, followed by a rapid gain in weight from September to the following March (Du Plessis, 1976). The dressing percentage of ungulate species is between 55 and 61%. No difference in dressing percentage seems evident between male and female animals. The dressing percentage of mature springbok and impala rams is approximately 58% (Van Zyl, Von La Chevallerie & Skinner, 1969). This percentage correlates with that of cattle (55-60%). The dressing percentage of sheep (50 to 55%) is thus lower than that of ungulates (Pauw, 1993).

1.2 Red hartebeest (*Alcephalus buselaphus)*

Originally red hartebeest were widely distributed, but are now only found in the regions of the northwestern Cape, Botswana, Namibia and in the Hwange Game Reserve in Zimbabwe (Zaburnis & Cross, 1974). This species has been introduced to Kwa-Zulu Natal nature reserves and some national parks. They are encountered in ecotones, which are transition areas between adjoining communities (Kok, 1975). Open grassland and arid scrub are the natural habitat of the red hartebeest (Anon, 1993). Red hartebeest occupy ridges and kopje summits and are known to maintain their territories for long periods (Kok, 1975).

The red hartebeest is high-shouldered with a narrow head. An adult bull stands about 1.25 m at the shoulder (Anon, 1993). The mean live weight of the male is 137.1 kg and that of the female 126.2 kg (Von La Chevallerie & Van Zyl, 1971). The average carcass weight of the hartebeest bull is 81.5 kg and 73.2 kg for the female (Ledger, Sachs & Smith, 1967). It appears that wild ungulates have a higher dressing percentage than cattle (Von La Chevallerie, 1970). When cropping for aesthetical or conservation reasons, mature weight is an important consideration.

The predominant colour of the animal is cinnamon, with the forehead covered with black hairs (Roberts, 1951), but calves have a paler colour (Maberly, 1959). The calves' colour can be used to identify them during cropping. Horns rise from a pedicle at the top of the head, projecting backwards and then upwards (Maberly, 1959). The tail is black and the rump is off-white (Anon, 1993). The anterior part of the foreleg to the hoof is covered with black hair (Roberts, 1951). The upper and hind parts of the haunches, inside, the anterior and upper edge of them, as well as the belly are pale yellow in colour (Roberts. 1951). The eyes have a reddish yellow iris (Maberly, 1959). Ground horning is mostly conducted by territorial bulls (Kok, 1975). This is a leisurely movement, which also has a territorial function. It is carried out by both sexes at a low intensity and often occurs when insects are present (Kok, 1975).

Three social groups, namely the harem herds, bachelor herds, and lone bulls can be distinguished. A harem herd consists of calves, cows, a single sub-adult bull and a full-grown bull. It is always the mature bull that takes the lead in a harem herd (Kok, 1975). Bachelor herds consist only of bulls, but from all age groups and lone bulls are usually young and have mostly been driven off by the herd (Kok, 1975).

Determining the sex of these animals is difficult, because both cows and bulls have horns. The horns are, however, more massive in the bulls (Maberley, 1959). The horn thickness is a more reliable method of sex determination because sex organs are not always visible in the field (Kok, 1975). Characteristic behaviour is an excellent determination of sex, but the perceptibility is not always as good as morphological features (Kok, 1975).

Although the rutting season is from January to March, with a peak period in February, mating also takes place outside this period (Kok, 1975). The mating season is preceded by an increase in irritation and aggression, particularly in the harem bulls (Kok, 1975). Cropping should be done after the mating season to ensure the optimal reproduction of the species. The intensity and frequency of mortality is at a peak when there is a sexual ratio of 1:1, because of domination fights (Van der Walt, De Graaff & Van Zyl, 1976). An animal may stop in the middle of a fight to scratch its head or neck or to paw the ground (Kok, 1975).

Calving is at a peak in summer (Zaburnis *et al.*, 1974), but new calves have been observed during almost every month of the year, because red hartebeest are territorial throughout the year (Kok, 1975). Red hartebeest cows produce a single calf, with a gestation period of eight months (Anon, 1993). After birth the mother will eat the placenta and lick the calf clean to ensure that predators don't smell the calf. She will also eat the calf's droppings and urine for a short period after birth (Kok, 1975), while the calf remains hidden in the tall grass. The mother visits the calf regularly and allows it to suckle until it is strong enough to follow her to the herd (Anon, 1993).

The calf's interdigital and pre-orbital glands do not secrete actively at first, but he can recognise his mother at a distance of 300 m (Kok, 1975). The calf flees directly behind his mother when they take flight, with the calf of the previous year further back. An effective way of escaping the attention of predators is that the calf can fall flat at full speed and lie still while his mother and older calf keep on moving (Kok, 1975). To eliminate or decrease the risk of shooting calves, cropping should take place to spring.

Cows must be able to produce enough milk from dry grazing because most births coincide with the start of the rainy season and therefore a change in vegetation. Calves start to graze seriously at about seven months, when they are weaned (Kok, 1975). Red hartebeest are grazers of the open field and drink water if it is available and can go without

water if necessary (Zaburnis *et al.*, 1974), because moisture is obtained from their food (Anon, 1993). They will travel great distances in arid areas in search of fresh grass (Anon, 1993).

Most activities of the red hartebeest take place in the early morning and late afternoon, with the animals resting during the heat of the day (Anon, 1993). The temperature gradient influences the animals' grazing activity (Ben-Shahar & Fairall, 1987). On cool days they remain active for longer than on hot days (Kok, 1975). Active and inactive periods are evenly distributed in places of shade and sun (Ben-Shahar *et al.*, 1987). During the day time bulls do not really sleep, whereas calves do. There are never more than four animals lying simultaneously in a sleeping position (Kok, 1975). This makes it easier for croppers to spot them in the field. Red hartebeest normally lie in a head-erect posture, although dozing individuals may let the lower jaw rest on the ground (Kok, 1975). Sleeping individuals prop their lower jaws on one of their hind legs (Kok, 1975).

By nature the red hartebeest is a silent animal and not aggressive (Roberts, 1951). They occasionally utter a snort when alarmed or inquisitive (Maberly, 1959). With every snort the animal's whole body jerks and the tail is whipped up (Kok, 1975).

The harem bull spends time in the immediate area of the dung patches in his territory, and often lies down on them (Kok, 1975). This ensures that his skin and hair has his own characteristic odour and that he can spread this odour further. Even humans can detect this odour, which strongly reminds one of a sheep kraal (Kok, 1975). The dung patches serve as visual landmarks and have a function in the maintenance of a territory. Hartebeest bulls will rather defecate on bare patches, than on parts with dense plant growth (Kok, 1975). Croppers will therefore be able to spot their dung easily.

2. Ante-mortem factors

Ante-mortem treatment of animals is known to be important as pertaining to its influence on meat quality and other related factors. The following factors will be discussed in this section of the Literature Review, i. e. age, sex, season and shooting procedures.

2.1 Age

When the economical aspects of meat production are concerned, attention should be given to the growth rate and the efficiency of feed conversion. The age of animals and optimum cropping weight are both influenced by the high costs of marketing, dressing and shooting (Von La Chevallerie, 1970). According to Hoffman and Bigalke (1999) the ideal age for efficient cropping of springbok, where meat quality should be at its best, is between six months and one year for both the male and female. Thus optimum age differs between the different game species. No optimum age for the cropping of blesbok and red hartebeest has yet been established.

2.2 Sex

From a production point of view, the weight differences between sexes are only significant when animals are cropped as adults. An improvement in the productivity of species could be created by manipulation of sex and age ratios (Hoffman & Bigalke, 1999). For springbok, Fairall (1985) found that changing the sex ratio from a ratio of one female to three males, to one of one female to ten males increased productivity by 30%.

The occurrence of a change in muscle composition due to different sexes, has a significant effect on the eating quality of meat (Quali, 1991). It is well-known that the meat from bulls is less tender and leaner than that from ewes. However, age has a less significant effect on tenderness than sex when comparing bulls and cows (Quali, 1991).

2.3 Season

Seasonal changes are related to food availability and food quality (Gallivan, Culverwell & Girdwood, 1995). In any cropping scheme, the seasonal fluctuations in the availability of feed should be taken into account (Von La Chevallerie, 1970). So, for example, Gallivan *et al.* (1995) reported that the majority of impala were in poor condition at the end of the dry season. Their study found that adult males and yearlings did not regain optimum condition after the spring rains. A further study on red deer showed that steaks cut from the post rut longissimus muscle appeared fresher and brighter in colour than pre rut steaks (Stevenson, Seman & Littlejohn, 1992). The study also found that post rut samples had lower flavour intensity and were slightly less tender than the pre rut sample. However, the seasonal pattern in the body mass of blesbok rams seems to indicate that there is little variance in body mass within each season (Kroon, Van Rensburg & Hofmeyr, 1972).

2.4 Shooting procedures

In terms of welfare regulations and conditions, headshots are the most desirable shots. Neck shots could result in paralysis without immediate death (Lewis, Pinchin & Kestin, 1996). The best time for harvesting game is at night (Veary, 1991), because night shooting results in less stress for the surviving animals and causes the least wastage and damage to the carcass (Hoffman & Ferreira, 2000). The fact that both blesbok and red hartebeest are grazers and are found in areas with little trees and bush makes it ideal to harvest the animals during the night.

3. Physical properties and *rigor mortis*

3.1 Colour

The appropriate measurement for colour is the so-called CIELab-system where L*= lightness, a*and b*=chromaticity. Colour is important because it often plays an important role in meat quality (Stevenson, Seman, Weatherall & Littlejohn, 1989). In South Africa game meat is perceived to have an unattractive dark red colour. Intra-muscular fat can increase lightness if present in large quantities, even if the pigment content is increased (Fiems *et al.*, 2000). Assessing the colour of game meat is easier than measuring colour of meat with a large amount of marbling.

The a*- and b*-values tend to decrease with storage time (Stevenson et al., 1989). In contrast to beef, a*-values of red deer meat are not affected by electrical stimulation (Wiklund, Pickova, Samples, & Lundström, 2001). If b* rotates towards a* there is an increase in redness in the meat. This is due to an increase in the hue angle (H). Muscles appear brighter when the a*- and b*-values are high, because this results in higher saturation (Onyango, Izumimoto & Kutima, 1998). In a study by Von La Chevallerie (1970) the two largest ungulate species, the meat of the eland and gemsbok had the lightest colour. The meat colour of the other species varied from dark red brown to a pale red colour. The red hartebeest's meat had a cherry red colour and the impala's meat was a reddish-brown brick colour.

3.2 Water-holding capacity (WHC)

The water-holding capacity (WHC) of meat is an important attribute and is measured according to the type of meat product (Honikel, 1998). In this study drip loss in raw meat samples and cooking loss in cooked meat samples will be used for measuring the WHC. The pH of meat influences the WHC to a great extent (Honikel, 1991). The method of

cropping is of the utmost importance to ensure that the animal is exposed to the minimum stress during cropping. Post-mortem glycolysis in a muscle will usually reach an ultimate pH of approximately 5.5, which is also the iso-electric point of the principal proteins in muscle. Therefore loss in WHC is an inevitable consequence of the death of the animal and WHC is thus affected by the extent of post-mortem glycolysis, which result in the pH falling. The higher the ultimate pH, the lower the diminution in WHC (Lawrie, 1979). Game meat has a lower fat content and higher protein content and this could increase the WHC significantly. Therefore, game meat could be used successfully as an ingredient in cured or emulsion-type products (Pietersen, 1993).

The diminution of *in vivo* WHC (drip) makes the product less acceptable for the consumer. Drip loss is caused by the shrinkage of myofibrils. The fluid moves to the extra cellular spaces and thereafter to the meat surface (Offer & Knight, 1988). Drip loss can be predicted by sarcoplasmic and total protein solubility measurements after seven days of storage (Den Hertog-Meischke *et al*, 1997).

Cooking loss is usually greater than drip loss. Some of the loss is non-aqueous in nature, as high temperatures tend to melt fat. Moisture loss during cooking will be increased by a fast decrease in pH and protein denaturation (Lawrie, 1979).

3.3 *Rigor mortis*

In any animal species meat toughness increases as the muscle goes into *rigor*. The completion of *rigor mortis* is approximately 24 to 36 h post slaughter. The rate, as well as the extent to which the post-mortem pH fall, are very important in this process. *Rigor mortis* is important in every species, because it influences WHC, cooking loss, colour and shelf life (Quali, 1991). *Rigor* shortening increases as the *rigor* temperature increases above the minimum of 10 to 15°C (Locker & Hagyard, 1963). In this process, charged myosin molecule heads attach to actin molecules and ATP (adenosine triphosphate) splits into ADP (adenosine diphosphate) with a release of energy when a muscle contracts. The myosin head then swivels and causes filament sliding. Only if a new ATP molecule is available to bind, will the myosin head, which is still attached to the actin, detach itself (Swatland, 1984). Myosin molecule heads remain attached to actin when muscle is converted to meat. During *rigor mortis,* passive filament sliding is impossible (Swatland, 1984).

Cold-shortening occurs if the relationship between the refrigeration system and the meat exposed to it is such that the temperature of the meat can be lowered to about 15 to 19°C. This must happen while the muscles are still in early pre-rigor condition with a pH of approximately 6.8. To avoid cold-shortening, the meat must be cooled swiftly to approximately 15°C. The meat must then be held at this temperature to allow the onset of *rigor mortis* (Lawrie, 1979). Cold-shortening produces the toughest meat (Marsh & Leet, 1966).

3.4 pH

pH is the measure by which glycolysis is assessed. Post-mortem lactic acid accumulation, thus normal pH decline, occurs as a result of changes in muscle glycogen (Immonen, Ruusenen & Puolanne, 2000). The quantity of glycogen, which remains in the muscle at death, determines the ultimate (pHu) value (Varnam & Sutherland, 1995). Ultimate pH is one of the main determinants of WHC, but seems to have a negligible effect on juiciness in beef (Quali, 1991). Post-mortem glycolysis will normally proceed to an ultimate pH of approximately 5.5 and loss in WHC is thus an inevitable consequence of the death of the animal. The WHC will be affected by the extent of post-mortem pH fall, and the higher the ultimate pH the less will be the diminution in WHC (Lawrie, 1979).

Wiklund, Barnier, Smulders, Lundström and Malmfors (1997) found no significant correlations between ultimate pH and tenderness in their study on reindeer. Meat tenderness is also linked to the rate of pH fall. This is probably due to the swelling of the proteins above their iso-electric point. There is also a progressive increase in tenderness at low pH, because the proteins swell again. At pH between 4.5 and 4.0 the decrease in shear force values is very rapid and then slower to pH 3.5 (Bailey & Light, 1989). Wiklund *et al.* (1997) found that a high pH were associated with short sarcomere lengths. Cold-shortening can occur if the pH is too high in the early hours post-mortem and when the temperature of the muscle is lowered too quickly, which causes the toughening of the meat (McGeehin, Sheridan & Butler, 2000).

High ultimate pH game meat is sufficiently dark and can be distinguished from game meat of normal ultimate pH (MacDougall, Shaw, Nute & Rhodes, 1979). Jeremiah, Tong and Gibson (1991) found that only a slightly higher percentage of the carcasses segregated on the basis of both colour and pH were classified as being tough than when segregation was based upon pH alone. Stress, physical activity (Wiklund *et al.*, 1995), electrical stimulation (Varnam *et al.*, 1995), and chilling temperature (Bowling, Smith, Dutson & Carpenter, 1978) affect pH values and ultimately meat quality. Sex (Jeremiah *et al.*, 1991), species (Varnam *et al.*, 1995), season (Langlois & Minvielle, 1989) and age (Varnam *et al.*, 1995) may also have an effect. Furthermore, the pH rises as the animals become more exhausted (Harthoorn *et al.*, 1974). The normal pH value of beef is approximately 5.5 (Purchas *et al.*, 1999). McGeehin *et al.*, (2001) found that the pH of male lambs is higher than female lambs at 4 h post mortem.

DFD meat has a high pH value and contains low amounts of glucose. The pH value of DFD meat is defined as pH> 5.80 (Wiklund *et al.*, 1997). Wiklund, Andersson, Malmfors, Lundström and Danell (1995) conducted a study on a range of factors influencing the pH of reindeer meat and found that DFD characteristics are most often seen in the carcasses of bull calves and that the pH values of reindeer bulls and calves are not affected by lorry transport. They also found that DFD meat has a shorter shelf life. Reindeers fed on pellets had significantly lower pH in *M. longissimus, triceps brachii* and *biceps femoris,* compared to the reindeers that grazed on natural pasture (Wiklund *et al.*, 2001). The pH decline in reindeer meat is rapid, unlike other investigated ruminants (Wiklund *et al.*, 1995). When considering pH as a factor, pre-rigor meat temperatures should be taken into account while interpreting the pH values because *rigor* temperatures have an effect on pH (Devine *et al.*, 2002).

3.5 Shear force

Shear force measures meat toughness and the latter is dependent on the degree of contraction of the myofibrills in muscle of normal pH (Lawrie, 1979). According to a study on sheep, the shear force of muscles from the same animals changed due to the effect of *rigor* temperatures only (Devine *et al.*, 2002). At one-day post-mortem the shear force of the longissimus is strongly correlated to that after ageing of the muscle (Shackleford, Wheeler & Koohmaraie, 1997). An increase in ultimate pH from 5.5 to about 6 is associated with increased toughness in some studies (Purchas, Yan & Hartley, 1999). Croppers must try to expose game to the minimum stress to prevent a high pH.

4. Chemical composition

Proximate chemical analysis (total moisture, proteins and fat), as well as other chemical analyses including amino acids, fatty acids and cholesterol is discussed in this section of the Literature Review. Mineral and collagen analyses are also discussed in this section. The Adequate Intake (AI), Recommended Daily Allowance (RDA) and Estimated Average

Requirement (EAR) tables for minerals are given to illustrate their contribution to the diet of a male between the ages of 19-30 years.

4.1 Total moisture

Moisture in meat is determined by drying a sample at a high temperature. The loss in weight is reported as moisture (Doty & Maroney, 1960). Moisture content is also an indication of the protein and ash content (Kroon, Van Rensburg & Hofmeyr, 1972). Onyango *et al.* (1998) found that protein, moisture and ash values of beef and game meats were similar to that of other red meats. Von La Chevallerie (1972) found the moisture content of blesbok and red hartebeest to be 75.5% and 76.3%. The small percentage of marbling fat found in game meat affects the inherent moistness of the meat (Aidoo & Haworth, 1995). The appropriate cooking methods must be used to reduce the detrimental effects that the small amount of marbling fat may have on palatability.

4.2 Proteins and amino acids

The protein in meat is of high biological value. Eight amino acids (isoleucine, lysine, leucine, methionine, phenylalanine, threonine, tryptophan and valine) are essential for the maintenance of nitrogen balance in young adults (Rose, Wixom, Lockhart & Lambert, 1955). The proportion of essential amino acids determines the nutritional quality of a food protein. The RDA for protein is 56 g for the adult man. Red meat supplies 55.5% of the RDA for protein (Pearson, 1981). The protein content of a leg of beef is ± 19.4% and ± 24.2% for a leg of zebra (Onyango, Izumimoto & Kutima, 1998). The protein content of blesbok in summer is 22.9% and 21.20% in winter (Kroon *et al.*, 1972). According to Pietersen (1993) it seems as though game meat has a higher protein and lower fat content than other red meat. The amino acid profiles from African buffalo and English beef are almost identical (Crawford, 1968). Whitetail deer was found to have higher protein values than standard grade UK beef (Marchello, Berg, Slanger & Harrold, 1983).

4.3 Fat and fatty acids

Table 2 indicates that game meat has a lower amount of saturated fatty acids than lamb and a lower amount of monounsaturated fatty acids than beef. For the consumer the consumption of game meat provides a healthy alternative to red meat, because of the health risk associated with animal fat (Schönfeldt, 1993). According to dietary recommendations, fat must not contribute to more than 30% of the daily dietary energy intake. Protein, sodium and water are mainly found in the lean portion of meat, and will therefore be higher in game meat than in red meat because of the low fat content of game meat (Aidoo *et al.*, 1995). According to Lawrie (1979) the essential fatty acids are linoleic (C 18:2), linolenic (C 18:3) and arachidonic (C 20:4). Essential fatty acids are essential components of membranes and are precursors in prostaglandin synthesis (Pearson, 1981). Furthermore lipids carry fat-soluble vitamins A, D, E and K. The muscle tissue lipids reflect the lipid composition of the vegetation that the free-living animals consume (Crawford, Gale, Woodford & Casped, 1970). Free-living mammals, such as the eland's lipids are mainly polyunsaturated and phospholipids (Lawrie, 1979). The fatty acid profile of game meat is similar to that of other red meats with oleate as the main monounsatured fatty acid and palmitate and stearate as the predominant saturated fatty acids (Aidoo *et al.*, 1995). Polyunsaturated components of animal fats are essential for brain development (Lawrie, 1979). Von La Chevallerie and Van Zyl (1971) found that the fat content of springbok never exceeded 3.3%. Springbok meat contains lower amounts of saturated fatty acids than beef (Viljoen, 1999). Von La Chevallerie (1972) found the fat content of blesbok and red hartebeest to be 1.7 % and 2.0 %.

