MEAT QUALITY CHARACTERISTICS OF THREE SOUTH AFRICAN GAME SPECIES: BLACK WILDEBEEST (*Connochaetes gnou*), BLUE WILDEBEEST (*Connochaetes taurinus*) AND MOUNTAIN REEDBUCK (*Redunca fulvorufula*)

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DECLARATION

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

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SUMMARY

The purpose of this study was to investigate the effects of production region, age and sex on the meat quality characteristics of black wildebeest (*Connochaetes gnou*), blue wildebeest (*Connochaetes taurinus*) and mountain reedbuck (*Redunca fulvorufula*) in determining the carcass yield and physical, chemical and sensory properties of the *M. longissimus dorsi et lumborum*.

The black wildebeest (50.10% ± 3.04), blue wildebeest (51.00% ± 0.76) and mountain reedbuck (55.50% ± 0.91) all had similar dressing percentages. The morphological measurements indicated that all three main effects investigated had significant ($P \leq 0.05$) influences on the carcass size and length, and that these three species increase in size with an increase in animal age and that the males are larger than the females.

The physical characteristics proved that, just like meat from other sources, the rate pH and temperature decline, as well as the final pH and temperature, influence the physical properties of the meat, especially the drip loss, cooking loss and meat tenderness. The meat colour indicated an increase in darkness with an increase of animal age.

The chemical analyses indicated that black wildebeest (20.25% ± 0.29), blue wildebeest (22.99% ± 0.29) and mountain reedbuck (24.22% ± 0.21) meat had a high protein and (1.07% ± 0.09, 1.34% ± 0.12 and 2.61% ± 0.18) low fat content respectively. Both the female black wildebeest (20.73% ± 0.29) and mountain reedbuck (24.51% ± 0.20) had significantly higher ($P \leq 0.05$) protein contents than that (19.42% ± 0.29) of black wildebeest bulls and (23.68% ± 0.22) mountain reedbuck rams. The fatty acid composition was significantly affected by regional differences.

The sensory analysis was conducted on the *M. longissimus dorsi et lumborum* from the black wildebeest and mountain reedbuck samples. The regional and sex interactions of the meat samples indicated that the males have more intense game meat aroma, and were significantly ($P \leq 0.05$) tougher than the males and females. Sex x age interactions of the mountain reedbuck samples indicated the female sub-adult animals to be significantly ($P \leq 0.05$) than the female adults.

Seasonal changes in meat quality were illustrated in the morphological, physical and chemical properties of the meat from the black wildebeest. Average live and carcass weights indicated lighter weights and lower dressing percentages after the winter months. The animals harvested during spring (5.45% ± 0.74) had a significantly higher ($P \leq 0.05$) drip loss compared to those harvested during the winter (2.38% ± 0.16) and autumn (3.30% ± 0.55). Significant ($P \leq 0.05$) cooking losses were 39.69% ± 0.68 for spring compared to 34.71% ± 0.71 and

33.44% ± 0.62 for winter and autumn, respectively. Season also had an effect on the muscle colour. The proximate chemical composition reflected significant season x sex interactions for both the percentage protein (P=0.03) and the percentage fat (P=0.03).

In conclusion, it was found that the structural, compositional and biochemical properties of the meat of these species are all influenced to a greater and lesser extent by regions, year of harvesting, age and sex of the animal.

OPSOMMING

Die doel van hierdie studie was om die effek van die produksie area, ouderdom en geslag op die kwaliteitseienskappe van swart wildebees (*Connochaetes gnou*), blou wildebees (*Connochaetes taurinus*) en rooi ribbok (*Redunca fulvorufula*) vleis te ondersoek, deur die karkasopbrengs, fisiese, chemiese en sensoriese eienskappe van die *M. longissimus dorsi et lumborum* spier, te bepaal.

Die swart wildebeeste (50.10% ± 3.04), blou wildebeeste (51.00% ± 0.76) en rooi ribbokke (55.50% ± 0.91) het naastenby dieselfde uitslag-persentasies gehad. Die morfologiese metings het aangedui dat die drie hoof-effekte wat ondersoek is, die karkasgrootte en lengte van die drie spesies betekenisvol ($P \leq 0.05$) beïnvloed het, en dat die diere toeneem in grootte met ouderdom, en ook dat die manlike diere groter is as die vroulike diere.

Die fisiese eienskappe het bewys dat, net soos vleis van ander bronne, die tempo van pH en temperatuur-daling, sowel as die eind-pH en -temperatuur, die vleiskwaliteitseienskappe beïnvloed het, veral die drupverlies, kookverlies en taaiheid daarvan. Die kleur van die vleis het aangedui dat ouer diere donker vleis het.