Table 2
Fatty acid profile of fat extracts from game meat and other red meat cuts purchased from a supermarket (g/100 g total fatty acids)

Meat	Saturates	Monounsaturates	Polyunsaturates
Venison, combined cuts	48.6	43.2	3.1
Venison, chopped stew	47	44	3.2
Beef steak, stew	41	49.1	4.1
Lamb steak, leg	49.9	39.9	5

Aidoo *et al.*, 1995

4.4 Cholesterol

In literature most data on cholesterol content of meat range from 50-80-mg/100 g (Honikel, 1991). Animal fat contains high quantities of cholesterol and therefore the reduction of animal fats in the human diet has been recommended to reduce cardiovascular disease. Cholesterol is synthesised in amounts from 800 to 1500 mg daily by the human body. The daily intake is approximately 450 mg and the human body absorbs only 10% to 50% of that in the diet (Pearson, 1981). Lower levels of satured fatty acids could increase the serum cholesterol levels (Viljoen, 1999). The Food and Nutrition Board of United States has not made any recommendation about the reduction of dietary cholesterol levels for the healthy person because the relationship between serum cholesterol and cholesterol intake is not significantly related (Pearson, 1981).

4.5 Mineral content

A number of minerals are found in game meat. These are phosphorus, potassium, magnesium, sodium, iron, copper, calcium and zinc. In Table 3 the RDA or AI values for some of the minerals are indicated. Game meat is considered to be a good source of iron, and the best sources of iron are the liver, kidney, heart, lean meat, fish and poultry (Anderson, 2000). Red meat provides 4.7 mg/100 g iron (Pearson, 1981). An iron deficiency causes anaemia in humans and is the most common of all nutritional deficiencies (Anderson, 2000). Good sources of protein are generally also good sources of phosphorus. Raw beef contains 24.5 mg magnesium per 100 g (Lawrie, 1979). Magnesium deficiency may lead to symptoms such as tremor, anorexia and muscle spasm (Anderson, 2000). Copper is widely distributed in animal products and most diets provide the RDA of 2 mg per day. Symptoms of copper deficiency are skeletal abnormalities, neutropenia and anaemia (Anderson, 2000). The sodium content of game meat is similar to that of other meat (Aidoo *et al.*, 1995). Raw beef contains 69 mg sodium per 100 g (Lawrie, 1979). The dietary zinc in plants is often unavailable because phytate complexes with the zinc (Pearson, 1981). Animal proteins are therefore better sources of dietary zinc and the latter is found predominantly in muscle, the kidney, pancreas and the liver (Pearson, 1981).

Table 3
Dietary reference intake for micronutrients: minerals and trace elements in mg/day

Calcium AI	Phosphorus RDA/ AI	Magnesium RDA/ AI	Iron RDA/ AI	Zinc RDA/AI
1000	700	310	18	8

AI (Adequate Intake)
RDA (Recommended Dietary Allowances)
Dietary reference intake is for a male between the ages of 19-30

4.6 Collagen

Connective tissue is largely made up of collagen. Collagenous fibres are colourless, and each fibre consists of many parallel fibrils (Birkner & Auerbach, 1960). The arrangements of collagen fibres are used in determining the properties of tissue, e.g. the fibres are packed side by side to give a strong inextensible tissue in tendon. The amino acid hydroxiproline is present in collagen and is only present in a few other proteins. The presence of hydroxyproline in collagen is so characteristic that it is used to determine the amount of collagen present in a tissue (Sims & Bailey, 1981). When the ovine semimembranosus is cooked to an endpoint temperature similar to that of lightly cooked meat, collagen concentration is a better indicator of texture and sensory tenderness than collagen solubility (Young & Braggins, 1993). It seems that collagen is found in a smaller amount in low-activity muscles than in muscles that are used often. The nutritional state of the animal attributes to the variations in collagen distribution (Birkner *et al.*, 1960). In collagen, the most significant age-related change is its increasing insolubility (Sims *et al.*, 1981). Collagenous fibres undergo swelling, shrinkage and finally disintegrate when steaks are cooked to an internal temperature of 77°C (Birkner *et al.*, 1960).

5. Sensory quality characteristics

Meat will only be consumed in increasing quantities if it is acceptable to the consumer and appeals to the consumer on the basis of palatability (Weir, 1960). The sensory properties include aroma, flavour, juiciness and tenderness. A descriptive, analytical structured method of attribute rating is normally used (Zondagh, 1993).

5.1 Aroma

Aroma is perceived by the olfactory nerve as an odour when the volatiles pass into the nasal area from the mouth, or are sniffed through the nostrils (Meilgaard *et al.*, 1987). The meat of older animals has a stronger odour than the meat from younger animals of the same species (Weir, 1960). Often, the meat of mature males has an ammonia smell. Storage under unfavourable conditions can cause proteolytic odours from protein decomposition, sour odours as a result of microbial growth and rancid odours as a result of fat oxidation (Weir, 1960).

5.2 Flavour

Flavour can be defined as a complex mouth-feel sensation and includes the basic taste sensations (soluble substances in the mouth) and aroma (Charley, 1982). The flavour of cooked meat can be influenced by, for example the age of the animal, the type of feed and the length of time that the meat was stored for, and the conditions by which storing took place after slaughter (Weir, 1960). Immonen, Ruusunen and Puolanne (2000) found high off-flavour ratings on aged samples with a high percentage of residual glycogen. It is generally accepted that red meat has a more intense flavour than white meat (Quali, 1991). The higher lipid content can account for this phenomenon. In beef, the flavour only improves when the lipid content varies in a range of 1- 3.5%. The lipid effect therefore appears limited in beef (Quali, 1991). Studies done on mutton showed that the flavour of this meat is influenced more by muscle metabolic type than by lipid content (Quali, 1991).

5.3 Juiciness

Juiciness of cooked meat consists of two effects (AMSA, 1995). The first effect is sustained juiciness due to slow release of serum and the stimulating effect of fat on salivary flow. The second effect is the impression of wetness produced by the rapid release of meat fluids (Weir, 1960). Meat from young animals with less marbling is less juicy than meat from mature animals, which are well marbled. On first bite, meat from young animals gives a watery effect,

and a final impression of dryness (Weir, 1960). Tender meat's juices are released more quickly during chewing, than that of less tender meat. Ultimate pH seems to have a minimum effect on the juiciness of beef (Quali, 1991). Valin, Touraille, Vigneron and Ashmore (1982) conducted a study on lambs from selected muscle fibre type, and found that meat from "redder" animals to be juicier than meat from "whiter" ones. They concluded that muscle fibre type possibly could play an important role in juiciness.

5.4 Tenderness

Studies have indicated tenderness as the most important palatability factor that determines the acceptability of beef (Weir, 1960). It can safely be assumed thus that this quality is important in all types of meat. Pre-mortem and post-mortem factors have a direct affect on the tenderness of beef (Weir, 1960). The most important pre-mortem factors are genetic characteristics, physiological factors and feeding and management practices. The post-mortem factors include length of time and temperature of storage after slaughter, methods of trimming and cutting, methods of cooking, and the addition of tenderising agents (Weir, 1960). Tenderness decreases after slaughter for the first 24 h, when the meat is held at 0 to 5°C, while rigor mortis sets in. The tenderness increases after this. According to Weir (1960) the tenderness increase is greater as the freezing temperature is increased from -10°C to -80°C. Toughening of meat occurs when cold shortening is present if the temperature of the muscle is too low. This happens if the pH is too high early in post-mortem (McGeehin et al, 2001). The heat-dependent solubility of collagen decreases as cross-linking increases and in cooked meat more of the perimysial collagen remains as a resistant framework (Bailey *et al.*, 1989).

Conclusion

The reviews of the species indicate that blesbok and red hartebeest are ideal for cropping, mostly because they inhabit the open grasslands throughout South Africa. The pH of meat influences the WHC and therefore the croppers must try to expose game to the minimum stress to prevent a high pH.

Data on the carcass yield of African ungulates were collected in the seventies (Skinner, 1970; Von La Chevallerie, 1970), but no uniformity in slaughtering methods was applied. A standardized technique for determining the yield for ungulates was established by Ledger (1963), but is no longer used. Comparative assessment of the meat production of indigenous ungulates should be possible by using standardised commercial slaughter techniques.

There is also limited information available in literature on the factors that affect the physical, chemical and sensory meat quality characteristics of red hartebeest and blesbok, i.e. pre-slaughter (age, sex, season and shooting procedures) and post-slaughter factors (post-mortem glycolysis, temperature, *rigor mortis*, cooking).

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Morphological characteristics of blesbok (*Damaliscus dorcas phillipsi*) meat

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Abstract

The aim of this study was to determine the effect of the sex, age and region on the morphological characteristics of blesbok. A total of 73 blesbok, from both sexes, and from different age groups (adult, sub-adult and lamb) and different regions (Qua-Qua (QQ), Maria Moroka (MM), Rustfontein (RF) and Gariep (GR) in the Free State Province, South Africa) were measured. Within sex, the males had the highest values for all the characteristics, except for leg length. The male animals (67.38 kg) were significantly heavier than the females (60.19 kg). All carcass measurements (body weight, carcass weight, carcass length, carcass breadth, carcass depth, buttock circumference, chest girth and leg length) increased linearly with age. The sub-adults had the highest dressout percentage (54.31%) and blesbok from RF (50.57%) the lowest. Regarding region, blesbok from QQ had the highest values for all the characteristics, except for carcass length and leg length.

Keywords: morphological characteristics, blesbok, dressout percentage, yield

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Introduction

According to Von La Chevallerie (1970) it may be more economical to crop heavy animals when the fixed costs of shooting, dressing and marketing are very high. Furthermore, carcass weight and other morphological characteristics can give a good indication of the meat production potential of an animal. The dressing percentage of ungulates usually varies between 55 and 61% (Von La Chevallerie, 1970). It is well known that indigenous animals show a higher yield of meat per unit region than domestic species and this could ultimately result in a greater financial return (Hopcraft, 1980).

Although it is difficult to obtain the live weight values of game animals, Kroon, Van Rensburg and Hofmeyr (1972) found a small variation in the live weight of mature male blesbok within different seasons. However, the seasonal weight fluctuation of a blesbok population normaly consists of a decline from March to September, followed by a rapid gain in weight from September to March (Du Plessis, 1972).

The aim of this study was to compare the morphological carcass characteristics of blesbok (*Damaliscus dorcas phillipsi)* from four different regions and to determine the possible effects that sex and age may have on these characteristics.

Materials and methods

Harvesting

Blesbok, representing different age groups (adult, sub-adult and lamb) of both sexes were obtained during 2001 and 2002 from four nature reserves in the Free State Province (Table 1). Over and above the adult and sub-adult animals, two female and two male lambs were also obtained from Gariep (GR) Nature Reserve. As both the male and the female have horns, the length and width of the animals' horns were used to obtain the animals' age. Animals with no horns or short straight horns were classified as lambs and animals with horns of intermediate size were classified as sub-adults. Animals with fully developed horns were classified as adults. Only male and female adult blesbok were obtained from Qua-Qua (QQ) during 2001, whilst male and female blesbok from all three age groups were obtained from Maria Moroka (MM), GR and Rustfontein (RF) during 2002. All the animals were obtained in the period of May to September, i.e Autumn to early Spring. The animals were selected randomly during organized game cropping operations and shot either in the head or neck with .274 or .270 calibre rifles. All the animals were exsanguinated in the field. In 2001 the blesbok were shot during the daytime and either during the daytime or at night in 2002.

Table 1
Number of blesbok harvested during 2001 and 2002 in the Free State Province

Year	Region	Total	Adult		Sub-adult	
			Male	Female	Male	Female
2002	MM[a]	7	6	1	0	0
2002	GR[b]	36	5	24	0	3
2001	QQ[c]	13	8	5	0	0
2001	RF[d]	17	9	7	1	0
Total			28	37	1	3

[a]MM=Maria Moroka
[b]GR=Gariep
[c]QQ=Qua-Qua
[d]RF=Rustfontein

Morphological measurements

The morphological measurements described in Table 2 were executed on the blesbok in 2001 and 2002.

Table 2
Units, apparatus and description for measuring the morphological traits of blesbok

Characteristic	Unit	Apparatus	Description
Body weight	kg	Electronic scale	Animal weight after bleeding
Carcass weight	kg	Electronic scale	Weight of the skinned animal without the weight of the head, intestines and hooves
Dressout percentage	%		Carcass weight/ Body weight × 100
Carcass length	cm	Steel slide-rule	Measured from the base of the neck to the base of the tail at the junction of the pelvis
Carcass breadth	cm	Steel slide-rule	Measured between the widest points of the rib cage, posterior to the forelegs
Carcass depth	cm	Steel slide-rule	Measured from the spine to the sternum, posterior to the forelegs
Buttock	cm	Standard tape Measure	Measured at the top of the leg at the junction with the abdomen; around the leg
Chest	cm	Standard tape Measure	Measured around the chest, posterior to the forelegs
Leg length	cm	Standard tape Measure	Measured from the top of the inner thigh to the hock

Statistical analysis

A three factor factorial experiment was performed in a completely randomised design with unequal number of random replications. The factors were four areas (QQ, SV, MM and TDR), two sexes and three age groups (lamb, sub-adult and adult). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 1999) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). A Student's t-Least Significant Difference was calculated at the 95% confidence level to compare treatment means (Ott, 1998).

Results and discussion

The morphological results of blesbok are depicted in Table 3. It was difficult to see the effect of age as a result of the skewness due to sampling, as there were only four lambs and four sub-adults obtained for the study. Body weight indicated significant differences ($p \leq 0.05$) for sex, age groups and regions. Within sex, the males' body weight (67.38 kg) was significantly higher ($p \leq 0.05$) than that of the females (60.19 kg). Interactions ($p \leq 0.05$) were found for carcass weight between age groups and regions (Table 4). The adults from QQ had the highest carcass weight (39.93 kg) and the lambs from GR the lowest (19.93 kg). Von La Chevallerie and Van Zyl (1971) reported the carcass weight for blesbok males to be 38.60 kg and 35.00 kg for females.

Table 3
Mean morphological measurements of blesbok from different sexes, age groups and regions

	Sex			Age				Region				
	Female	Male	LSD[d]	Adult	Sub-adult	Lamb	LSD	QQ	MM	RF	GR	LSD
Body weight (kg)	60.19[b]	67.38[a]	3.26	66.11[a]	44.43[b]	36.95[b]	8.02	74.32[a]	73.07[a]	62.28[b]	57.71[b]	5.36
Carcass weight (kg)	31.29[b]	35.12[a]	1.65	IA[f]	IA	IA	IA	IA[a]	IA	IA	IA	IA
Dressout (%)	52.15	52.60	1.51	52.11	54.31	53.96	3.70	53.72[a]	52.12[ab]	50.57[b]	52.23[ab]	2.57
Carcass length (cm)	81.16[b]	85.23[a]	2.17	84.43[a]	74.48[b]	67.13[c]	5.35	86.32[b]	90.00[a]	87.13[ab]	78.18[c]	3.58
Carcass breadth (cm)	IA	IA	IA	IA	IA	IA	2.92	35.02[a]	29.84[b]	26.15[c]	26.83[c]	1.95
Carcass depth (cm)	34.93[b]	37.17[a]	1.29	36.75[a]	30.50[b]	27.58[b]	3.16	40.44[a]	39.99[a]	34.07[b]	34.28[b]	2.12
Buttock[e] (cm)	56.217[b]	58.27[a]	1.48	57.76[a]	54.73[a]	48.90[b]	3.64	59.96	59.69	58.19	54.99[b]	2.44
Chest girth (cm)	95.75[b]	98.92[a]	2.03	IA	IA	IA	IA	IA	IA	IA	IA	IA
Leg length (cm)	54.73	54.12	1.30	54.67	53.65	51.98	3.18	45.32[b]	57.01[a]	56.57[a]	56.38[a]	2.13

[a,b,c]Means in the same column within the same subgroup, with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e]Circumference
[f]IA=Interaction

Dressout percentage indicated significant differences ($p \leq 0.05$) for region. QQ contributed more adult males than females and this is possibly the reason why this region delivered the highest body weight and dressout percentage. However, the dressout percentage (54.31%) of blesbok from this investigation is lower than that reported for other ungulates. Van Zyl, Von La Chevallerie and Skinner (1969), for example, found the dressout percentage of impala rams and springbok to be 58%. These differences could be due to the differences in the methodology of determining this parameter, e.g. what was included in the carcass weight. Van Zyl and Ferreira (2001) found the dressing percentage of blesbok to be 62.80% when expressed as a percentage of empty body weight and 50.20% when expressed as a percentage of the live weight.

Carcass length and depth indicated significant differences ($p \leq 0.05$) for sexes, age groups and regions. The males' length (85.23 cm) and depth (37.17 cm) were significantly higher ($p \leq 0.05$) than that of the females. Blesbok from MM had the highest value for length (90.00 cm). This could be as a result of the fact that the animals cropped from MM consisted of six males and only one female.

Blesbok cropped from QQ had the highest value for carcass depth (40.44 cm), but this is probably because only adult animals were cropped from QQ. Interactions ($p \leq 0.05$) were found for breadth between sexes and age groups (Table 4). Carcass breadth indicated significant differences with the male adults (29.72 cm) having the highest breadth value and the female lambs (20.05 cm) the lowest.

Table 4
Morphological interactions present of blesbok as influenced by different sex, age and region combinations

	S[e]	A[f]	S*A	LSD[d]	A	R[g]	A*R	LSD
Carcass weight					Adult	GR	32.42[a]	5.08
					Lamb	GR	19.93[b]	
					Sub-adult	GR	21.67[a]	
					Adult	MM	36.47[a]	
					Adult	QQ	39.93[a]	
					Adult	RF	32.11[a]	
					Sub-adult	RF	32.00[a]	
Carcass breadth	Female	Adult	28.45	2.50				
	Female	Lamb	20.05					
	Female	Sub-adult	23.43					
	Male	Adult	29.72					
	Male	Lamb	26.10					
	Male	Sub-adult	28.50					
Chest girth					Adult	GR	96.47[b]	6.25
					Lamb	GR	80.80[c]	
					Sub-adult	GR	83.20[c]	
					Adult	MM	99.03[b]	
					Adult	QQ	107.52[a]	
					Adult	RF	95.69[b]	
					Sub-adult	RF	96.2[b]	

[a,b,c]Means in the same column between the subgroups with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e,f,g] S=Sex; A=Age; R=Region

Buttock circumference indicated significant differences ($p \leq 0.05$) for sex, age groups and regions. The males' buttock circumference (58.27 cm) was higher than that of the females. According to Huntley (1971), the buttock circumference of mature male blesbok is 59.3 cm. A possible reason why the latter from the present investigation is lower could be because younger (sub-adult and lamb) animals were included in the present study. The female buttock circumference is usually higher because of the fat deposits on the buttocks, but this was not found in the present study. Interactions ($p \leq 0.05$) were found for chest girth between age groups and regions. The adult animals from QQ (107.52 cm) had the highest value and the lambs from GR (80.80 cm) the lowest (Table 4).

Conclusion

As anticipated, the results indicated that the male and adult animals had the highest values for almost all the characteristics. Within age, all the characteristics, except dressout percentage, increased linearly with age. However, the reason for this could be due to the skewness of sampling. The blesbok obtained from GR had the lowest body weight and carcass weight. This could be due to high number of females that were obtained from this region. More adult males

than females were cropped from QQ and this caused QQ to have the highest values on all the characteristics, except carcass length and leg length. The differences in dressout percentage compared to that of other studies could be due to differences in the methodology of determining this parameter. Interactions were found for carcass weight and chest girth between age groups and regions, and for carcass breadth between sexes and age groups.

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Chemical characteristics of blesbok (*Damaliscus dorcas phillipsi*) meat

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Abstract

The aim of this study was to determine the effect of the sex, age and region on the chemical characteristics of M. longissimus dorsi (MLD) from blesbok. The parameters measured included proximate composition, total collagen, amino acid, mineral, cholesterol and fatty acid content. A total sample of 73 blesbok, from both sexes, from different age groups (adult, sub-adult and lamb) and from four regions (Qua-Qua (QQ), Maria Moroka (MM), Rustfontein (RF) and Gariep (GR) in the Free State Province, South Africa) were obtained and used in this study. No significant differences were found for protein, moisture and ash content. The sub-adult animals had the highest protein value (23.11 g/100g) and the sub-adults from RF the highest collagen value (2.21%). The MLD of the females had a significantly higher lipid content (1.14 g/100 g) than that of the males (0.76 g/100 g). At 54.56 mg/100 g meat sample the animals from GR had the highest cholesterol content. No significant differences were found for amino acids within sex and age groups, with the animals from RF measuring the highest value for all the amino acids. Palmitic (C16:0), stearic (C18:0) and linoleic acid (C18:2n6) were found to be the main fatty acids in blesbok meat. The n-6:n-3 ratio of 4.6 for blesbok meat is below the recommended value of 5, whereas the ratio for polyunsaturated to saturated fatty acids (1.07) is well above the recommended minimum value of 0.7.

***Keywords*:** proximate composition, total collagen, cholesterol, amino acids, minerals, fatty acids, game meat

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Introduction

It is widely acknowledged that there is a great potential for meat production from African ungulate species (Ledger, Sachs & Smith, 1967). In southern Africa game farming is growing in popularity and many cattle farms are being game fenced to accommodate game (Ebedes, 2002). However, according to Hoffman and Bigalke (1999) a strict management program is required to maintain the illusion of wild animals in an unspoilt habitat. As a normal practice this management plan would includes the regular cropping of animals, which could increase the availability of game meat on a larger and more organized scale.

Although the estimated gross income from the game industry in South Africa was R843m for 2000 (Eloff, 2002), the per capita consumption of red meat is declining. This trend is probably due to the consumers' negative perception of red meat and the association of red meat with cardiovascular and other lifestyle diseases. As a result of these negative perceptions, consumers tend to consume more white meat and other non-meat sources of protein.

Limited detailed information is available on the nutritional composition of game meat and the suitability of game meat products to complement the consumers' growing demand for healthy products (Aidoo & Haworth, 1995). It is well known that red meat such as mutton has a relatively high fat content of between 20 and 25%. In contrast, game meat has a much lower fat content (2 to 3 g per 100 g meat), and is therefore considered to be a very attractive source of protein for the health-conscious consumer (Schönfeldt, 1993). The low fat content of game meat, however, implicates that weight for weight, the protein, sodium and water content will be higher than in other red meat types. The nutrient density of game meat is fairly high. According to Schönfeldt (1993) the iron content of game meat is considered to be exceptional. Furthermore, blesbok (*Damaliscus dorcas phillipsi*) contains 81.8% of the total essential amino acids (EAA), whilst springbok contains 72.9% of the total EEA required by man (Van Zyl & Ferreira, 2003). It is, however, necessary to consider the cholesterol content of meat, and Jiminez-Colmenero, Carballo and Cofrades (2001) suggest limiting this intake to 300 mg/day. In general, the contribution of meat and meat products is considered to be less than 75 mg/100 g (Chizzolini, Zanardi, Dorigono & Ghidini, 1999).

Although genetic and environmental factors affect the intramuscular fatty acid composition of meat (Raes, De Smet & Demeyer, 2003), a concerted effort is being made by the meat industry to increase the ratio of polyunsaturated fatty acids to saturated fatty acids (P:S ratio) (Wood, Enser & Warriss, 1991). According to Aidoo and Haworth (1995), the fatty acid profile of game meat and other red meat types is quite similar because palmitic and stearic acids are the predominant saturated fatty acids and oleic acid the main mono-unsaturated fatty acid. However, blesbok and other game species come from a natural environment and it is presumed that this meat should have a reasonable healthy fatty acid profile. According to Wiklund, Pickova, Sampels and Lundström (2001), meat from pasture fed animals showed a high content of α-linolenic acid (C18:3n-3) and this should have a positive effect on the ultimate P:S ratio.

In view of the fact that limited chemical data is available on the meat of specific game species, this study set out to determine the effect of the sex, age and region on the chemical composition (proximate chemical composition, total collagen, cholesterol, amino acid, mineral and fatty acid content) of blesbok meat.

Materials and methods

Harvesting

Blesbok from both sexes (males and females) and different age groups (adult, sub-adult and lamb) were harvested during 2001 and 2002 from nature reserves in the Free State Province (Table 1). Apart from the adult and sub-adult animals, two female and two male lambs were obtained from Gariep (GR) Nature Reserve. As both male and the female blesbok have horns, the length and width of their horns were used to determine the age of the animals. Animals with no horns, or with short straight horns were classified as lambs and animals with horns of intermediate size classified as sub-adults. Animals with fully developed horns were classified as adults. All the animals were obtained between May and September (Autumn to Spring). During organized game culling operations, the animals were selected randomly, and shot either in the head or neck with .274 or .270 calibre rifles. All the animals were exsanguinated in the field. The blesbok harvested in 2001 were shot during the day, and those harvested in 2002 either during the day or at night. A sub-sample was used to determine the total collagen, cholesterol, amino acid, mineral and fatty acid content of blesbok meat.

Table 1

Number of blesbok harvested during 2001 and 2002 in the Free State Province

Year	Region	Total	Adult		Sub-adult	
			Male	Female	Male	Female
2002	MM[a]	7	6	1	0	0
2002	GR[b]	36	5	24	0	3
2001	QQ[c]	13	8	5	0	0
2001	RF[d]	17	9	7	1	0

[a]MM=Maria Moroka
[b]GR=Gariep
[c]QQ=Qua-Qua
[d]RF=Rustfontein

Chemical analyses

The carcasses of the animals were transported to the slaughtering facility where they were skinned. It was hung by the Achilles-tendons in a cooler at a temperature of 4°C. For chemical analyses, the *M. longissimus dorsi (*MLD*)* of each animal was removed between the 6th and 7th ribs and anterior to the 5th lumbar vertebrae. The samples were ground three times through a 2 mm sieve to ensure homogeneity.

The total percentages of moisture, protein, fat and ash were determined for all the samples according to a technique described by the Association of Official Analytical Chemists' Standard Techniques (AOAC, 1997). The moisture content was determined by drying at 100°C for 24 hours. Ashing was done at 500°C for 5 h. The block digestion method was used to determine the protein content (N × 6.25), and the lipid content determined by solvent extraction, according to the method of Lee, Trevino and Chaiyawat (1996). The hydroxyproline method was used to determine the total collagen content in meat (Nordic Committee, 2002).

Using a modification of the method of Bidlingmeyer, Cohen and Tarvin (1984), the amino acid composition was determined on a defatted, dried meat sample, using a Waters high performance liquid chromatography system (1525 HPLC with a binary gradient delivery, 717 auto-sampler and Injector, 1500 column heater, 2487 dual wavelength UV detector) and a Breeze data workstation (Waters, Millford, MA, USA). The meat sample was defatted by solvent extraction, according to the method of Lee, Trevino and Chaiyawat (1996). The sample was hydrolyzed with 6 N HCl in a vacuum-sealed tube at 110°C for 24 h. The samples were centrifuged (15 krpm for 5 min) and vacuum dried for 90 min to 2 h. The pH was adjusted by adding 20 µl solution of 2:2:1 ethanol:water:triethylamine and the samples were dried for a further 90 min to 2 h. The resulting sample was derivatized by adding 20 µl of 7:1:1:1 ethanol:water:triethylamine:phenylisothiocyanate derivatizing solution, which was allowed to react at room temperature for 10 min prior to drying under vacuum for a minimum of 3 h. The sample was re-suspended in 200 µl of Picotag sample diluent (Waters, Millford, MA, USA) and a 8 µl sub-sample injected for separation by HPLC under gradient conditions, where Buffer A was sodium acetate buffer (pH 6.4) containing 5000ppm EDTA, 1:2000 triethylamine and 6% acetonitrile and Buffer B was 60% acetonitrile with 5000 ppm EDTA. The data was analysed using Breeze Software (Waters, USA).

The mineral composition of the meat was determined after ashing the defatted meat samples. The meat samples (1- 3 g) were air-dried and ground to pass through a 0.5 - 1.0 mm sieve. Following this procedure, the samples were ashed overnight in a muffle furnace at 550°C. After ashing, 5 cm^3 of a 6 M HCl was added to dissolve the cooled sample. The samples were then dried on a water bath. After cooling, a 5 cm^3 6 M nitric acid (HNO_3) solution was added to the samples, which were then heated on a waterbath and removed when it reached boiling point. The solution was consequently filtered through filter paper into a 100 cm^3 volumetric flask and diluted to volume with deionized water (Giron, 1973). Element concentrations were measured on an ICP-Thermo Jarrel Ash, IRIS (AP).

The fatty acid content was determined according to the method, described by Tichelaar, Smuts, Van Stuijvenvenberg, Faber and Benade (1998). After thawing the meat, a 2 g sample was extracted with chloroform/methanol (CM 2:1; v/v) in accordance to a method, modified by Folch *et al.* (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenize the sample within the extraction solvent. Heptadecanoic acid (C17:0) was used as an internal standard to quantify the individual fatty acids. A sub-sample of the extracted lipids was transmethylated for 2 h at 70°C using methanol/sulphuric acid (19:1; v/v) as transmethylating agent. After cooling, the resulting 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 flame ionisation detection) using 60 m BPX70 Capillary columns of 0.25 mm internal diameter (SGE, Australia). Gas flow rates were: hydrogen, 25 ml/min; and hydrogen carrier gas 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 were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

From the same lipid extraction used for determining fatty acid content, a sub-sample was used to measure cholesterol. 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% ethanolic KOH used to saphonifize the extraction for two hours at 70°C, in a heating block. After cooling, distilled water and hexane were added and the resultant extraction 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 analysis

A three factor factorial experiment was performed in a completely randomised design with unequal number of random replications. The factors were the four areas (QQ, SV, MM and TDR), the two sexes and three age groups (lamb, sub-adult and adult). A single carcass was considered to be one experimental unit. The variables were recorded as interval data, and subjected to an analysis of variance using SAS version 8.2 (SAS, 1999) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). A Student's t-Least Significant Difference was calculated at the 95% confidence level to compare treatment means (Ott, 1998). Where applicable, Pearson's correlations were determined using the Proc Corr procedure of SAS (1999).

Results and discussion

The mean proximate content and the total collagen content of the *MLD* of the blesbok are depicted in Table 2. No significant differences ($p>0.05$) were found between groups for protein, moisture and ash content. Although Kroon and Hofmeyer (1972) stated that the moisture content is an indicator for the ash and protein content, no significant ($p\leq0.05$) correlations were found between these parameters.

Table 2
Means for proximate chemical composition (g/100 g) and total collagen content (%) of *MLD* of blesbok as influenced by different sexes, age groups and regions

	Sex			Age				Region				
	Female	Male	LSD[c]	Adult	Sub-adult	Lamb	LSD	QQ	MM	RF	GR	LSD
Protein	22.31	22.39	0.47	22.29	23.11	22.42	1.51	22.19	22.45	22.42	22.35	0.77
Moisture	75.02	75.12	0.61	75.07	75.05	74.92	1.51	75.22	74.92	75.46	74.84	1.01
Lipid	1.14[a]	0.76[b]	0.16	0.92[b]	1.13[b]	1.60[a]	0.40	1.19[a]	0.21[b]	0.22[b]	1.42[a]	0.27
Ash	1.29	1.26	0.08	1.29	1.12	1.30	0.20	1.38	1.28	1.25	1.26	0.13
Collagen	0.88	1.67	1.79	IA[e]	IA	NE[d]	IA	NE	IA	IA	IA	IA

[a,b]Means in the same row within the same subgroup, with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d]NE=Not executed
[e]IA=Interactions

The difference in lipid content measured was significant ($p\leq0.05$) between sexes, age groups and regions. In this study the lipid content of the females (1.14 g/100 g muscle) was significantly higher ($p\leq0.05$) than that of the males (0.76 g/100 g muscle). Lawrie (1979) noted that the meat from male animals, in general, has less intramuscular fat than that of female animals, and that intramuscular fat tends to increase with age. This was, however, not found to be true in this study, as the meat from the lambs had the highest lipid content (1.60 g/100 g muscle). This was significantly higher than the lipid content measured in the sub-adults (1.13 g/100 g muscle) and adults (0.92 g/100 g muscle). The high lipid value measured in the meat of the lambs could possibly be attributed to the fact that a limited number of lambs were cropped. Thus the lipid value could be biased. Of all the regions, the meat from the animals obtained from GR measured the highest lipid content (1.42 g/100 g muscle), although this was not found to be significantly higher than that of the animals from QQ. This can be explained if one remembers that the lipid content of meat obtained from females is higher than that of the males, and that more female animals were obtained in the sample from GR (Table 1). The highest lipid content measured was 1.42 g/100 g muscle. In 1972, Von La Chevallerie measured lipid content of 1.70% for blesbok, which is slightly higher than that found in this study. Von La Chevallerie and Van Zyl (1971) found that the fat content of springbok meat, an ungulate species regularly inhabiting the same areas as blesbok, never to exceed a value of 3.30%.

Significant interactions ($p\leq0.05$) were found for the total collagen content between age and region. The meat from the sub-adults from RF measured the highest collagen value at 2.21 %. Studies have shown that muscles, rich in collagen, tend to be tougher (Young & Braggins, 1993). Although no significant correlations were found, the meat obtained from RF scored the lowest for sensory tenderness (Smit, 2003).

Within region, significant differences ($p\leq0.05$) were found for all the amino acids (Table 3). The animals from RF measured the highest values for all the amino acids and the animals from MM the lowest. Within age groups, the values

of amino acids measured in the meat of the sub-adults were higher than for the adults. These higher values measured in the sub-adults correlate with the higher protein value for sub-adults, depicted in Table 2.

Table 3

Means for amino acid composition of MLD from blesbok as influenced by different sexes, age groups and regions (g/100 g meat sample)

	Sex			Age			Region			
	Female	Male	LSD[d]	Adult	Sub-adult	LSD	MM	GR	RF	LSD
Aspartic acid[e]	7.92	7.79	4.26	7.34	10.42	5.72	2.27[b]	8.38[a]	10.78[a]	5.33
Glutamic acid[f]	8.24	8.33	4.06	7.82	10.61	5.45	2.93[b]	8.85[a]	11.04[a]	5.09
Serine	4.97	5.00	2.52	4.68	6.51	3.38	1.48[b]	5.22[a]	6.89[a]	3.15
Glycine	4.92	5.05	2.63	4.72	6.33	3.53	1.61[b]	5.22[a]	6.82[a]	3.29
Histidine	1.77	1.71	0.74	1.66	2.18	0.99	0.76[b]	1.81[a]	2.28[a]	0.93
Arginine	3.70	3.69	1.98	3.44	4.93	2.66	1.14[b]	3.96[a]	5.01[a]	2.48
Threonine	4.66	4.68	2.38	4.40	6.04	3.19	1.49[b]	4.60[a]	6.35[a]	2.97
Alanine	6.98	7.01	3.66	6.55	9.24	4.92	2.29[b]	7.49[a]	9.42[a]	4.59
Proline	3.50	3.52	1.86	3.32	4.44	2.50	1.22[b]	3.72[a]	4.72[a]	2.33
Tyrosine	2.00	1.98	0.93	1.87	2.60	1.25	0.68[b]	2.09[a]	2.69[a]	1.17
Valine	3.92	3.86	1.96	3.65	5.06	2.63	1.34[b]	4.10[a]	5.25[a]	2.45
Methionine	1.94	1.87	0.93	1.78	2.49	1.25	0.62[b]	2.00[a]	2.59[a]	1.17
Cystine	0.63	0.60	0.32	0.58	0.81	0.42	0.18[b]	0.63[a]	0.86[a]	0.40
Isoleucine	3.11	3.09	1.58	2.92	4.02	2.12	1.05[b]	3.30[a]	4.18[a]	1.98
Leucine	6.53	6.41	3.24	6.07	8.49	4.35	2.04[b]	6.85[a]	8.82[a]	4.06
Phenylalanine	2.31	2.40	1.18	2.17	3.27	1.58	0.77[b]	2.48[a]	3.21[a]	1.47
Lysine	9.01	10.8	7.27	9.58	11.55	9.75	1.40[b]	9.53[ab]	15.31[a]	9.10

[a,b,c]Means in the same row within the same subgroup, with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e, f] Aspartic acid= aspartic acid + aspartine; Glutamic acid= Glutamic acid + glutamine

With the exception of sodium and copper no significant differences ($p>0.05$) were found for mineral content (Table 4) within sex, age groups and region. The significant differences in sodium content were found between age groups, with the sub-adults measuring a higher sodium content (17.04 mg/100 g muscle) than the adults (14.63 mg/100 g muscle). It is interesting to note that the sodium content of beef measures at 69 mg/100 g muscle (Lawrie, 1979), which is much higher than that of blesbok meat.

Significant differences ($p\leq0.05$) were found between the sexes, age groups and regions for fatty acids in mg/100 g (Table 5) and within region for percentage fatty acids (Table 6). Palmitic acid (C16:0), stearic acid (C18:0) and linoleic acid (C18:2n6) were identified as the main fatty acids in blesbok meat. Schönfeldt (1993) stated that stearic acid is a cholesterol-neutral fatty acid, whereas myristic acid (C14:0) and palmitic acid are cholesterol-raising fatty acids. The main cholesterol-lowering fatty acids are oleic acid (C18:1n-9), linoleic acid and arachidonic acid (C20:4n-6).

As can be seen in Table 5, a significant difference ($p\leq0.05$) was found for palmitic acid, which can be attributed to age and region. The meat from the adult animals (1.13 mg/100 g), from the animals obtained in MM (0.96 mg/100 g meat sample) and from GR (1.10 mg/100 g meat sample) measured significantly lower values for palmitic acid than the other groups. Beef has an average palmitic acid value of 3.27 mg/100 g, and it seems as if the cholesterol-raising capacity of blesbok is slightly lower. For stearic acid, the so-called cholesterol-neutral fatty acid, there was a significant ($p\leq0.05$) interaction (Table 7). The meat from the female animals from RF measured the highest stearic acid value (2.56 mg/100 g meat sample) and the females found in MM the lowest (1.33 mg/100 g meat sample).

Table 4
Means for mineral composition of *MLD* for blesbok as influenced by different sexes, age groups and regions (mg/100 g meat sample)

	Sex			Age			Region			
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	RF	GR	LSD
P	152.81	145.31	2.45	150.04	154.48	56.05	129.37	154.89	154.06	58.79
K	144.98	150.47	33.31	147.95	146.91	40.59	157.84	147.98	142.46	42.57
Ca	5.85	6.94	2.37	6.45	6.19	22.89	6.77	6.67	5.98	3.02
Mg	19.77	20.40	6.12	19.97	20.52	7.46	16.92	22.50	19.66	7.82
Na	14.47	15.82	1.95	14.63[b]	17.04[a]	2.38	14.49	15.52	15.16	2.50
Fe	3.31	3.96	1.24	3.79	3.06	1.51	3.73	3.34	3.83	1.59
Cu	0.13	0.27	0.24	0.21	0.14	0.29	0.44[a]	0.12[b]	0.14[ab]	0.31
Zn	2.67	1.48	4.50	2.35	1.17	5.61	1.49	1.23	3.02	5.84

[a,b]Means in the same row within the same subgroup, with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)

Table 5 shows that the sub-adults also measured a significantly higher value for stearic acid (2.19 mg/100 g meat sample). This result could, however, have been caused by the fact that there were only four sub-adults in this sample. Of the cholesterol-lowering fatty acids, only oleic acid illustrated a significant ($p \leq 0.05$) interaction with the female animals from RF having the highest value of 2.56 mg /100 g and the females from MM the lowest (1.33 mg/100 g meat sample) (Table 7). For linoleic acid and arachidonic acid there were no significant differences between the different groups (Tables 5 & 6). It was found, however, that the meat from the females and the animals from RF had the lowest values for the two respective cholesterol-lowering fatty acids.

An significant interaction ($p > 0.05$) for the P:S ratio was found between age groups and regions (Table 7) with the adults from GR measuring the highest value (1.07) and the sub-adults from RF the lowest value (0.65). In this study oleic, as well as linoleic acid, were found to be the main contributors to the PUFA. The lowest P:S ratio for blesbok meat was measured at 0.73, which is in line with the recommended P:S ratio of >0.7 (Raes *et al.*, 2003). Significant interactions ($p \leq 0.05$) were found between region and sex for the total unsaturated fatty acids (TUFA) and desirable fatty acids (DFA= C18:0 + TUFA). Meat from the female animals from RF measured the highest value for TUFA (5.24 mg/100 g) and for DFA (7.80 mg/100 g).

Significant differences ($p \leq 0.05$) were found for the n-6:n-3 ratio within age group and region (Table 5). The adults (3.69) had a higher ratio than the sub-adults (2.34). Within region, animals from MM had the highest ratio (4.90) and animals from GR (2.90) the lowest. A study concluded (Aro, Amaral, Kesteloot, Rimestad, Thamm *et al.*, 1998) that the percentage of n-3 fatty acids was found to be decreasing in the human diet. This can mainly be attributed to the consumption of high amounts of saturated fatty acids.

Raes *et al.* (2003) confirmed that research done in the field of Meat Science has recommended a decrease in the n-6:n-3 ratio of meat to a value below 5. Girolami, Marsico, D'Andrea, Braghieri, Napolitano and Cifuni (2003) reported that high amounts of linoleic and arachidonic acids were recorded in ostrich meat which resulted in a n-6:n-3 ratio of approximately 4. In this study, the n-6:n-3 ratio for blesbok ranges between 2.34 for the sub-adult animals and 4.90 for animals from MM. These values are well within the latter recommendation for the n-6:n-3 ratio.

Table 5
Means of fatty acid composition of *MLD* of blesbok as influenced by different sexes, age groups and regions (mg/100 g of total fatty acids)

	Sex			Age			Region			
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	RF	GR	LSD
Total lipid	7.73	7.22	0.94	7.16[b]	8.62[a]	1.14	6.94[b]	8.20[a]	7.30[ab]	0.23
C16:0	1.23	1.16	0.18	1.13[b]	1.43[a]	0.22	0.96[b]	1.45[a]	1.10[b]	0.23
C18:0	IA[i]	IA	IA	1.85[b]	2.19[a]	0.32	IA	IA	IA	IA
C20:0	0.02	0.02	0.01	0.21	0.02	0.01	0.02	0.03	0.02	0.01
C22:0	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
C24:0	0.04	0.04	0.02	0.04	0.04	0.03	0.03	0.04	0.04	0.03
C16:1n-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:1n-9	IA	IA	IA	1.31	1.90	0.71	IA	IA	IA	IA
C20:1n-9	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01
C24:1n-9	0.04	0.03	0.07	0.04	0.03	0.08	0.02	0.05	0.04	0.08
C18:2n-6	1.30	1.35	0.44	1.31	1.37	0.53	1.32	1.28	1.36	0.56
C18:3n-6	0.01	0.01	0.01	IA	IA	IA	IA	IA	IA	IA
C18:3n-3	0.33	0.27	0.10	0.27[b]	0.41[a]	0.12	0.22	0.33	0.32	0.13
C20:2n-6	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01
C20:3n-6	0.07	0.12	0.09	0.11	0.06	0.11	0.09	0.11	0.09	0.12
C20:4n-6	0.58	0.77	0.32	0.70	0.59	0.39	0.70	0.59	0.74	0.41
C20:5n-3	0.18	0.17	0.09	0.16	0.22	0.11	0.12	0.14	0.23	0.12
C22:4n-6	0.03	0.02	0.03	0.02	0.03	0.04	0.02	0.03	0.02	0.04
C22:5n-3	0.17	0.17	0.10	0.16	0.22	0.12	0.08[b]	0.17[ab]	0.21[a]	0.12
C22:6n-3	0.03	0.03	0.02	0.03[b]	0.05[a]	0.02	0.02[b]	0.03[ab]	0.04[a]	0.02
SFA[d]	3.38[a]	3.02[b]	2.45	3.06[b]	3.71[a]	0.34	2.67[b]	3.73[a]	3.02[b]	0.36
MUFA[e]	1.65	1.30	0.61	1.35	1.94	0.74	1.34	1.80	1.28	0.77
PUFA[f]	3.70	2.89	0.99	2.75	2.97	1.20	2.58	2.68	3.01	1.26
TUFA[g]	IA	IA	IA	4.10	4.91	1.20	IA	IA	IA	IA
DFA[h]	IA	IA	IA	5.95	7.11	1.25	IA	IA	IA	IA
PUFA:SFA	0.80	1.00	0.39	IA	IA	IA	IA	IA	IA	IA
n-6	1.99	2.26	0.78	2.14	2.07	0.95	2.14	2.01	2.22	1.00
n-3	0.71	0.63	0.27	IA	IA	IA	IA	IA	IA	IA
n-6:n-3	3.17	3.62	0.75	3.69[a]	2.34[b]	0.91	4.90[a]	3.09[b]	2.90[b]	0.96
Cholesterol	54.32	51.38	2.57	52.63	54.07	13.40	49.74	52.33	54.56	15.43

[a,b]Means in the same roe with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d,e,f,g,h] SFA=Saturated Fatty Acids; MUFA= Monounsaturated Fatty Acids; PUFA=Polyunsaturated Fatty Acids; TUFA=Total Unsaturated Fatty Acids; DFA= Desirable Fatty Acids (C18:0 + TUFA)
[i]IA=Interactions

No significant differences (p>0.05) were found for cholesterol (Table 5) content within sex, age groups and region. Within region, blesbok from GR measured the highest cholesterol content at 54.56 mg/100 g. This was probably due to the fact that more animals were obtained from the GR region than from the other regions. The cholesterol content of blesbok seems relatively low in comparison to other types of meat. South African beef has a cholesterol content of 89.58 mg/100 g (Schönfeldt, 1993). According to Horbanczuk *et al.* (1998), however, the cholesterol content of ostrich is 65.63 mg/100 g.

Table 6

Means of fatty acid composition (% of total fatty acids identified) of *MLD* for blesbok as influenced by different sexes, age groups and regions (%)

	Sex			Age			Region			
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	RF	GR	LSD
C16:0	16.34	16.44	3.50	16.36	16.51	4.27	15.56	18.19	15.31	4.48
C18:0	27.19	24.70	3.98	26.08	25.46	4.85	26.19	26.71	25.20	5.09
C20:0	0.29	0.31	0.07	0.30	0.30	0.09	0.30	0.33	0.28	0.09
C22:0	0.28	0.31	0.16	0.30	0.27	0.19	0.28	0.29	0.31	0.20
C24:0	0.50	0.57	0.28	0.56	0.46	0.34	0.44	0.53	0.58	0.36
C16:1n-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:1n-9	IA[d]	IA	IA	16.97	21.42	7.78	IA	IA	IA	IA
C20:1n-9	0.05	0.04	0.10	0.05	0.04	0.11	0.05	0.00	0.09	0.12
C24:1n-9	0.51	0.49	0.97	0.51	0.47	1.18	0.28	0.69	0.46	1.23
C18:2n-6	16.89	18.89	4.48	18.39	16.09	5.46	19.85	15.83	18.63	5.72
C18:3n-6	0.07	0.08	0.09	IA	IA	IA	IA	IA	IA	IA
C18:3n-3	4.16	3.72	1.28	3.71	4.81	1.56	3.22	4.07	4.20	1.64
C20:2n-6	0.05	0.03	0.08	0.04	0.04	0.10	0.02	0.00	0.08	0.10
C20:3n-6	1.00	1.85	1.48	1.60	0.77	1.8	1.38	1.60	1.30	1.89
C20:4n-6	7.73	10.96	3.40	10.00	6.94	4.14	10.49	7.66	10.21	4.34
C20:5n-3	2.26	2.39	0.93	2.24	2.63	1.13	1.84[b]	1.75[b]	3.05[a]	1.18
C22:4n-6	0.35	0.22	0.41	0.26	0.39	0.50	0.34	0.35	0.20	0.52
C22:5n-3	2.22	2.43	1.07	2.23	2.66	1.30	1.29[b]	2.22[ab]	2.93[a]	1.37
C22:6n-3	0.41	0.39	0.13	IA	IA	IA	IA	IA	IA	IA

[a,b]Means in the same row with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d]IA=Interactions

Table 7

Fatty acid interactions (means) present in *MLD* of blesbok as influenced by different sex, age and region combinations

	R[d]	S[e]	R*S	LSD[c]	R	A[f]	R*A	LSD
C18:0	GR	Female	2.01[b]	0.50				
(mg/100 g)	GR	Male	1.49[c]					
	MM	Female	1.33[c]					
	MM	Male	1.82[b]					
	RF	Female	2.56[a]					
	RF	Male	1.95[b]					
C18:1n-9	GR	Female	1.57[a]	1.10				
(mg/100 g)	GR	Male	0.58[b]					
	MM	Female	0.38[b]					
	MM	Male	1.79[a]					
	RF	Female	2.29[a]					
	RF	Male	1.39[a]					
C18:3n-6					GR	Adult	0.010[b]	0.001
(mg/100 g)					GR	Sub-adult	0.005[c]	
					MM	Adult	0.003[d]	
					RF	Adult	0.000[e]	
					RF	Sub-adult	0.030[a]	
C18:01	GR	Female	20.12[a]	12.13				
(%)	GR	Male	9.40[b]					
	MM	Female	9.17[b]					
	MM	Male	22.62[a]					
	RF	Female	24.09[a]					
	RF	Male	16.37[a]					
C18:3n-6					GR	Adult	0.14[a]	0.17
(%)					GR	Sub-adult	0.07[b]	
					MM	Adult	0.03[b]	
					RF	Adult	0.00[b]	
					RF	Sub-adult	0.29[a]	
C22:6n-3					GR	Adult	0.10	0.23
					GR	Sub-adult	0.06	
					MM	Adult	0.02	
					RF	Adult	0.00	
					RF	Sub-adult	0.00	
TUFA	GR	Female	4.54[a]	1.86				
(mg/100 g)	GR	Male	3.79[a]					
	MM	Female	1.86[b]					
	MM	Male	4.95[a]					
	RF	Female	5.24[a]					
	RF	Male	3.97[a]					
DFA	GR	Female	6.54[a]	1.95				
(mg/100 g)	GR	Male	5.28[b]					
	MM	Female	3.19[c]					
	MM	Male	6.77[a]					
	RF	Female	7.80[a]					
	RF	Male	5.91[a]					
P:S					GR	Adult	1.07	0.71
					GR	Sub-adult	0.91	
					MM	Adult	0.97	
					RF	Adult	0.76	
					RF	Sub-adult	0.65	
n-3					GR	Adult	0.72	0.49
					GR	Sub-adult	0.93	
					MM	Adult	0.45	
					RF	Adult	0.62	
					RF	Sub-adult	0.86	

[a,b]Means in the same column between the subgroups with different superscripts are significantly different

[c]LSD=Least significant difference (p=0.05)

[d,e,f] R=Region, S=Sex, A=Age

Conclusion

Significant differences were in the meat samples found for lipid content, amino acids and fatty acids, and between the sexes for lipid and fatty acid content. In this study the lipid content of the females was higher than that of the males. The highest mean value recorded for lipid content was 1.42 g/100 g. This is lower than the value recorded for springbok in a similar study (Von La Chevallerie & Van Zyl, 1971). Significant differences were found within age groups for lipid, mineral (Na) and fatty acid content (C16:0). The adult animals also had a higher n-6:n-3 ratio than the sub-adult animals. Significant differences were also found between regions for lipid, mineral (Cu), amino acids and fatty acid content. The animals from the GR region had the highest values for most of the amino acids and animals from the RF region the highest value for palmitic and stearic acid. Blesbok from the MM region had the highest n-6:n-3 ratio, whereas animals from the GR and RF regions measured significantly lower.

Significant interactions were found for total collagen content between regions and age groups. Likewise the interactions for fatty acids found between regions and sexes, as well as between regions and age groups were significant. Meat from the female animals found in RF had the highest TUFA and DFA interaction, and the adults from GR the highest P:S interaction.

Finally it can be concluded that the sex, age group and region did not significantly influence the chemical composition of meat. Although there were differences, it was mostly statistical. The chemical composition of blesbok meat should be taken into account in the composition of human dietary tables. The data provides evidence that the meat of the blesbok should be considered as a healthy alternative source of protein.

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Physical and sensory characteristics of blesbok (*Damaliscus dorcas phillipsi*) meat

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Abstract

The aim of this study was to determine the effect of the sex and age of the animals and possible regional influences on the physical (pH_{45}, $Temp_{45}$, pH_{24}, $Temp_{24}$, L*-value, a*-value, b*-value, hue-angle, chroma, percentage drip loss, percentage cooking loss and Warner-Bratzler shear force value (WBS)) and sensory properties (aroma, flavour, initial juiciness, sustained juiciness, first bite and residue) of *M. longissimus dorsi* (*MLD*) from blesbok. A total of 73 blesbok (males and females), from different age groups (adult, sub-adult and lamb) and from four regions (Qua-Qua (QQ), Maria Moroka (MM), Rustfontein (RF) and Gariep (GR) in the Free State Province, South Africa) were used to determine the physical properties. Sex and age had no effect on pH_{24}, whilst the meat from the blesbok from RF had the highest pH_{24} (5.74) and tended to be dark, firm and dry. Within region, animals from QQ had the darkest meat (L*-value=27.94) and animals from GR had the highest a*-value (13.67) and b*-value (9.52). The animals from QQ had the highest drip loss (8.22%), whilst the blesbok from MM had the highest cooking loss (40.58%). Animals from QQ had the highest WBS values (3.56 kg/1.27 cm diameter). Region had an effect on aroma, with animals from GR having the highest game aroma (6.46). Significant interactions were found between sexes and age groups for initial juiciness, sustained juiciness, first bite and residue.

Keywords: pH, temperature, colour, drip loss, cooking loss, shear force, sensory characteristics

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Introduction

Throughout South Africa an increase in the utilization of wildlife on private land has occurred. In 1985 it was estimated that approximately 10 000 farmers derived an income from wildlife utilization (Luxmore, 1985). This is nowhere more evident than in the Limpopo Province of South Africa. Here, cattle numbers have declined in favour of game-ranching activities (Robinson & Lademann, 1998). Therefore, the development of game meat marketing in South Africa has been identified as a key priority to the game industry (Pauw, 1993).

Game meat is a unique product in that it is low in fat, is produced organically and the meat from each species has a distinctive flavour (Pauw, 1993). The significant growth in human population and advancing agriculture, necessitates

researchers to obtain knowledge of the potential of game meat as an alternative source of proteins, minerals and other nutrients (Von La Chevallerie, 1970).

Meat will only be consumed in increasing quantities if it is acceptable to consumers and appeals on the basis of taste, colour and palatability (Weir, 1960). Red meat is considered to have a more intense flavour than meat with a whiter colour (Quali, 1991) and it is generally known that the different fatty acids affect the flavour profile of the meat (Fisher et al., 2000).

The colour of meat is also important because it plays an important role in acceptability (Stevenson, Seman, Weatherall & Littlejohn, 1989). Game meat is often perceived as having an unattractive dark red colour (Von La Chevallerie, 1972). According to Hoffman (2000a), game meat is darker than that of domestic animals. The increased level of myoglobin due to high levels of physical activity is partly responsible for the darker colour of game meat (Vestergaard, Oksbjerg & Henckel, 2000). However, according to Hoffman (2000a) an intensely dark colour could also be due to the ante-mortem stress caused during the cropping of the animals.

In addition to colour, other characteristics such as juiciness and tenderness can also influence the acceptability thereof. Dark, firm and dry (DFD) meat is defined as meat with pH higher than 5.8 (Wiklund, Barnier, Smulders, Lundström, & Malmfors, 1997). In meat from non-domestic animals such as reindeer, DFD characteristics are sometimes present in carcasses of bull calves (Wiklund, Andersson, Malmfors, Lundström, & Danell, 1995). Percentage drip loss is often regarded as an indication of juiciness. The drip loss of beef is estimated at 4 to 6% (Hornick, Van Eenaeme, Clinquart, Diez & Istasse, 1998), whereas according to Hoffman (2000a), the drip loss of game species such as impala is much lower at approximately 2.55%. Game meat is not always perceived as tender. However, Wicklund et al. (1997) found that the Warner-Bratzler shear force values (WBS) were very low for reindeer meat regardless of sarcomere length and ultimate pH. Hoffman (2000a) also found that the WBS values of impala (3.65 kg/1.27 cm diameter) were similar to that for pigs (3 kg/1.27 cm diameter), as reported by Fisher, Mellet and Hoffman (2000a).

Limited scientific data is available on the physical and sensory characteristics of blesbok meat and therefore the purpose of this study was to determine the effects of sex, age groups and possible regional effects on the physical and sensory characteristics of blesbok meat.

Materials and methods

Harvesting

Blesbok, representing different age groups (adult, sub-adult and lamb) and both sexes were harvested during 2001 and 2002 from nature reserves in the Free State Province (Table 1). Apart from the adult and sub-adult animals mentioned in Table 1, two male and two female lambs were also obtained from Gariep (GR) Nature Reserve. As both males and females have horns, the length and width of the animals' horns were used to obtain the animals' age. Animals with no horns or short straight horns were classified as lambs and animals with horns of intermediate size were classified as sub-adults. Animals with fully developed horns were classified as adults. All the animals were obtained in the period of May to September (Autumn to Spring). Blesbok from Qua-Qua (QQ) were culled in the middle of July in cold, windy conditions (±-7°C). The animals were selected randomly during organized game culling operations and shot either in the head or neck with .274 or .270 calibre rifles. All the animals were exsanguinated in the field. During 2001 the

blesbok were shot during the daytime and either during the daytime or at night in 2002. Due to unforeseen circumstances neither lambs nor samples from QQ were used for sensory evaluation (Table 2).

Table 1
Number of blesbok harvested during 2001 and 2002 in the Free State Province

Year	Region	Total	Adult		Sub-adult	
			Male	Female	Male	Female
2002	MM[a]	7	6	1	0	0
2002	GR[b]	36	5	24	0	3
2001	QQ[c]	13	8	5	0	0
2001	RF[d]	17	9	7	1	0

[a]MM=Maria Moroka
[b]GR=Gariep
[c]QQ=Qua-Qua
[d]RF=Rustfontein

Table 2

Distribution of blesbok according to classgroups utilised for sensory evaluation

	Sex		Age		Region		
Total	Female	Male	Adult	Sub-adult	GR	MM	RF
14	7	7	11	3	6	3	5

Physical analyses

pH

After being shot, the pH values (pH_{45} and pH_{24}) of the *M. longissimus dorsi et lumborum (MLD)* were measured between the 6th and 7th rib with a hand-held Crison pH/ mV- 506 meter equipped with a glass-electrode. The pH meter was re-calibrated after every 4th reading. The electrode was rinsed with distilled water between measurements. After the first pH reading was taken, the animals were transported to the slaughter facility where they were skinned. The carcasses were then hung by their Achilles-tendon in a cooler at a set temperature of 4°C. Both the *MLD* was removed between the 6th and th rib and anterior to the 5th lumber vertebrae from the carcasses at 24 hours post-mortem. Where applicable, the muscle on the right-hand side was used for sensory analysis and the muscle on the left-hand side for the physical analyses. For the determination of colour, drip and cooking losses, 1.0-1.5 cm thick steaks were removed from the anterior section of the *MLD*.

Colour

The meat colour was evaluated using a Minolta Chroma Meter CR 200 (Pacific Scientific, Silver Spring, MD, USA) after a blooming period of 20 min. The parameters measured were the L* (lightness), a* (red-green range) and b* (blue-yellow range) values (Honikel, 1998). The hue angles and chroma values were calculated according to the method of Hunter and Harold (1987).

Drip loss

Percentage drip loss was determined on fresh *MLD* steak. The meat samples were weighed individually (approximately 20 g and ±1 cm thick) and placed in a net enclosed in a bag in such a manner that the exudate did not come into contact with the sample. The meat samples were dried and weighed again after a storage period of 24 h at 4°C and the percentage drip loss was expressed as a percentage of the initial weight (Honikel, 1998).

Cooking loss

The percentage cooking loss was also determined on the fresh meat samples after weighing the MLD steaks. Individual slices (approximately 20 g and ±1 cm thick) were placed in a water bath and at a temperature of 75°C for 50 min. The samples were then removed from the water bath and cooled in cold water. The meat was removed from the bag, blotted dry, weighed and cooking loss was expressed as a percentage of the initial sample weight (Honikel, 1998).

Warner-Bratzler shear force

The shear force of the cooked meat (the same samples that were used for cooking loss) was determined by using a Warner-Bratzler shear attachment (Voisey, 1976) fitted to an electronic scale. Three cylindrical samples were removed from the centre of each *MLD* muscle by using a 12.7 mm diameter core. Maximum shear force (kg/1.27 cm diameter) required for shearing a cylindrical sample of cooked muscle perpendicular to the grain was recorded (Honikel, 1998) at a crosshead speed of 229 mm/min. A higher value indicated a greater shear force and therefore tougher meat.

Descriptive sensory analysis

The cuts selected for sensory analysis were kept frozen at -20 °C. Samples of the *MLD* were roasted for sensory analysis. The cuts were defrosted for 24 h at a temperature of 3°C - 4°C and were wrapped individually in cooking bags and placed on a grid of an open roasting pan. The *MLD* samples were roasted in two electric Defy 835 ovens connected to a computerised temperature control system (Viljoen, Muller, De Swart, Sadie, & Vosloo, 2001). Thermocouples were inserted in the centre of each piece of meat and the samples were roasted to an internal temperature of 70°C in a preheated oven at 180°C (AMSA, 1995). After the roasting process, 1.5 cm x 1.5 cm cubed samples were taken from the middle of each muscle, wrapped in foil and marked with three digit codes, and placed in preheated glass ramekins. The samples were evaluated within 10 min from the time the meat was removed from the oven.

A six-member descriptive panel was selected and trained according to the generic descriptive analysis technique and the procedures described in the American Meat Science Association (AMSA, 1995) guidelines. The panel evaluated the meat for the following attributes: game aroma intensity, initial and sustained juiciness, first bite, residue and overall game flavour. The judges rated the samples using an 8-point structured scale (AMSA, 1995). Crackers and distilled water were used to cleanse the palate between samples. The reliability of the panellists was tested through a test-retest session. Statistical analysis of the data proved that all the panellists were consistent in their discrimination between the samples. They were all experienced panel members and have tasted various meat samples for the past four years.

Statistical analysis

A three factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were four areas (QQ, MM, RF and GR), two sexes and two or three age groups (lamb, sub-adult and adult). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 1999) statistical software. A Shapiro-Wilk test was performed to test for non-normality (Shapiro and Wilk, 1965). Student's t-Least Significant Differences were calculated at the 95% confidence level to compare treatment means (Ott, 1998). Where applicable, Pearson's correlations were determined using the Proc Corr procedure of SAS (1990).

Results and discussion

Physical characteristics

The physical characteristics of the MLD of blesbok are depicted in Table 3. Significant differences ($p \leq 0.05$) were found for pH_{45} within age and region, where lamb had the highest pH_{45} (6.24) and sub-adults the lowest pH_{45} (5.84). Animals from MM were cropped during daytime and had the highest pH_{45} (6.25) and blesbok with the lowest pH_{45} (5.74) were obtained from QQ during the night. By contrast, Kritzinger (2002) found that the pH_{45} of impala cropped at night were significantly higher than those shot in daytime. Significant differences ($p \leq 0.05$) for $Temp_{45}$ were found between the regions where RF had the highest (37.41°C) value. The latter high value could be ascribed to the fact that blesbok cropped at RF ran for kilometers before they were shot. Interactions ($p \leq 0.05$) were found for $Temp_{45}$ between sex and age groups. The female sub-adults had a significant higher (26.38°C) value than the other combinations although this value could be biased because female sub-adults were only obtained from GR, whilst the female lambs had the lowest value (30.60°C).

Significant differences ($p \leq 0.05$) were found for $Temp_{24}$ and pH_{24} between sexes, age groups and regions. The males had a higher value for both pH_{24} (5.54) and $Temp_{24}$ (7.25°C) when compared to the females. Regarding age, the adults had the highest value for both pH_{24} (5.49) and $Temp_{24}$ (6.62°C) and lamb the lowest. Animals from RF probably had the highest pH_{24} because all the animals experienced stress during culling in this region. These animals were shot during the daytime when animals are usually anxious. Another reason for the high pH_{24} could be the fact that the animals ran for kilometers before they were shot and the fact that the position of the shot varied from neck, breast, shoulder and buttock, which, in both cases, could also cause the animals to stress. The animals obtained from MM had the lowest pH_{24}, probably because the animals were shot at night in the head without running significant distances. Hoffman (2000a) also noted that impala cropped during the daytime had higher pH_{24} values than those shot at night. In the latter study only two animals moved slightly (20 m and 200 m) before they were shot. Veary (1991) also reported higher ultimate pH values for springbok harvested during the daytime. In this study, the blesbok at MM were cropped at the end of August when the ambient night temperature was much higher (±6°C) than in the middle of the winter (±-5°C) and this explains the high $Temp_{24}$ for this region. However, in QQ the blesbok were culled in the middle of July with a cold wind blowing, where after the carcasses were transported in a cool truck of approximately 4°C. This could be the reason for the low $Temp_{24}$ for QQ. The reason why the male's pH_{45} and pH_{24} were slightly higher than that of the female animals could be as a result of the heightened physical activity of the males due to the rutting season.

Sex and age had no statistically significant effect on the muscle colour, but significant differences ($p \leq 0.05$) were found for L*-, a*-, b*- and chroma values between regions. Within region, animals from QQ had the darkest meat (L*-value = 27.94) and animals from GR had the highest a*-value (13.67) and b*-value (9.52) indicating meat with a prominent red colour. Hoffman (2000a) recorded similar values for night-cropped impala (L*-value=29.22, a*-value=11.26, b*-value=7.76). No significant differences ($p > 0.05$) were found for hue angles. High a*- and b*-values caused a higher saturation (chroma) and this was the case for GR with the highest chroma value (16.72). A high chroma value is desirable because the muscle will appear bright with greater colour purity (Onyango, Izumimoto & Kutima, 1998). The typical dark red colour of blesbok meat is due to the low percentage of intra-muscular fat present in the meat (Hoffman, 2000b). Furthermore, free-range animals such as blesbok are much more active than stall-fed animals and therefore have more muscle pigment (Lawrie, 1979). Thus, one can expect game meat to have a dark red colour.

Significant differences ($p \leq 0.05$) were found for drip loss and cooking loss between regions. Blesbok obtained from QQ (8.22%) had the highest drip loss and animals obtained from MM (2.47%) the lowest.

Table 3
Means for pH_{45}, $Temp_{45}$, pH24, $Temp_{24}$, L*-, a*- and b*-values, drip loss, cooking loss and WBS of *MLD* for blesbok as influenced by different sexes, age groups and regions.

	Sex			Age				Region				
	Female	Male	LSD[d]	Adult	Sub-adult	Lamb	LSD	QQ	MM	RF	GR	LSD
pH_{45}	6.12	6.18	0.15	6.16^{ab}	5.84^{b}	6.24^{a}	0.34	5.74^{b}	6.25^{a}	6.14^{a}	6.19^{a}	0.27
$Temp_{45}$	IA[f]	IA	IA	IA	IA	IA	IA	34.38^{b}	34.54^{b}	37.41^{a}	35.83^{ab}	2.44
pH_{24}	5.46	5.54	0.11	5.49	5.58	5.43	0.24	5.47^{b}	5.30^{b}	5.74^{a}	5.41^{b}	0.19
$Temp_{24}$	5.85^{b}	7.25^{a}	0.54	6.62^{a}	5.67^{ab}	4.80^{b}	1.30	1.94^{d}	10.10^{a}	8.54^{b}	5.21^{c}	0.96
L*-value	31.18	30.53	1.53	30.59	33.64	32.961	3.712	27.94^{c}	32.86^{a}	30.07^{bc}	31.96^{ab}	2.51
a*-value	13.10	12.54	0.88	12.88	11.94	13.46	2.13	12.35^{ab}	12.23^{b}	11.84^{b}	13.67^{a}	1.44
b*-value	8.94	8.46	0.96	8.67	8.54	9.82	2.32	7.80^{b}	8.28^{ab}	8.01^{ab}	9.52^{a}	1.57
Hue	33.62	33.98	2.74	33.54	35.01	36.10	6.68	31.51	33.89	33.49	34.66	4.51
Chroma	15.98	15.26	1.11	15.66	14.77	16.75	2.70	14.82^{b}	14.92^{ab}	14.43^{b}	16.72^{a}	1.82
Drip loss (%)	4.49	4.30	2.57	4.51	3.12	4.01	6.31	8.22^{a}	2.48^{b}	3.44^{b}	3.97^{ab}	4.26
Cooking loss (%)	33.47^{b}	36.11^{a}	1.72	34.54	33.66	36.61	4.45	29.21^{c}	40.58^{a}	35.19^{b}	34.94^{b}	2.80
WBS (kg/1.27 cm diameter)	2.70	3.05	0.46	2.89	2.35	2.55	1.12	3.56^{a}	3.31^{ab}	2.73^{b}	2.56^{b}	0.76

[a,b,c]Means in the same row within subgroups with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e]IA=Interaction

Conversely, animals from MM had the highest cooking loss (40.58%) and blesbok from QQ the lowest cooking loss (29.21%). No significant correlations were found to explain these results. Muscles high in intramuscular fat tend to have a high water-holding capacity (Saffle & Bratzler, 1959), however, no significant ($p > 0.05$) correlations ($r = 0.14$) were found between fat and water-holding capacity for this study. This low correlation could most likely be ascribed to the low fat content of blesbok meat (Smit, 2003).

Significant differences ($p \leq 0.05$) were found for WBS between regions. Animals from QQ (3.56 kg/1.27 cm diameter) had the highest shear force value, whilst blesbok from GR (2.56 kg/1.27 cm diameter) had the lowest. According to Bailey and Light (1989) there is a relation between pH and tenderness. However, no significant ($p > 0.05$) correlation ($r = -0.02$) was found in the present study between pH_{24} and WBS values. This tendency could be due to the fact that GR with the lowest value for WBS had more females in the sample and QQ with the highest WBS value more males in the sample. In the other regions such as RF, the high $Temp_{24}$ could have caused an earlier activation of μ-calpain, which tends to result in more tender meat at 24 h post-mortem (Hwang & Thompson, 2001). Literature indicates that μ-calpain is responsible for the degradation of myofibrillar and associated proteins (Koohmaraie, 1996).

Sensory characteristics

Significant differences ($p \leq 0.05$) for aroma were only found within region (Table 4). Animals from GR had the highest game aroma (6.46), whilst animals from MM (6.00) the lowest. According to Lawrie (1979), the aroma of older animals is stronger than that of younger animals of the same species. Although not significant, there was a tendency for the samples of the sub-adults to have a less strong aroma than the adult animals. Significant interactions ($p \leq 0.05$) were found for flavour between sex and age groups with the sub-adult males having the least intense game flavour (Table 5).

As expected, a significant ($p \leq 0.05$) correlation ($r=0.03$) was found between flavour and aroma. However, the correlation ($r=0.23$) between flavour and lipid content (Smit, 2003) was not significant ($p>0.05$).

Table 4
Means for the sensory quality characteristics of *MLD* for blesbok as influenced by different sexes, age groups and regions

	Sex			Age			Region			
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	GR	RF	MM	LSD
Aroma[d]	6.07	6.41	0.34	6.56	6.15	0.41	6.46[a]	6.13[ab]	6.00[b]	0.43
Game flavour[d]	IA[h]	IA	IA	IA	IA	IA	6.20	6.10	5.89	0.38
Initial juiciness[e]	IA	IA	IA	IA	IA	IA	6.42	6.33	6.61	0.38
Sustained juiciness[e]	IA	IA	IA	IA	IA	IA	6.22[ab]	5.93[b]	6.39[a]	0.40
First bite[f]	IA	IA	IA	IA	IA	IA	6.69[a]	6.03[b]	6.44[ab]	0.44
Residue[g]	7.00[b]	7.33[a]	0.28	7.28	7.14	0.34	7.33[a]	6.83[b]	7.39[a]	0.35

[a,b]Means in the same row within subgroups with different superscripts are significantly different
[c]LSD=Least significant difference ($p=0.05$)
[d]1=extremely bland, 8=extremely intense
[e]1=extremely dry, 8=extremely juicy
[f]1=extremely tough, 8=extremely tender
[g]1=abundant, 8=none
[h]IA = Interaction

Although no significant differences ($p>0.05$) were found for initial juiciness, significant differences ($p \leq 0.05$) were found for sustained juiciness within region (Table 4). Animals from MM (6.39) had the highest sustained juiciness and animals from RF (5.93), the lowest. This difference could not be explained by cooking loss, as no significant ($p>0.05$) correlation was found between cooking loss and sustained juiciness ($r=-0.12$). The lipid content for both regions are nearly the same and this could not have had any effect on these attributes (Smit, 2003).

Table 5
Means for significant sex and age interactions for the sensory characteristics of *MLD* from blesbok

	S[g]	A[h]	S*A	LSD[c]
Initial juiciness[d]	Female	Sub-adult	6.08[b]	0.54
	Female	Adult	6.40[b]	
	Male	Sub-adult	7.33[a]	
	Male	Adult	6.42[b]	
Sustained juiciness[d]	Female	Sub-adult	5.92[b]	0.59
	Female	Adult	6.23[a]	
	Male	Sub-adult	6.67[a]	
	Male	Adult	6.08[b]	
First bite[e]	Female	Sub-adult	6.75[a]	0.64
	Female	Adult	6.53[a]	
	Male	Sub-adult	7.00[a]	
	Male	Adult	6.08[b]	
Game flavour[f]	Female	Sub-adult	6.33[a]	0.63
	Female	Adult	6.13[a]	
	Male	Sub-adult	5.50[b]	
	Male	Adult	5.97[b]	

[a,b]Means in the same row between subgroups with different superscripts are significantly different
[c]LSD=Least significant difference ($p=0.05$)
[d]1=extremely dry, 8=extremely juicy
[e]1=extremely tough, 8=extremely tender
[f]1=extremely bland, 8=extremely intense
[g,h] S=Sex, A= Age group

Significant interactions ($p \leq 0.05$) were found for initial and sustained juiciness between sex and age groups (Table 5). For both juiciness characteristics, the male sub-adults had the highest value and the female sub-adults the lowest. These values could, however, be biased because a limited number of sub-adult animals were included in this study.

First bite indicated significant differences ($p \leq 0.05$) within region (Table 4). Blesbok from GR had the highest value for first bite (6.69) and animals from RF the lowest value (6.03). Similar results were obtained for residue indicating that the meat from GR is slightly more tender than that from RF. Significant interactions ($p \leq 0.05$) were also found for first bite between sex and age groups, with the male sub-adults (7.00) having slightly more tender meat than the male adults (6.08) (Table 5). However, with regard to the sensory attribute residue, the males (7.33) and adult animals (7.28) had higher values indicating increased tenderness (Table 4). In this study no significant ($p > 0.05$) correlation ($r = -0.34$) was found between sensory tenderness and WBS, as well as between total collagen (Smit, 2003) and first bite ($r = -0.11$).

Conclusion

This study found that sex, age and regions do affect the physical and sensory properties of blesbok meat. A sex-effect was found for $Temp_{24}$, percentage cooking loss and tenderness (residue). The results further indicate that the males had the highest values for pH_{45}, pH_{24}, $Temp_{24}$, percentage cooking loss, WBS and hue. An age group effect was only found for pH_{45} and $Temp_{24}$. Ambient temperature, stress and daytime activity influenced $Temp_{45}$. However, as only four sub-adults were used in the study, the results regarding the sub-adults could be biased. Significant interactions between sex and age were found for four of the six sensory characteristics. The male sub-adult animals had the highest value for initial and sustained juiciness and first bite (indicating a juicy and tender cut of meat) and the lowest value for game flavour (indicating a moderately strong game flavour).

A regional effect was found for all the physical characteristics, except for hue values, due to the distribution of different sex and age groups as well as pre-slaughter stress. Animals from GR had the highest values for a*-, b*-colour value, chroma values, as well as hue angle indicating a slightly brighter red meat colour. The dark red colour of blesbok meat could be as a result of the low percentage of intra-muscular fat, as well the fact that game meat contains a high percentage muscle pigment. Region also had a significant effect on the sensory quality characteristics. With regard to juiciness, MM scored higher that RF, whereas in the case of tenderness GR scored higher than RF.

The differences between the main effects were mainly statistical and the consumer will not be able to recognize a difference. The taste panel used only the upper part of the sensory scale, and this indicates that although blesbok meat is low in fat, it still tends to be a juicy and tender product. Therefore, blesbok meat is a suitable alternative for the consumer who is looking for a healthy and high quality product.

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Morphological characteristics of red hartebeest (*Alcelaphus buselaphus caama*) meat

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Abstract

The aim of this study was to determine the effect of sex, age and region on the morphological characteristics (body weight, carcass weight, length, breadth, depth, buttock circumference, chest circumference, leg length and dressout percentage) of red hartebeest. A total of 49 red hartebeest of different sexes (male and female), different age groups (adult, sub-adult and calf) and four regions (Qua-Qua (QQ), Maria Moroka (MM), Sandveld (SV) and Tussen die Riviere (TDR) in the Free State Province, South Africa) were measured. The male body weight (126.36 kg) and carcass weight (68.46 kg) was significantly higher than that of the females. As expected, the adults' body weight and carcass weight measured the highest within age groups. Within region, red hartebeest from QQ had the highest body weight (142.19 kg) and carcass weight (74.85 kg). In the Age*Region interaction for dressout percentage the sub-adults from TDR had the highest (57.92%) and adults from MM (47.26%) the lowest value. Body weight, carcass weight, carcass depth and buttock circumference were the only characteristics that increased linearly with age. The females had a higher leg length (66.03 cm) than the males.

Keywords: morphological characteristics, game meat, yield

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Introduction

Game meat is usually sold per animal or per kilogram. It is therefore important to know which animals will give the highest dressout percentage or yield of meat. During culling, certain morphological characteristics are frequently used in the field to determine the sex and age of the animal, and this can ultimately give an indication of its potential yield of meat. Von La Chevallerie (1970) notes that the live weight of an animal alone does not reflect its meat production potential. However, carcass weight can give a good indication of an animal's meat production potential if sufficient data on the carcass composition is available. Indigenous animals frequently show an higher yield of meat per unit region and this results in greater financial return from meat production (Hopcraft, 1980). Furthermore, Berry (1986) noted that game meat production was the most profitable strategy for game farms in terms of return per kilogram of biomass when compared to live sales, trophy hunting and recreational hunting. According to Von La Chevallerie (1970) the dressing percentage of ungulates vary between 55 and 61%.

In 1994 the estimated number of red hartebeest (*Alcelaphus buselaphus caama)* in the Limpopo Province (previously known as Northern Province) was 15 000 (Van der Waal & Dekker, 2000). This indicates that there is an enormous potential for red hartebeest meat production.

The aim of this study was to compare the morphological carcass characteristics of red hartebeest from four different regions, and to determine the possible effects of sex and age on these characteristics.

Materials and methods

Harvesting

Red hartebeest, representing different age groups (adult, sub-adult and calf) and both sexes were obtained during 2001 and 2002 from four nature reserves in the Free State Province, South Africa (Table 1). Apart from the sub-adult and adult animals, one female calf was also obtained from Tussen die Riviere (TDR) Nature Reserve. As both the male and the female have horns, the length and width of the animals' horns were used to determine the animals' age. Animals with no horns or straight horns were classified as calves. Animals with horns of intermediate size were classified as sub-adults and animals with fully developed horns were classified as adults. Only male and female adult and sub-adult red hartebeest were obtained from Qua-Qua (QQ), Maria Moroka (MM) and Sandveld (SV) during 2001, whilst animals from all three age groups were obtained from and TDR during 2002 (Table 1). Due to unforeseen circumstances it was not possible to obtain the measurements from SV and some of the carcass weights from TDR. The animals were selected randomly and either shot in the head or neck with .274 or .270 calibre rifles during organized game cropping operations. No trophy animals (identified by their horn size) were shot. All the animals were exsanguinated in the field as soon as possible after shooting. In 2001 red hartebeest were shot during the daytime and during the night in 2002.

Morphological measurements

The morphological measurements described in Table 2 were executed on the red hartebeest in 2001 and 2002. From Table 2 it can be seen that there is an uneven distribution of the animals regarding age.

Table 1
Number of red hartebeest harvested during 2001 and 2002 in the Free State Province

Year	Region	Total	Adult		Sub-adult	
			Male	Female	Male	Female
2002	MM[a]	19	2	9	3	5
2002	TDR[b]	12	5	3	0	4
2001	QQ[c]	7	5	2	0	0
2001	SV[d]	10	1	2	5	2
Total			13	16	8	11

[a]Maria Moroka
[b]Tussen die Riviere
[c]Qua-Qua
[d]Sandveld

Statistical analysis

A three factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were the four areas (QQ, SV, MM and TDR), the two sexes and the three age groups (calf, sub-adult and adult). A single carcass was considered to be an experimental unit. The variables were recorded as

interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 1999) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro and Wilk, 1965). Student's t-Least Significant Differences were calculated at the 95% confidence level to compare treatment means (Ott, 1998).

Table 2
Units, apparatus and description for measuring the morphological traits of red hartebeest

Characteristic	Unit	Apparatus	Description
Body weight	kg	Electronic scale	Animal weight after bleeding
Carcass weight	kg	Electronic scale	Weight of the skinned animal without the weight of the head, intestines and hooves
Dressout percentage	%		Carcass weight/ Body weight × 100
Carcass length	cm	Steel slide-rule	Measured from the base of the neck to the base of the tail at the junction of the pelvis
Carcass breadth	cm	Steel slide-rule	Measured between the widest points of the rib cage, posterior to the forelegs
Carcass depth	cm	Steel slide-rule	Measured from the spine to the sternum, posterior to the forelegs
Buttock	cm	Standard tape measure	Measured at the top of the leg at the junction with the abdomen; around the leg
Chest	cm	Standard tape measure	Measured around the chest, posterior to the forelegs
Leg length	cm	Standard tape measure	Measured from the top of the inner thigh to the hock

Results and discussion

The morphological results of red hartebeest are depicted in Table 3. It was difficult to see the effect of age as a result of the skewness due to sampling. Body weight and carcass weight indicated significant differences ($p \leq 0.05$) for sexes, age groups and regions. Within sexes, the male body weight (126.36 kg) and carcass weight (68.46 kg) were significantly ($p \leq 0.05$) higher than the females' body weight (99.31 kg) and carcass weight (51.48 kg). In comparison to the females, the male animals usually have a higher weight, because of their thicker necks and heavier forequarters. According to Von La Chevallerie (1970) mature males are heavier than mature females in most species. The hartebeest from QQ had the highest mean body weight (142.18 kg) and carcass weight (74.85 kg), compared to the other regions. This was most probably due to the fact that more males than females were obtained from QQ.

Interactions ($p \leq 0.05$) were found for dressout percentage for age groups and regions as well as for sex and regions. In the Age*Region interaction, the adult animals from MM had the lowest (47.26%) and the sub-adults from TDR the highest (57.92%) dressout percentage. The female animals from MM had the lowest (47.93%) and the males from TDR the highest values in the Sex*Region interaction. However, the dressout percentage of red hartebeest from this study is lower than that reported for other ungulates. Ledger, Sachs and Smith (1967) reported that the carcass weight for red hartebeest males is 81.50 kg and 73.20 kg for females. This difference could be due to the differences in the methodology of determining this parameter, eg. what was included in the carcass weight.

Carcass length indicated significant differences ($p \leq 0.05$) for sexes, age groups and regions. On the other hand, carcass breadth and depth only differed significantly ($p \leq 0.05$) between age groups and regions. The males' carcass length (111.41 cm) and breadth (38.31 cm) were higher than that of the females, although only male length was significantly

higher. As expected, the carcass length (110.77 cm), breadth (40.28 cm) and depth (48.25 cm) for the adult animals were higher than that for the sub-adults and calves. The hartebeest from MM had the lowest value for carcass length (96.13 cm), breadth (34.42 cm) and depth (44.22 cm). This could be due to the fact that a substantial number of sub-adults and females were obtained from MM (Table 1).

Table 3
Morphological measurements of red hartebeest from different sexes, age groups and regions

	Sex			Age				Region			
	Female	Male	LSD[c]	Adult	Sub-adult	Calf	LSD	MM	TDR	QQ	LSD
Body weight (kg)	99.31[b]	126.36[a]	13.70	128.57[a]	72.51[b]	66.00[b]	36.01	99.16[b]	107.65[b]	142.19[a]	17.74
Carcass weight (kg)	51.48[b]	68.46[a]	7.33	67.05[a]	40.10[b]	38.00[b]	17.77	50.01[c]	60.01[b]	74.85[a]	9.44
Dressout (%)	IA[f]	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA
Carcass length (cm)	100.87[b]	111.41[a]	5.44	110.77[a]	92.93[b]	97.10[ab]	14.29	96.13[b]	115.19[a]	109.76[a]	7.04
Carcass breadth (cm)	36.16	38.31	3.80	40.28[a]	29.76[b]	31.90[ab]	9.93	34.42[b]	36.99[b]	43.71[a]	4.90
Carcass depth (cm)	44.67[a]	46.80[b]	2.72	48.25[a]	39.70[b]	38.10[b]	7.11	44.22[b]	44.82[b]	50.09[a]	3.51
Buttock[e] (cm)	67.83[b]	72.49[a]	4.44	73.52[a]	61.97[ab]	60.00[b]	1.66	66.07[b]	69.32[b]	79.80[a]	5.75
Chest girth (cm)	113.23[b]	122.25[a]	5.05	124.09[a]	101.83[b]	103.00[b]	13.27	110.32[c]	117.96[b]	131.66[a]	6.54
Leg length (cm)	66.03	62.72	4.93	66.69	60.68	63.50	12.94	65.07[a]	70.77[a]	52.76[b]	6.38

[a,b,c]Means in the same row within the same subgroup, with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e]Circumference
[f]IA=Interaction

Chest girth and buttock circumference indicated significant differences ($p \leq 0.05$) for sexes, age groups and region. The male chest girth (122.25 cm) and buttock circumference (72.49 cm) were higher than that of the females. Usually one would expect the female animal to have the largest buttock circumference due to fat deposits and secondary sexual dimorphism (Kritzinger, 2002). The red hartebeest from QQ had the highest chest girth (131.66 cm) and buttock circumference (79.80 cm). Once more this can be attributed to the fact that more males than females were obtained from QQ.

Conclusion

As expected, the results indicated that the male and adult animals had the highest values for almost all the morphological characteristics. Due to the skewness of the sampling, it was difficult to see the effects of age on the morphological characteristics. Within region, the red hartebeest from QQ had the highest values for body weight, carcass weight, carcass breadth, carcass depth, buttock circumference and chest girth. This was probably because only adult, and mainly male animals were cropped at QQ. The female red hartebeest from MM had the lowest dressout percentage (47.93%) for the Sex*Region interaction, and this could probably be ascribed to the higher number of females that were obtained from this region. The males from TDR had the highest dressout percentage (57.37%) for the sex*region interaction and this can be ascribed to the high body weight of the males. The differences in dressout percentage compared to that of other studies could be due to differences in the methodology of determining this parameter.

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Chemical characteristics of red hartebeest (*Alcelaphus buselaphus caama*) meat

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Abstract

The aim of this study was to determine the effect of sex, age and region on the chemical characteristics of the red hartebeest's *M. longissimus dorsi* (*MLD*). The parameters measured included proximate chemical composition, total collagen, amino acid, mineral, cholesterol and fatty acid content. A total of 49 red hartebeest differing in sex (male and female), age groups (adult, sub-adult and calf) and regions (Qua-Qua (QQ), Maria Moroka (MM), Sandveld (SV) and Tussen die Riviere (TDR) in the Free State Province, South Africa) were used for this study. The animals obtained from SV had the highest protein value (24.17 g/100 g meat sample) and the adult animals had the highest lipid content (4.49 g/100 g meat sample). Within region, the animals from QQ had the highest ash value (1.29 g/100 g meat sample). The males had the highest total collagen (0.98%) value and the sub-adults the highest value for histidine (1.44 mg/100 g meat sample) and isoleucine (1.88 mg/100 g meat sample). The meat of the males also had a high iron content of 11.51 mg/100 g muscle and the sub-adults (55.96 mg/100 g meat sample) had the highest cholesterol content. Red hartebeest from TDR had the highest value for linoleic acid (0.99 mg/100 g meat sample) and α-linolenic acid (0.30 mg/100 g meat sample). The ratio of polyunsaturated: saturated fatty acids (P:S ratio), as well as the n-6:n-3 ratio was above the recommended value and therefore has positive implications for human health.

***Keywords*:** proximate chemical composition, total collagen, amino acids, minerals, cholesterol, fatty acids, game meat

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Introduction

Red hartebeest (*Alcelaphus buselaphus caama)* are found in regions of the North Western Cape (South Africa), Botswana, Namibia and in Zimbabwe (Zaburnis & Cross, 1974). This species has also been introduced to reserves in Kwa-Zulu Natal and other national parks in South Africa. Red hartebeest occupy ridge and kopje summits and are known to maintain their territories for long periods (Kok, 1975).

According to Onyango, Izumimoto and Kutima (1998) the decrease in the per capita supply of high quality protein and the increase in the world's population have intensified the need to search for alternative sources of protein. Although there is an increase in the demand for game meat, there is a tendency for the meat to be sold under the generic name of "game meat" or "venison", with no specific indication of species. A possible reason for generic marketing is the fact that nutritional information on the meat of most game species is unavailable.

South African game meat is often described as an organic product, as no fertilizers or growth stimulators are used in the production system (Pauw, 1993). The negative health image that many consumers associate with red meat is due to its

predominantly saturated animal fat, that is associated with health risks. Beef, for example has a fat content of between 20 to 25%, whereas the fat content of game meat measures significantly lower at 2 to 3 g per 100 g. This factor in itself makes game meat an attractive alternative for health-conscious consumers (Schönfeldt, 1993).

The current dietary recommendations emphasize an increased intake of polyunsaturated fatty acids and a decreased intake of saturated fatty acids. Meat from free-ranging game such as eland is rich in polyunsaturated fatty acids (Lawrie, 1979), and meat from pasture-fed animals such as reindeer has a high percentage of α-linolenic acid (C18:3n-3) (Wicklund, Pickova, Sampels & Lundström, 2001). An increased consumption of meat from free-ranging or pasture-fed animals could contribute to an intake of more polyunsaturated fatty acids.

The purpose of this study was to determine the effect of the sex, age and region on the chemical composition (proximates, total collagen, cholesterol, amino acid, mineral and fatty acid content) of red hartebeest meat.

Materials and methods

Harvesting

Red hartebeest, representing different age groups (adult, sub-adult and calf) and both sexes, were harvested during 2001 and 2002 from nature reserves in the Free State Province (Table 1). Apart from the sub-adult and adult animals, one female calf was also obtained from Tussen die Riviere (TDR) Nature Reserve. As both the male and the female have horns, the length and width of the animals' horns were used to obtain the animals' age. Animals with no horns or short straight horns were classified as calves and animals with horns of intermediate size as sub-adults. Animals with fully developed horns were classified as adults. All the animals were obtained between May to September (Autumn to Spring). The animals were selected randomly during organized game culling operations and shot either in the head or neck with .274 or .270 calibre rifles. All the animals were exsanguinated in the field. During 2001 the red hartebeest were shot during the daytime and either during the daytime or at night in 2002.

Table 1
Number of red hartebeest harvested during 2001 and 2002 in the Free State Province

Year	Region	Total	Adult		Sub-adult	
			Male	Female	Male	Female
2002	MM[a]	19	2	9	3	5
2002	TDR[b]	12	5	3	0	4
2001	QQ[c]	7	5	2	0	0
2001	SV[d]	10	1	2	5	2
Total			13	16	8	11

[a]Maria Moroka
[b]Tussen die Riviere
[c]Qua-Qua
[d]Sandveld

Chemical analyses

For chemical analyses, the *M. longissimus dorsi (MLD)* of each animal was cut between the 6th rib and anterior to the 5th lumbar vertebrae. Proximate analysis was conducted on all the samples in Table 1 and a group of these samples was used for the determination of collagen content, amino acid composition, mineral and fatty acid content. The samples were minced through a 2 mm sieve three times, to ensure homogeneity.

The moisture, protein, fat and ash content (g/100 g meat) were determined according to the Association of Official Analytical Chemists' Standard Techniques (AOAC, 1997) for all the samples. The moisture content was determined by drying at 100°C for 24 h. Ashing was done at 500°C for 5 h. The block digestion method was used to determine the protein content (N × 6.25). The lipid content was determined by solvent extraction according to the method of Lee, Trevino and Chaiyawat (1996). The cholesterol content (mg/100 g meat sample) was determined according to the technique of the AOAC (1997). The hydroxyproline method was used to determine the total collagen in meat (Nordic Committee, 2002).

The amino acid composition was determined using a modification of the method of Bidlingmeyer, Cohen and Tarvin (1984) on a defatted, dried meat sample using a Waters high performance liquid chromatography system (1525 HPLC with a binary gradient delivery, 717 auto-sampler and Injector, 1500 column heater, 2487 dual wavelength UV detector) and a Breeze data workstation (Waters, Millford, MA, USA). The meat sample was defatted by solvent extraction according to the method of Lee, Trevino and Chaiyawat (1996). The sample was hydrolyzed with 6 N HCl in a vacuum-sealed tube for 24 h at 110°C. Thereafter the samples were centrifuged (15 krpm for 5 min) and dried under vacuum for 90 min to 2h. The pH was adjusted by adding 20 µl solution of 2:2:1 ethanol:water:triethylamine and the samples were dried for a further 90 min to 2h. The resulting sample was derivatized by adding 20 µl of 7:1:1:1 ethanol:water:triethylamine:phenylisothiocyanate derivatizing solution which was allowed to react at room temperature for 10 min prior to drying under vacuum (minimum of 3h). The sample was resuspended in 200 µl of Picotag sample diluent (Waters, Millford, MA, USA) and an 8 µl sub-sample was then injected for separation by HPLC under gradient conditions, where buffer A was sodium acetate buffer (pH 6.4) containing 5000 ppm EDTA, 1:2000 triethylamine and 6% acetonitrile and buffer B was 60% acetonitrile with 5000ppm EDTA. The data was analysed using Breeze software (Waters, USA).

The mineral composition of the meat was determined after ashing of the defatted meat samples. The meat samples (1- 3 g) were air-dried and ground to pass through a 0.5 - 1.0 mm sieve. Thereafter the samples were ashed overnight in a muffle furnace at 550°C. 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 which were then heated on a water bath and removed after boiling point was reached. The solution was consequently 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).

The fatty acid content was determined by the method described by Tichelaar, Smuts, Van Stuijvenvenberg, Faber and Benade (1998). After thawing the meat a 2 g sample was extracted with chloroform/methanol (CM 2:1; v/v) according to a modified method of Folch *et al.* (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenize the sample within the extraction solvent. Heptadecanoic acid (C17:0) was used as an internal standard to quantify the individual fatty acids. A sub-sample of the extracted lipids was transmethylated for 2 h at 70°C using methanol/sulphuric acid (19:1; v/v) as transmethylating agent. After cooling, the resulting 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 flame ionisation detection) using 60 m BPX70 Capillary columns of 0.25 mm internal diameter (SGE, Australia).

Gas flow rates were: hydrogen, 25 ml/min; and hydrogen carrier gas 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 were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

From the same lipid extraction used for 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% ethanolic KOH used to saphonifize the extraction for two hours 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

A three factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were the four areas (QQ, SV, MM and TDR), the two sexes and the three age groups (calf, sub-adult and adult). A single carcass was considered to be an experimental unit. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 1999) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro and Wilk, 1965). Student's t-Least Significant Differences were calculated at the 95% confidence level to compare treatment means (Ott, 1998). Where applicable, Pearson's correlations were determined using the Proc Corr procedure of SAS (1999).

Results and discussion

In Table 2 the data on the mean moisture, protein, lipid, and ash content of the *MLD* of the red hartebeest, as classed for sex, age and production region are depicted. No significant ($p>0.05$) correlations were found between any of the characteristics. Furthermore, no significant differences ($p>0.05$) were found for moisture content within the different classes. However, significant differences ($p\leq0.05$) were found for protein and ash content within region. The animals obtained from SV had the highest protein value (24.17 g/100 g muscle). The protein content of red hartebeest is similar to that of impala (24.87 mg/100 g muscle), as noted by Kritzinger (2002), and the higher percentage protein in red hartebeest for the SV region could possibly be ascribed to different vegetation types in the different regions.

Although significant differences ($p\leq0.05$) were found for lipid content between the sexes, age groups and regions, the mean values are still very low compared to other traditional animal species. In this study the meat from the males were found to have a significantly higher ($p\leq0.05$) lipid content than that of the females. According to Lawrie (1979) males usually have less intramuscular fat than females.

Within the age groups, the adult animals had the highest lipid content (4.49 g/100 g muscle) and the calves the lowest (2.08 g/100 g muscle).

Table 2

Means for proximate chemical analysis (g/100 g) and total collagen (%) of *MLD* for red hartebeest as influenced by different sexes, age groups and regions

	Sex			Age				Region				
	Female	Male	LSD[d]	Adult	Sub-adult	Calf	LSD	MM	SV	TDR	QQ	LSD
Protein	23.10	23.34	0.60	23.01	23.54	22.39	1.78	22.60[c]	24.17[a]	23.52[ab]	22.90[bc]	0.90
Moisture	74.75	75.08	0.67	74.93	74.80	75.25	1.99	75.18	74.70	74.68	74.75	1.01
Lipid	2.81[b]	4.69[a]	0.79	4.49[a]	2.45[ab]	2.08[b]	2.32	2.45[b]	2.46[b]	2.98[b]	1.08[a]	1.21
Ash	1.22	1.16	0.11	1.21	1.19	1.12	0.31	1.18[ab]	1.08[b]	1.26[a]	1.29[a]	0.16
Collagen[e]	0.57	0.98	1.10	0.74	0.60	NE	1.00	0.65	NE[f]	0.71	NE	0.99

[a,b,c]Means in the same row within the classes with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e]Total collagen
[f]NE=Not executed

According to Lawrie (1979), intramuscular fat tends to increase with age and therefore the high fat content in the meat of the animals from TDR (2.98 g/100 g muscle) could possibly be ascribed to the high number of adults were cropped in this region (Table 1). The fat content of beef and mutton loin is approximately 25% and 16% respectively (Lushbough *et al.* 1960), and the fat content of red hartebeest measures significantly lower. The latter is due to the small percentage of subcutaneous fat present in the animal. Only adults (Table 1) were obtained from QQ and this is probably why red hartebeest from QQ had the highest ash value (1.29 g/100 g muscle). The low ash value for this ungulate species is supported by the findings of Kritzinger (2002), who recorded a mean ash value of 1.23 g/100 g muscle for impala.

No significant differences ($p>0.05$) were found for total collagen (Table 2) within the sexes, age groups or regions. According to Lawrie (1979), the collagen content of calves, steers and old cows is 0.67%, 0.42% and 0.41% respectively. The latter values are substantially lower than the values given in Table 2. According to Dransfield (1977), muscles rich in collagen tend to be tougher. Although not significant, the adults had a slightly higher collagen content than the sub-adults, and the latter can therefore be expected to have slightly lower shear force values.

Significant differences ($p\leq0.05$) were found for amino acid within the sexes, age groups and regions (Table 3). Other than histidine the meat from the female animals measured higher values for all the amino acids. Within age groups, significant differences ($p\leq0.05$) were only found for histidine, with sub-adults having a higher value (1.44 mg/100 g muscle) than the adults (1.00 mg/100 g). Within region, significant differences ($p\leq0.05$) were found for histidine and isoleucine. The animals from MM had a higher histidine value (1.37 mg/100 g muscle) when compared to the animals from TDR (1.00 mg/100 g muscle). The red hartebeest from TDR had a higher isoleucine (0.21 mg/100 g muscle) value than the animals from MM (0.18 mg/100 g muscle). In this study evidence was found to confirm the findings of previous studies (Lawrie, 1979), that there was a tendency for certain amino acids such as arginine, valine, methionine and phenylalanine to increase with age.

No significant differences ($p>0.05$) for minerals measured (Table 4) were found between the sexes and age groups. However, region indicated significant differences ($p\leq0.05$) for sodium. Animals from TDR had the highest sodium value (19.470 mg/100 g muscle) and animals from MM the lowest content (13.025 mg/100 g muscle). In some cases the

red hartebeest meat is an excellent source of iron, as was obvious for the meat from the males and adults which measured in values of 11.51 and 7.78 mg/100 g meat sample.

Table 3

Means for amino acid composition of *MLD* from red hartebeest as influenced by different sexes, age groups and regions (g/100 g meat sample)

	Sex			Age			Region		
	Female	Male	LSD[d]	Adult	Sub-adult	LSD	MM	TDR	LSD
Aspartic acid[e]	2.48[a]	1.84[b]	0.45	2.35	2.14	0.43	2.47	2.10	0.43
Glutamic acid[f]	3.37[a]	2.67[b]	0.50	3.23	3.01	0.48	3.04	3.23	0.48
Serine	1.68[a]	1.33[b]	0.25	1.65	1.44	0.24	1.61	1.52	0.23
Glycine	1.84[a]	1.53[b]	0.27	1.81	1.63	0.26	1.74	1.74	0.25
Histidine	0.97[b]	1.57[a]	0.14	1.00[b]	1.44[a]	0.13	1.37[a]	1.00[b]	0.13
Arginine	1.36[a]	1.06[b]	0.22	1.31	1.19	0.22	1.26	1.26	0.21
Threonine	1.65[a]	1.32[b]	0.21	1.60	1.46	0.20	1.55	1.53	0.20
Alanine	2.54[a]	2.09[b]	0.28	2.48	2.25	0.27	2.36	2.41	0.27
Proline	1.34	1.18	0.20	1.36	1.18	0.19	1.25	1.33	0.18
Tyrosine	0.76[a]	0.58[b]	0.10	0.72	0.67	0.10	0.70	0.70	0.10
Valine	1.45[a]	1.15[b]	0.18	1.39	1.29	0.17	1.35	1.35	0.17
Methionine	0.72[a]	0.58[b]	0.10	0.71	0.62	0.10	0.68	0.67	0.10
Cystine	0.21[a]	0.15[b]	0.03	0.20	1.88	0.03	0.18[b]	0.21[a]	0.03
Isoleucine	1.15[a]	0.90[b]	0.14	1.09	1.03	0.14	1.06	1.07	0.14
Leucine	2.29[a]	1.85[b]	0.34	2.22	2.03	0.32	2.12	2.16	0.32
Phenylalanine	0.85[a]	0.65[b]	0.11	0.81	0.74	0.10	0.78	0.78	0.10
Lysine	1.68[a]	1.29[b]	0.31	1.62	1.44	0.30	1.59	1.51	0.30

[a,b,c]Means in the same row within the classes with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e, f] Aspartic acid= aspartic acid + aspartine; Glutamic acid= Glutamic acid + glutamine

The iron values reported by Lawrie (1979) and Lushbough *et al.* (1960) for beef steak (4.3 mg/100 g) and beef loin (2.5 mg/100 g) were much lower. The higher iron content of game meat could be attributed to a higher myoglobin content as wild ungulates are know to have more myoglobin than domesticated and farmed animals. Animals from MM had the lowest potassium, sodium, copper and zinc content, which could probably be attributed to a low mineral content in the soil. Although not significant, animals from TDR had the highest potassium, sodium, copper and zinc content. This is possibly because TDR is situated between two rivers, and probably has richer soil.

Table 4

Means for mineral composition of *MLD* for red hartebeest as influenced by different sexes, age groups and regions (mg/100 g meat sample)

	Sex			Age			Region		
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	TDR	LSD
P	133.65	117.81	53.08	123.76	135.30	51.08	123.72	132.44	50.16
K	140.96	139.22	104.46	143.90	135.59	101.14	125.90	154.78	100.10
Ca	6.74	7.03	3.29	6.74	6.99	3.17	6.92	6.77	3.11
Mg	19.02	15.96	6.05	18.33	17.50	5.82	19.62	16.57	5.71
Na	15.32	18.74	5.36	17.50	14.91	5.15	13.03[b]	19.47[a]	5.06
Fe	2.69	11.51	14.98	7.78	2.41	14.42	2.73	8.17	14.16
Cu	0.167	0.13	0.13	0.15	0.16	0.12	0.10	0.20	0.12
Zn	1.513	1.42	0.48	1.49	1.46	0.46	1.38	1.57	0.45

[a,b]Means in the same row within the classes with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)

No significant differences ($p>0.05$) were found for cholesterol content within the subgroups (Table 5). The cholesterol content of ostrich is 65.63 mg/100 g (Horbanczuk, Sales, Celeda, Konecka, Zieba & Kawka, 1998). In this study the highest cholesterol value for red hartebeest was 55.95 mg/100 meat sample. The lower cholesterol content of red hartebeest can be considered an important quality attribute, and should be emphasised in the marketing of the meat of this species as game meat.

According to Table 5 significant differences ($p\leq0.05$) in fatty acids (mg/100 g) were only present between age groups and regions for α-linolenic (C18:3n-3), and between regions for dihomo-y-linolenic (C20:3n-6) acid. Table 6 indicates significant differences for fatty acids (%) for α-linolenic (C18:3n-3) and docosahexaenoic (C22:6n-3) acid.

Table 5 and Table 6 illustrate that palmitic (C16:0) and stearic (C18:0) acid are the major constituents of the saturated fatty acid (SFA) component and oleic acid is the major constituent of monounsaturated fatty acids (MUFA) component. Red hartebeest in MM had a C16:0 value of 19.07% and an oleic acid (C18:1n-9) value of 16.13%. According to Kritzinger (2002), oleic acid also makes up the largest proportion of the MUFA of impala meat. In the case of beef the palmitic acid value (29%) and oleic acid value (42%) are both higher than that of the meat of red hartebeest (Enser *et al.*, 1998).

Several significant interactions ($p\leq0.05$) were found for sex and age groups, region and age groups, as well as region and sex, as pertaining to the fatty acid composition. In the Sex*Age interaction, there is a tendency for the Male x Sub-adult combination to be responsible for the significant differences, and in the Age*Region interaction the Sub-adults at MM (Table 7).

As can be seen in Table 5 no significant differences ($p>0.05$) were found for the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and the ratio of PUFA to SFA (P:S ratio). The fatty acid composition is currently receiving a lot of attention because of its implications for human health. The aim is to bring the P:S ratio of meat closer to the recommended value (>0.70), as well as the n-6:n-3 ratio (<5.0) (Raes, De Smet, Demeyer, 2003; Sanudo *et al.*, 2000). Red hartebeest from TDR had the highest P:S ratio (0.87) and MM the lowest (0.63). According to Enser *et al.* (1998) meat of ruminant animals usually has a low P:S ratio, whereas venison such as ostrich can have a much higher and more positive P:S ratio, due to a high PUFA content (Girolami, Marsico, D'Andrea, Braghieri, Napolitano *et al.*, 2003).

Significant differences ($p\leq0.05$) were also found for n-3 and n-6:n-3 ratio values (Table 5) for age groups and regions. The n-6:n-3 ratios for all subgroups of red hartebeest are below 5, with animals from TDR and MM having a ratio of approximately 3. Red hartebeest meat is therefore a valuable source of polyunsaturated fatty acids and it contributes positively towards a higher P:S ratio and a lower n-6:n-3 ratio.

Table 5
Means of fatty acid composition and cholesterol content of *MLD* of red hartebeest as influenced by different sexes, age groups and regions (mg/100 g of total fatty acids)

	Sex			Age			Region		
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	TDR	LSD
Total lipid	5.86	5.72	2.03	6.50	4.78	1.96	5.32	6.24	1.92
C16:0	0.98	1.00	0.44	1.08	0.85	0.43	0.97	1.00	0.42
C18:0	1.68	1.73	0.84	1.91	1.37	0.81	1.64	1.75	0.79
C20:0	0.02	0.03	0.01	0.03	0.02	0.01	0.03	0.02	0.01
C22:0	0.02	0.02	0.01	0.02	0.03	0.01	0.02	0.02	0.01
C24:0	0.04	0.03	0.01	0.04	0.04	0.01	0.04	0.03	0.01
C16:1n-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:1n-9	1.06	1.01	0.76	1.25	0.74	0.73	0.95	1.13	0.72
C20:1n-9	IA[d]	IA	IA	IA	IA	IA	0.00	0.01	0.01
C24:1n-9	0.03	0.04	0.03	0.04	0.02	0.03	0.03	0.04	0.03
C18:2n-6	0.90	0.82	0.30	0.93	0.78	0.29	0.73	0.99	0.29
C18:3n-6	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01
C18:3n-3	0.23	0.23	0.09	0.25[a]	0.20[a]	0.09	0.15[b]	0.30[a]	0.08
C20:2n-6	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
C20:3n-9	0.08	0.06	0.02	IA	IA	IA	IA	IA	AI
C20:4n-6	0.43	0.40	0.16	0.47	0.35	0.15	0.38	0.46	0.15
C20:5n-3	0.15	0.13	0.06	0.16	0.12	0.06	0.11	0.17	0.06
C22:4n-6	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
C22:5n-3	0.17	0.13	0.06	IA	IA	IA	IA	IA	AI
C22:6n-3	0.03	0.02	0.01	0.02	0.03	0.01	0.02	0.03	0.01
Cholesterol	50.36	50.90	15.33	47.27	55.95	14.67	54.08	46.98	14.21
SFA	2.74	2.82	1.29	3.07	2.30	1.24	2.69	2.82	1.21
MUFA[f]	1.10	1.06	0.78	1.29	0.77	0.75	0.98	1.17	0.74
PUFA[g]	2.02	1.85	0.68	2.13	1.70	0.65	1.64	2.24	0.64
TUFA[h]	3.11	2.91	1.01	3.43	2.47	0.98	2.62	3.41	0.96
DFA[i]	4.79	4.64	1.66	5.34	3.84	1.60	4.26	5.16	1.57
P:S	0.77	0.75	0.46	0.78	0.73	0.44	0.63	0.87	0.43
n-6	1.45	1.33	0.47	1.54	1.22	0.46	1.23	1.57	0.47
n-3	0.57	0.52	0.21	0.59	0.48	0.20	0.41[b]	0.67[a]	0.20
n-6:n-3	2.66	2.75	0.36	2.64	2.76	0.35	3.07[a]	2.36[b]	0.34

[a,b]Means in the same row within the subgroups with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d]IA=Interaction
[e,f,g,h,i]SFA=Saturated Fatty Acids; MUFA= Monounsaturated Fatty Acids; PUFA=Polyunsaturated Fatty Acids; TUFA=Total Unsaturated Fatty Acids; DFA= Desirable Fatty Acids (C18:0 + TUFA)

Table 6
Means of fatty acid composition (% of total fatty acids identified) of *M. longissimus dorsi* of red hartebeest as influenced by different sexes, age groups and regions

	Sex			Age			Region		
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	TDR	LSD
C16:0	17.06	18.27	4.25	16.33	19.16	4.09	19.07	16.05	4.02
C18:0	AI	AI	AI	AI	AI	AI	31.52	27.64	5.25
C20:0	0.43	0.49	0.09	AI	AI	AI	AI	AI	AI
C22:0	AI	AI	AI	0.33[b]	0.55[a]	0.07	AI	AI	AI
C24:0	AI	AI	AI	AI	AI	AI	AI	AI	AI
C16:1n-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C18:1n-9	17.18	16.01	6.19	18.39	14.39	5.96	16.13	17.37	5.85
C20:1n-9	AI	AI	AI	AI	AI	AI	AI	AI	AI
C24:1n-9	AI	AI	AI	AI	AI	AI	0.48	0.53	0.35
C18:2n-6	15.60	14.55	5.94	0.93	0.78	7.20	13.91	16.42	7.47
C18:3n-6	0.24	0.26	0.21	0.28	0.19	0.2	0.16	0.32	0.2
C18:3n-3	3.84	4.06	1.74	4.04	3.72	1.67	2.72[b]	4.96[a]	11.64
C20:2n-6	0.05	0.08	0.16	0.08	0.03	0.16	0.05	0.07	0.15
C20:3n-9	1.39	1.11	0.45	1.38	1.18	0.44	1.50	1.13	0.43
C20:4n-6	7.58	7.01	2.92	7.68	6.96	2.81	7.12	7.63	2.76
C20:5n-3	2.56	2.38	1.21	2.61	2.33	1.16	2.11	2.85	1.14
C22:4n-6	0.41	0.28	0.37	0.37	0.37	0.36	0.38	0.36	0.35
C22:5n-3	2.89	2.31	1.08	2.66	2.75	1.04	2.51	2.86	1.02
C22:6n-3	0.44	0.37	0.18	0.34[b]	0.53[a]	0.17	0.38	0.45	0.17

[a,b]Means in the same row within the subgroups with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d]IA=Interaction

Table 7
Fatty acid interactions (means) present in *MLD* of red hartebeest as influenced by different sex, age and region combinations

	S[f]	A[e]	S*A	LSD[d]	A	R[g]	A* R	LSD	R	S	R*S	LSD
C20:1n-9	Female	Adult	0.002[b]	0.009	Adult	MM	0.003[a]	0.007				
(mg/100	Female	Sub-adult	0.000[b]		Sub-adult	MM	0.007[a]					
g)	Male	Adult	0.010[b]		Adult	TDR	0.008[a]					
	Male	Sub-adult	0.020[a]		Sub-adult	TDR	0.000[b]					
C20:3n-9					Adult	MM	0.11[a]	0.03				
(mg/ 100					Adult	TDR	0.07[b]					
g)					Sub-adult	MM	0.05[b]					
					Sub-adult	TDR	0.06[b]					
C22:5n-3					Adult	MM	0.17[a]	0.08				
(mg/ 100					Adult	TDR	0.16[a]					
g)					Sub-adult	MM	0.08[b]					
					Sub-adult	TDR	0.20[a]					
C18:0	Female	Adult	29.78[b]	9.23								
(%)	Male	Adult	27.55[b]									
	Female	Sub-adult	27.60[b]									
	Male	Sub-adult	44.61[a]									
C20:0					Adult	MM	0.41[b]	0.13				
(%)					Adult	TDR	0.38[c]					
					Sub-adult	MM	0.67[a]					
					Sub-adult	TDR	0.41[b]					
C20:1n-9	Female	Adult	0.05[b]	0.15	Adult	MM	0.06[b]	0.12				
(%)	Male	Adult	0.11[b]		Adult	TDR	0.09[a]					
	Female	Sub-adult	0.00[b]		Sub-adult	MM	0.21[a]					
	Male	Sub-adult	0.64[a]		Sub-adult	TDR	0.00[b]					
C22:0									MM	Female	0.45[b]	0.11
(%)									TDR	Female	0.38[c]	
									MM	Male	0.65[a]	
									TDR	Male	0.27[c]	
C24:0	Female	Adult	0.64[b]	0.24	Adult	MM	0.56[b]	0.20				
(%)	Male	Adult	0.53[b]		Adult	TDR	0.61[b]					
	Female	Sub-adult	0.75[b]		Sub-adult	MM	1.14[a]					
	Male	Sub-adult	1.23[a]		Sub-adult	TDR	0.53[b]					
C24:1n-9	Female	Adult	0.50[a]	0.61								
(%)	Male	Adult	0.67[a]									
	Female	Sub-adult	0.47[a]									
	Male	Sub-adult	0.00[b]									
TUFA					Adult	MM	3.48[a]	1.39				
					Sub-adult	MM	1.48[b]					
					Adult	TDR	3.38[a]					
					Sub-adult	TDR	3.45[a]					

[a,b,c]Means in the same row between the subgroups with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e,f,g] A=Age; S=Sex; R=Region

Conclusion

From the results of this study it is clear that sex, age groups and regions affect the proximate composition, the amino acid, mineral and fatty acid contents of meat, although the effect is mostly statistical. Significant differences were found between the sexes and age groups for total lipid content, amino acids and fatty acids. The lipid content of red hartebeest

meat is low compared to other meat species and certain amino acid values were found to increase with age. Red hartebeest meat has a positive P:S and n-6:n-3 ratio, and therefore has definite health benefits.

Significant differences were found between region for protein, lipid, ash, amino acids, minerals (Na) and fatty acid values. The protein value of red hartebeest meat is the same as that of other game meat species. The regional differences found for the lipid value could possibly be ascribed to the high number of adults cropped in a specific region. It is concluded that the meat from the red hartebeest will be an ideal low fat alternative for the consumer. The meat is also high in other nutrients and contributes the same amount of proteins as other red meat to the daily dietary intake. The differences found within and between the main effects are small and does not have be taken into account for e.g. labelling. However, the chemical composition data can be used for human food composition tables and related purposes.

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Chapter 8

Physical and sensory characteristics of the red hartebeest (*Alcelaphus buselaphus caama*) meat

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Abstract

The aim of this study was to determine the effect of the sex and age groups and possible regional influences thereof, on the physical (pH_{45}, $Temp_{45}$, pH_{24}, $Temp_{24}$, L*, a*, b*, hue angle, chroma, percentage drip loss, percentage cooking loss and Warner-Bratzler shear force values (WBS) and sensory properties (aroma, game flavour, initial juiciness sustained juiciness, first bite and residue) of *M. longissimus dorsi* (*MLD*) from red hartebeest. A total of 49 red hartebeest differing in sex (male and female), age groups (adult, sub-adult and calf) and four regions (Qua-Qua (QQ), Maria Moroka (MM), Sandveld (SV) and Tussen die Riviere (TDR) in the Free State Province, South Africa) were used for this study. The adults had the highest pH_{45} (6.21) and animals from SV had the highest $Temp_{45}$ (37.10°C). Red hartebeest from TDR had the highest pH_{24} (5.65) and the females from QQ had a lighter meat colour (L*=37.17) and the males from QQ (L*=30.86) the darkest. The animals from MM had the highest (38.71%) cooking loss whilst the males (3.64 kg/1.27 cm diameter), adults (3.65 kg/1.27 diameter) and animals from MM (3.87 kg/1.27 cm diameter) had the highest WBS values. No significant differences were found for aroma and flavour. The females had the highest initial juiciness (6.52) and the sub-adults from TDR had the highest sustained juiciness (6.63) within the age group and region interaction. The sensory results indicated that within region and sex, age do have a significant effect on tenderness.

Keywords: pH, temperature, colour, drip loss, cooking loss, shear force, sensory characteristics

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Introduction

The diverse taste of game meat makes it an unique product to market. Game meat in South Africa may be described as an organic product, since no growth stimulators or fertilizers are used in the production system. Therefore, the marketing of game meat could center on its healthy qualities (Pauw, 1993).

The handling of animals prior to slaughter is of great importance and can have a significant effect on meat quality. Stressful situations and procedures lead to glycogen depletion. This affects the ultimate pH values and ultimately the meat quality (Wiklund, Andersson, Malmfors, Lundström & Danell, 1995). According to Viljoen, De Kock and Webb (2002) consumers prefer the red colour of raw meat with a normal pH to meat with a slightly higher pH and a dark, firm and dry (DFD) appearance. However, Carpenter, Cornforth and Whittier (2001) found that colour did not affect taste scores at all.

Flavour is a complex mouthfeel sensation, which is becoming increasingly important when assessing meat quality. The flavour of cooked meat can be influenced by a number of factors, e.g. the animals' age, the type of feed, as well as the length of time and conditions of storing the meat after slaughter (Weir, 1960). Tenderness, on the other hand, is often considered the primary quality parameter when evaluating the acceptability of meat. A number of pre- and post-mortem factors are involved in tenderness. On post-mortem storage of meat, the toughness increases as the muscle goes into *rigor,* regardless of the animal species (Quali, 1991). Furthermore, many studies have reported that the level of fat has a significant effect on juiciness, as well as tenderness (Wood, 1990).

Extensive research has been done on the factors that affect the quality of meat, but very limited data is available on the factors influencing the meat quality of specific game species, such as red hartebeest. Therefore, the purpose of this study was to determine the effect of sex, age groups and region on the physical and sensory characteristics of red hartebeest *(Alcelaphus buselaphus caama)* meat.

Materials and methods

Harvesting

Red hartebeest, representing different age groups (adult, sub-adult and lamb) and both sexes were obtained during 2001 and 2002 from nature reserves in the Free State Province (Table 1). Apart from the sub-adult and adult animals, one female calf was also obtained from Tussen die Riviere (TDR) Nature Reserve. As both the male and the female have horns, the length and width of the animals' horns were used to determine the animals' age. Animals with no horns or short straight horns were classified as calves. Animals with horns of intermediate size were classified as sub-adults and animals with fully developed horns were classified as adults. All the animals were obtained in the period of May to September, i.e. Autumn to Spring. The animals were selected randomly during organized game culling operations and shot either in the head or neck with .274 or .270 calibre rifles. All the animals were exsanguinated in the field. During 2001, red hartebeest were shot during the daytime and either in the daytime or at night in 2002. Drip loss and cooking loss could not be conducted on samples from TDR. The red hartebeest used for sensory analysis are depicted in Table 2.

Table 1
Number of red hartebeest harvested during 2001 and 2002 in the Free State Province

Year	Region	Total	Adult		Sub-adult	
			Male	Female	Male	Female
2002	MM[a]	19	2	9	3	5
2002	TDR[b]	12	5	3	0	4
2001	QQ[c]	7	5	2	0	0
2001	SV[d]	10	1	2	5	2
Total			13	16	8	11

[a]Maria Moroka
[b]Tussen die Riviere
[c]Qua-Qua
[d]Sandveld

Table 2
Distribution of red hartebeest according to subgroups utilised for sensory analysis

	Sex		Age		Region	
Total	Female	Male	Adult	Sub-adult	MM	TDR
21	14	7	15	6	10	11

Physical analyses

pH

After being shot, the pH values (pH_{45} and pH_{24}) of the *M. longissimus dorsi et lumborum (MLD)* were measured between the 6th and 7th rib with a hand-held Crison pH/ mV- 506 meter, equipped with a glass electrode. The pH-meter was re-calibrated after every fourth reading, and the electrode rinsed with distilled water between measurements. After the first pH-reading was taken, the carcasses of the animals were transported to the slaughter facility where they were skinned. The carcasses were hung by their Achilles-tendon in a cooler, at a set temperature of 4°C. The *MLD* on both the right and left were removed between the 6th and 7th rib and anterior to the 5th lumber vertebrae from the carcasses at 24 h post-mortem. Where possible, the muscle on the right-hand side was used for sensory analysis and the muscle on the left-hand side for the physical analyses. For the determination of colour, drip and cooking losses, 1.0-1.5 cm thick steaks were removed from the anterior section of the *MLD*.

Colour

The meat colour was evaluated using a Minolta Chroma Meter CR 200 (Pacific Scientific, Silver Spring, MD, USA) after a blooming period of 20 min. The parameters measured were the L* (lightness), a* (red-green range) and b* (blue-yellow range) values (Honikel, 1998). The hue angles and chroma-values were calculated according to Hunter and Harold's method (1987).

Drip loss

Percentage drip loss was determined on fresh *MLD* steak. The meat samples were weighed individually (approximately 20 g and ±1 cm thick) and placed in a net contained in a bag so as to ensure that the exudate could not come into contact with the sample. The meat samples were dried and weighed again after a storage period of 24 hours at 4°C and the percentage drip loss was expressed as a percentage of the initial weight (Honikel, 1998).

Cooking loss

After weighing the MLD steaks, the percentage cooking loss was determined on the fresh meat. Individual slices (of approximately 20g and ±1cm thick) were placed in a water bath and at a temperature of 75°C for 50 minutes. The samples were then removed from the water bath and cooled in cold water. The meat was removed from the bag, blotted dry, weighed and cooking loss was expressed as a percentage of the initial sample weight (Honikel, 1998).

Warner-Bratzler shear force

The shear force of the cooked meat (the same samples that were used for cooking loss) was determined by using a Warner-Bratzler shear attachment (Voisey, 1976) fitted to an electronic scale. Three cylindrical samples were removed from the centre of each *MLD* muscle by using a 12.7mm diameter core. Maximum shear force (kg/1.27cm diameter) required for shearing a cylindrical sample of cooked muscle perpendicular to the grain was recorded (Honikel, 1998) at a crosshead speed of 229mm/minute. A higher value was an indication of a greater shear force that resulted in tougher meat.

Descriptive sensory analysis

The *MLD* cuts selected for sensory analysis were kept frozen at -20°C. The meat cuts were defrosted for 24 hours at a temperature of 3°C - 4°C and were wrapped individually in cooking bags and placed on a meat grid on an open roasting pan. The *MLD* samples were roasted in two DEFY 835 electric ovens, connected to a computerised temperature control

system (Viljoen, Muller, De Swardt, Sadie, & Vosloo, 2001). Thermocouples were inserted in the centre of each piece of meat and the samples were roasted to an internal temperature of 70°C in a preheated oven at 180°C (AMSA, 1995). After the roasting process, 1.5cm x 1.5cm cubed samples were taken from the middle of each muscle, wrapped in foil and marked with three digit codes, and placed in preheated glass ramekins. The samples were evaluated within 10 minutes from the time the meat was removed from the oven.

A six-member descriptive panel was selected and trained according to the generic descriptive analysis technique and the procedures described in the American Meat Science Association (AMSA) guidelines. The panel evaluated the meat for the following specific attributes: aroma intensity, initial impression of juiciness, sustained juiciness, first bite, residue and overall game flavour. The judges rated the samples using an 8-point structured scale. Crackers and distilled water were used to cleanse the palates between samples. The reliability of the panellists was tested through a test-retest session. Statistical analysis of the data proved that all the panellists were consistent in their discrimination between the samples.

Statistical analysis

A three factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were the four areas (QQ, SV, MM and TDR), two sexes and two or three age groups (calf, sub-adult and adult). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 1999) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro and Wilk, 1965). Student's t-Least Significant Differences were calculated at the 95% confidence level to compare treatment means (Ott, 1998). Where applicable, Pearson's correlations were determined using the Proc Corr procedure of SAS (1990).

Results and discussion

Physical characteristics

The physical characteristics of red hartebeest are depicted in Table 3. Significant differences ($p \leq 0.05$) were found for pH_{45} within age groups. The pH_{45} increased linearly with age, with the adult animals having the highest mean pH_{45} of 6.21. The adult animals were not wounded and did not run before they were shot, therefore the reason for the high pH values is probably due to the cumulative stress that the animals experienced as culling took place over a whole week, this would also explain the tendency for this group to have a higher pH_{24}. Significant differences ($p \leq 0.05$) were found for $Temp_{45}$ within age groups and regions. The sub-adults (34.7°C) and animals from SV (37.1°C) had the highest $Temp_{45}$. Significant differences ($p \leq 0.05$) were also found for pH_{24} between regions where the animals from TDR had the highest pH_{24} (5.65). Only one calf was cropped and this could have influenced the latter pH. Significant interactions ($p \leq 0.05$) were found for $Temp_{24}$ between the sex and age groups (Table 4) and it is clear that the low value for the female calf was responsible for this interaction. If data of the calf were removed from the analyses the data would have been affected to a great extent.

Red hartebeest and other game species such as impala have less intra-muscular fat than domestic animals (Hoffman, 2000), and this could result in the meat appearing darker. Interactions ($p \leq 0.05$) were found for the L*-values between region and sex and the *MLD* of the females from QQ (L*=37.17) was significantly lighter than that of the other animals

(Table 4). Significant differences ($p \leq 0.05$) were also found for the a*-values between regions. The animals from TDR had the highest a*-value (14.43), indicating a dark red colour, whereas the animals from QQ had an a*-value of 12.42, indicating a slightly less intense red colour (Table 3). Interactions ($p \leq 0.05$) were also found for the b*-values between region and age, as well as between region and sex (Table 4): b*-values indicate the yellowness of the samples and in this case the females from QQ had a significantly higher b*-value (11.90) and furthermore the adults from QQ also had the highest b*-value. These results indicate that the meat of the female red hartebeest in QQ was slightly lighter and not so intensely red. High a*- and b*-values causes a higher saturation (chroma) and this is desirable because the muscle will appear bright with greater colour purity (Onyango, Izumimoto & Kutima, 1998). Again QQ had the highest value for chroma at 17.04 (Table 3).

Table 3
Means of pH_{45}, $Temp_{45}$, pH_{24}, $Temp_{24}$, L*, a*, b*-values, drip loss, cooking loss and WBS of *MLD* for Red hartebeest as influenced by different sexes, age groups and regions

	Sex			Age				Region				
	Female	Male	LSD[d]	Adult	Sub-Adult	Calf	LSD	MM	SV	QQ	TDR	LSD
pH_{45}	6.12	6.10	0.26	6.21[a]	6.05[a]	5.12[b]	0.70	6.14	6.11	NE[f]	6.07	0.32
$Temp_{45}$	33.12	34.12	2.11	32.94[a]	34.70[a]	23.30[b]	5.69	35.06[a]	37.10[a]	NE	28.46[b]	2.60
pH_{24}	5.53	5.44	0.12	5.57	5.39	5.64	0.32	5.43[b]	5.40[b]	NE	5.65[a]	0.15
$Temp_{24}$	IA[e]	IA	IA	IA	IA	IA	IA	12.30[a]	3.92[c]	NE	4.87[b]	0.79
L*-value	IA	IA	IA	31.35	32.81	33.66	3.58	IA	IA	IA	IA	IA
a*-value	12.72	13.08	0.92	13.22	12.45	10.95	2.71	12.85[b]	12.42[b]	12.42[b]	14.43[a]	1.37
b*-value	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA
Hue	33.61	31.05	3.13	32.01	32.87	40.09	9.24	32.22[ab]	29.61[b]	30.57[b]	36.20[a]	4.68
Chroma	15.46	15.38	0.87	15.77	14.96	14.31	2.55	15.39[b]	14.33[b]	17.04[a]	15.45[b]	1.29
Drip loss (%)	3.55	4.95	3.56	3.35	5.32	NE	3.58	3.33	5.56	4.46	NE	4.70
Cooking loss (%)	35.54	33.67	2.75	35.08	34.19	NE	2.77	38.71[a]	30.19[b]	30.31[b]	NE	3.64
WBS (kg/1.27 cm diameter)	3.21	3.64	0.58	3.65	3.05	2.48	1.72	3.87[a]	2.65[b]	3.45[ab]	3.07[ab]	0.87

[a,b,c]Means in the same row within subgroups with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e]IA=Interaction
[f]NE=Not executed

No significant differences ($p > 0.05$) were found for drip loss within any of the main effects. The correlation ($r = -0.07$) between pH_{24} and drip loss was not significant ($p > 0.05$). Significant differences ($p \leq 0.05$) were found for cooking loss between regions, with animals from MM having the highest (38.71%) cooking loss. The females also had a higher cooking loss than the males. A possible reason for this observation might be found in the fact that more female animals than male animals were taken from this region. In a study by Purchas, Yan and Hartley (1999) it was found that the cooking loss decreased as the ultimate pH increased. This observation was, however, not noted in this study.

Significant differences ($p \leq 0.05$) were found for WBS values between regions. Red hartebeest from MM (3.87kg/1.27cm diameter) had the highest WBS values. As the correlation ($r = 0.09$) between pH_{24} and WBS was not significant ($p > 0.05$), the high WBS value was probably due to the high number of adults that were obtained from MM. O'Halloran, Troy and Buckley (1997) noted that the pH decline influences the toughness of meat. Generally, an increase in age is associated with a decrease in tenderness (Lawrie, 1979). Although not significant ($p > 0.05$), the adult

animals had a higher shear force value than the sub-adults, and correspondingly the sub-adults had a higher shear force value than the calves.

Table 4

Mean interactions found for physical characteristics ($Temp_{24}$, L*- and b*-values) of *MLD* from red hartebeest as influenced by different sex, age and region combinations

	S[d]	A[e]	S*A	LSD[d]	A	R[f]	A*R	LSD	R	S	R*S	LSD
$Temp_{24}$	Female	Adult	9.18[a]	1.52								
	Female	Calf	3.80[b]									
	Female	Sub-adult	8.44[a]									
	Male	Adult	6.80[a]									
	Male	Sub-adult	7.07[a]									
L*-value									MM	Female	33.61[b]	2.75
									MM	Male	33.38[b]	
									QQ	Female	37.17[a]	
									QQ	Male	29.13[b]	
									SV	Female	30.14[b]	
									SV	Male	30.15[b]	
									TDR	Female	31.57[b]	
									TDR	Male	30.95[b]	
b*-value					Adult	MM	7.54	1.50	MM	Female	8.12[b]	1.70
					Sub-adult	MM	8.86		MM	Male	8.03[b]	
					Adult	QQ	8.72		QQ	Female	11.9[a]	
					Adult	QQ	8.01		QQ	Male	7.45[b]	
					Sub-adult	SV	6.63		SV	Female	7.00[b]	
									SV	Male	7.06[b]	
									TDR	Female	9.02[b]	
									TDR	Male	8.87[b]	

[a,b]Means in the same row between subgroups with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d,e,f]S=Sex, A=Age group; R= Region

Sensory characteristics

No significant differences ($p>0.05$) were found for aroma and flavour attributes of the *MLD* within the main effects (Table 5). It is commonly understood that the flavour of older animals is stronger than that of younger animals (Lawrie, 1979). Although not significant, there was a tendency for the flavour of the adult red hartebeest to be rated stronger than that of the sub-adult.

Significant differences ($p\leq0.05$) were found for initial juiciness (Table 5) within sexes with the meat of the females having the highest initial juiciness (6.52). No significant differences for this attribute was, however, found within the age groups and regions. For sustained juiciness the meat of the females were also significantly ($p\leq0.05$) juicier (Table 5), and according to Table 6 there were significant interactions ($p\leq0.05$) for sustained juiciness between age groups and

regions, however, there was no definite pattern: The meat from the sub-adults from TDR had the highest sustained juiciness (6.63), whereas in MM the adult animals displayed the highest sustained juiciness (6.30).

Table 5

Means for the sensory quality characteristics of *MLD* from red hartebeest as influenced by different sexes, age groups and regions

	Sex			Age			Region		
	Female	Male	LSD[c]	Adult	Sub-adult	LSD	MM	TDR	LSD
Aroma[d]	5.81	5.71	0.31	5.82	5.70	0.31	5.68	5.86	0.29
Game flavour[d]	5.74	5.66	0.19	5.77	5.61	0.19	5.80	5.63	0.18
Initial juiciness[e]	6.52[a]	6.12[b]	0.28	6.42	6.35	0.27	6.48	6.31	0.26
Sustained juiciness[e]	6.10[a]	5.76[b]	0.31	IA[h]	IA	IA	IA	IA	IA
First bite[f]	6.36[a]	6.07[a]	0.38	IA	IA	IA	IA	IA	IA
Residue[g]	IA	IA	IA	IA	IA	IA	IA	IA	IA

[a,b]Means in the same row within subgroups with different superscripts are significantly different
[c]LSD=Least significant difference (p=0.05)
[d]1=extremely bland, 8=extremely intense
[e]1=extremely dry, 8=extremely juicy
[f]1=extremely tough, 8=extremely tender
[g]1=abundant, 8=none
[h]IA = Interaction

Table 6

Mean interactions found for sensory characteristics of *MLD* from red hartebeest between sex, age and region combinations

	A[f]	R[g]	A*R	LSD[d]	A	S[e]	R	A*S*R	LSD
Sustained juiciness[h]	Sub-adult	MM	5.79[b]	0.43					
	Sub-adult	TDR	6.63[a]						
	Adult	MM	6.30[a]						
	Adult	TDR	5.56[b]						
First bite[i]	Sub-adult	MM	6.67[b]	0.53					
	Sub-adult	TDR	7.21[a]						
	Adult	MM	6.47[b]						
	Adult	TDR	5.50[c]						
Residue[j]					Sub-adult	Female	MM	7.00[a]	0.90
					Sub-adult	Female	TDR	7.56[a]	
					Adult	Female	MM	7.23[a]	
					Adult	Female	TDR	6.33[b]	
					Sub-adult	Male	MM	7.33[a]	
					Sub-adult	Male	TDR	7.00[a]	
					Adult	Male	MM	7.00[a]	
					Adult	Male	TDR	6.86[a]	

[a,b,c]Means in the same row between subgroups with different superscripts are significantly different
[d]LSD=Least significant difference (p=0.05)
[e,f,g] S=Sex, A=Age group; R= Region
[h]1=extremely dry, 8=extremely juicy
[i]1=extremely tough, 8=extremely tender
[j]1=abundant, 8=none

According to Table 6 significant interactions ($p \leq 0.05$) were also found for first bite between age groups and regions with the sub-adults from TDR having the most tender meat (7.21) and the adults from TDR the least tender meat (5.50). Table 6 also indicates interactions ($p \leq 0.05$) for residue between age groups, regions and sexes. The sub-adult females

from TDR had the highest (7.56) and the adult females from TDR the lowest (6.33) residue value. The latter sensory results indicate that within a region and sex group, age can have a significant influence on tenderness (Lawrie, 1979). In this investigation, no significant correlation ($p>0.05$) was found between WBS and first bite ($r=0.74$) and therefore the WBS results could not substantiate the sensory results. Smit (2003) also found this observation to be true, and found no significant correlation between total collagen content and first bite. In contrast, Weir (1960) found that the meat with the highest tenderness also had the smallest amount of connective tissue.

Conclusion

In this study it was found that main effects (sex, age groups and regions) affect the physical and sensory properties of red hartebeest. Although sex had no effect on any of the physical parameters measured, it had an effect on the sensory characteristics of initial juiciness, sustained juiciness and first bite. Furthermore, the females had a higher cooking loss than the males. As more female than male animals were taken from this MM, the assumption can be made that this factor led to the meat of the animals from MM having the highest cooking loss. In general, an increase in age was associated with a decrease in tenderness. Age differences were also found for pH_{45}, $Temp_{45}$ and initial juiciness. A regional effect was also found for $Temp_{45}$, pH_{24}, $Temp_{24}$, a*- colour value, cooking loss, initial juiciness and WBS. Red hartebeest from MM had the highest WBS probably due to the larger proportion of adults that were obtained from MM.

The most important significant statistical interactions noted were the L*- colour value, which was influenced by region and sex, whilst the sensory tenderness of the meat was influenced by age, sex as well as region. Presently, red hartebeest meat is being sold without displaying any indication of age, sex and region. Although statistically significant differences were found for some of the quality attributes of the meat, it could be argued that these were minor and that the general consumer would not notice these differences. This aspect does, however, warrant further research.

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Chapter 9

General conclusions

The growth in the human population world-wide makes it necessary to gain knowledge of the potential of game meat as a viable source of protein. From a meat production point of view, meat scientists should gain knowledge about the percentage tissue available for human consumption (Von La Chevallerie, 1970). The criteria that apply for the meat production of game species are similar to those of domestic stock (Skinner, 1984). However, limited information on the chemical composition of game meat and the viability of game meat products as a means of complementing the growing demand for healthy food products, are available (Aidoo & Haworth, 1995). It is well known that red meat such as mutton has a fat content of between 20 and 25%, which is considered to be relatively high. In contrast, game meat has a much lower fat content (2 to 3 g per 100 g meat), which would make it an attractive alternative for the health-conscious consumer (Schönfeldt, 1993).

Throughout South Africa there has been an increase in the utilization of wildlife on private land. In 1985 it was estimated that approximately 10 000 farmers derived an income from wildlife utilization (Luxmore, 1985). This is nowhere more evident than in the Limpopo Province of South Africa where cattle numbers have declined in favour of game-ranching activities (Robinson & Lademann, 1998). Unfortunately, most game farmers seem to consider game meat production as the last option. As a result of this trend, the development of the game meat market in South Africa has been identified as a key priority to the game industry (Pauw, 1993). The regular cropping of surplus animals could increase the availability of game meat on a more organized and larger scale (Hoffman & Bigalke, 1999). However, information on factors such as pre- and post-mortem stress and the effect thereof on meat quality is very limited (Hoffman, 2000).

The aim of this study was to characterize blesbok and red hartebeest meat. As a primary objective it was necessary to qualify some of the factors that could influence the meat quality of the *M. longissimus dorsi* of these two species. The independent variables were the samples of male and female, sub-adult and lamb/calf of blesbok and red hartebeest. The dependant variables were the chemical and physical properties, as well as the sensory properties of the meat.

As far as the morphological characteristics of both blesbok and red hartebeest are concerned, the male animals had the highest values for most of the characteristics measured. This could be ascribed to the fact that male animals have heavier forequarters and thicker necks. Due to the skewness of the sampling the effect of the age on the characteristics could not be accurately assessed. The regional results were mostly affected by the distribution of animals in the other sub-groups. The dressout percentage of both species measured lower than reported for the other ungulates. These differences could be due to the difference in the methodology used in determining this parameter, e.g. what was included in the carcass weight.

The physical characteristics were mostly affected by uncontrolled factors, e.g. ambient temperature and stress. Region affected the colour of blesbok meat, and region and age affected the colour of red hartebeest meat. Blesbok from Qua-

Qua (QQ) had the darkest meat (L*=27.94). The meat from the female red hartebeest from QQ was slightly lighter in colour and not so intensely red (L*=37.17; b*=11.9). Blesbok, red hartebeest and other game species such as impala have less intra-muscular fat than domestic animals (Hoffman, 2000), and this could be the reason why the colour of the meat appears significantly darker. Furthermore, free-range animals are much more active than stall-fed animals and therefore have more muscle pigment (Lawrie, 1979), and it can thus be expected of game meat to have a darker red colour. Some of the animals experienced a great deal of stress before they were shot and this influenced the temperature and pH. Between the sexes, the high pH of the male blesbok's meat can be ascribed to the heightened physical activity of the males during to the rutting period. The low temperatures of the blesbok meat from QQ can be ascribed to the low ambient temperatures. As expected, the pH influenced the percentage of cooking and drip loss.

Sensory characteristics were affected by sex and region, although the effect was not significant. In general, the taste panel found all the meat to have a moderate aroma and game meat flavour, and that the meat could be described as juicy and tender. The meat from the blesbok sub-adults had a stronger flavour than the adults, although Lawrie (1979) found that the aroma of older animals tend to be stronger than that of younger animals. Although not significant, there was a tendency for the flavour of adult red hartebeest to be stronger than that of the sub-adult. For the blesbok study, both the shear force value and the taste panel showed the meat from older animals to be less tender than meat from younger animals. No correlation was found between total collagen content and first bite of red hartebeest meat, although Weir (1960) found that the meat with the highest tenderness also had the smallest amount of connective tissue.

The contribution of sex, age and region to the chemical characteristics of blesbok and red hartebeest meat was not substantial. In this study the highest fat content of blesbok and red hartebeest meat respectively measured 1.42 g/100 g and 4.49 g/100 g. Von La Chevallerie (1972) found that the fat content of springbok, an ungulate species regularly found in the same habitat as blesbok and red hartebeest, never exceeded 3.30%. The meat from blesbok and red hartebeest males had the highest protein (22.39 g/100 g and 23.34 g/100 g meat sample) and total collagen content (1.67% and 0.98%). Red hartebeest meat is an excellent source of iron with values of 11.51 mg/100 g and 7.78 mg/100 g for the males and the adults compared to values of 4.3 mg/100 g for beef steak and 2.5 mg/100 g for beef loin (Lawrie, 1979; Lushbough & Schweighert, 1960). According to Schönfeldt (1993) stearic acid (C18:0) is considered a cholesterol-neutral fatty acid; whereas myristic acid (C14:0) and palmitic acid (C16:0) are considered the cholesterol-raising fatty acids. The main cholesterol-lowering fatty acids are oleic acid (C18:1*n*-9), linoleic acid (C18:2*n*-6) and arachidonic acid (C20:4*n*-6). Beef has an average value of 3.27 mg/100 g for palmitic acid. The cholesterol-raising capacity of blesbok (1.45 mg/100 g) and red hartebeest (0.98 mg/100 g) is thus slightly lower. For stearic acid (C18:0), the so-called cholesterol-neutral fatty acid, there was a significant ($p \leq 0.05$) interaction for blesbok with the females from RF having the highest stearic acid value (2.56 mg/100g) and the females from MM the lowest (1.33 mg/100g). The sub-adult blesbok animals also had a significantly higher value for stearic acid (2.19 mg/100g), but the latter result could be biased as there were only four sub-adults in the sample. For the cholesterol-lowering fatty acids, only oleic acid illustrated a significant ($p \leq 0.05$) interaction with the blesbok female animals from RF having the highest value of 2.56 mg /100 g. The adult red hartebeest had the highest (1.25 mg/100 g) oleic acid value and the sub-adult animals the lowest (0.74 mg/100 g). For linoleic acid and arachidonic acid there were no significant differences between the different groups for both species, however, it is interesting to note that the blesbok females and the blesbok from RF had the lowest values for the two respective cholesterol-lowering fatty acids. The fatty acid composition of meat is currently receiving a lot of attention because of its implications for human health. The aim is to bring the polyunsaturated:saturated fatty acids ratio (P:S ratio) of meat closer to the recommended value (>0.7) (Raes, De Smit,

Demeyer, 2003; Sanudo *et al.*, 2000). Red hartebeest from TDR had the highest P:S ratio (0.87) and MM the lowest (0.63). There was a significant interaction for the P:S ratio of blesbok with the adult animals from GR having the highest (1.07) and sub-adults from RF the lowest (0.65) ratio. According to Enser *et al.* (1998) meat of ruminant animals usually has a low ratio of P:S, whereas venison can have a much higher and more positive P:S ratio due to a high PUFA content (Girolami, Marsico, D'Andrea, Braghieri, Napolitano *et al.*, 2003). Red hartebeest and blesbok meat is therefore a valuable source of polyunsaturated fatty acids and it contributes positively towards a higher P:S ratio and a lower n-6:n-3 ratio. Raes *et al.* (2003) stated that research within the field of Meat Science had been carried out with the aim of decreasing the n-6:n-3 ratio of meat to a value below 5. In this regard Girolami *et al.* (2003) reported that high amounts of linoleic and arachidonic acids were recorded in ostrich meat, which resulted in a n-6:n-3 ratio of approximately 4. The n-6:n-3 ratio for blesbok ranges between 2.34 for the sub-adult animals and 4.90 for animals from MM and between 3.07 for red hartebeest from MM and 2.36 for red hartebeest from TDR. These values are well within the latter recommendation for the n-6:n-3 ratio. The female blesbok (54.32 mg/100 g meat sample) and the sub-adult red hartebeest (55.95 mg/100 g meat sample) had the highest cholesterol content. Nevertheless, these two species have a relatively low cholesterol content when compared to other types of meat. For example, South African beef has a cholesterol content of 89.58 mg/100 g (Schönfeldt, 1993), whereas according to Horbanczuk *et al.* (1998) the cholesterol content of ostrich is 65.63 mg/100 g.

It can thus be concluded that sex, age and region did not have a significant influence on the overall quality of the meat of either the blesbok or the red hartebeest. Farmers of game species therefore need not concentrate on these three factors in their strive to produce game meat with an optimum quality. Blesbok and red hartebeest meat can both be regarded as a suitable alternative source of protein for the health-conscious consumer.

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