Die chemiese ontledings het bewys dat swart wildebees (20.25% ± 0.29), blou wildebees (22.99% ± 0.29) en rooi ribbok (24.22% ± 0.21) vleis 'n hoë proteien en lae vet inhoud (1.07% ± 0.09, 1.34% ± 0.12 en 2.61% ± 0.18, onderskeidelik) bevat. Beide die swart wildebeeskoeie (20.73% ± 0.29) en rooi ribbokooie (24.51% ± 0.20) het 'n betekenisvol hoër ($P \leq 0.05$) protein inhoud gehad as die (19.42% ± 0.29) swart wildebeesbulle en (23.68% ± 0.22) rooi ribbokramme. Die vetsuursamestelling betekenisvolle verskille getoon het tussen die verskillende areas waar die diere geoes is.

Die sensoriese onledings is uitgevoer is op die *M. longissimus dorsi et lumborum* van die swart wildebees en rooi ribbok monsters. Die area en geslag interaksies van die swart wildebees vleismonsters het aangedui dat die bulle 'n betekenisvol ($P \leq 0.05$) sterker wildsvleis aroma het en ook betekenisvol ($P \leq 0.05$) taaier was in vergelyking met die bulle en koeie. Geslag x ouderdom interaksies van die rooi ribbok monsters het aangetoon dat die vroulike onvolwasse diere betekenisvol ($P \leq 0.05$) sappiger en sagter was as die volwasse ooie.

Die seisoenale veranderinge op die vleiskwaliteit was sigbaar in die morfologiese, fisiese, sowel as chemiese ontledings wat uitgevoer was. Die gemidddelde lewendige - en karkasmassa was ligter en 'n laer uitslag persentasie is ook na die winter gekry. Die diere wat geoes is gedurende die lente (5.45% ± 0.74) het 'n betekenisvol hoër persentasie drup verlies gehad in vergelyking met die diere wat in die winter (2.38% ± 0.16) en herfs (3.30% ±

0.55) geoes was. Dié diere het ook 'n hoër persentasie kookverlies gehad van 39.69% (± 0.68) in vergelyking met winter (34.71% ± 0.71) en herfs (33.44% ± 0.62). Seisoen het ook 'n effek gehad op die vleiskleur. Die proksimale chemiese samestelling het betekenisvolle seisoen x geslag interaksies gehad, vir beide die proteïn inhoud (P=0.03) en die persentasie vet (P=0.03).

Daar is dus gevind dat die strukturele komponente, die samestelling en biochemiese samestelling van die vleis van die bogenoemde spesies tot 'n mindere en meerdere mate beïnvloed word deur area, jaar wanneer dit geoes word, ouderdom en die geslag van die dier.

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TABLE OF CONTENTS

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 was unavoidable.

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

1. Van Schalkwyk, S., Hoffman, L.C. & Muller, M. (2003). Seasonal changes in the physical and chemical composition of black wildebeest (*Connochaetus gnou*) meat. In: Proc South African Wildlife Management Association Symposium; Balancing the Books for Biodiversity, Ganzekraal, 21-23 September 2003.

2. Van Schalkwyk, S., Hoffman, L.C. & Muller, M. (2003). Effect of different harvesting regions and animal sex on the sensory characteristics of black wildebeest (*Connochaetes gnou*) meat. In: Proc South African Wildlife Management Association Symposium; Balancing the Books for Biodiversity, Ganzekraal, 21-23 September 2003.

3. Van Schalkwyk, S., Hoffman, L.C. & Muller, M. (2003). Comparison of the fatty acid composition of mountain reedbuck (*Redunca fulvorufula*) meat with that of beef, mutton and pork. In: Proc South African Wildlife Management Association Symposium; Balancing the Books for Biodiversity, Ganzekraal, 21-23 September 2003.

LIST OF ABBREVIATIONS

DFD	Dark, Firm and Dry meat
LSD	Least Significant Difference
MLD	*M. longissimus dorsi et lumborum*
MM	Maria Moroka Nature Reserve
MUFA	Mono-unsaturated fatty acids
P:S	Ratio of polyunsaturated fatty acids to saturated fatty acids
PUFA	Polyunsaturated fatty acids
SFA	Saturated fatty acids
SI	Significant Interaction between main effects
SV	Sandveld Nature Reserve
TUFA	Total unsaturated fatty acids

CHAPTER 1

INTRODUCTION AND MOTIVATION

The quality of meat, its sensory, physical and chemical properties, nutritional composition, and consumer acceptability are largely determined by the species, as well as events and conditions encountered by the animal. Factors such as the production region, diet, seasonal influences, as well as cropping and processing methods have an effect on the nature of the muscles and the ultimate quality of the meat. Control of the factors that influence the properties of meat, and further enhancement of these are dependent on an increased knowledge and fuller understanding of the commodity at all processing stages. This includes a wide spectrum of variables, from conception, growth and development to territorial and environmental behaviour, cropping methods, time of slaughter as well as processing, preparation, distribution, cooking and consumption of the meat (Zotte, 2002).

Limited research has been conducted on South African game meat. When producing meat from wild ungulates, the same criteria apply as those applying to meat produced from domestic stock, like that of beef, lamb and pork. The criteria include factors such as yield, physical characteristics, as well as chemical composition, which also includes mineral, fatty acid and amino acid contents, all these factors having an effect on the overall meat quality. Knowledge of these factors will indicate not only the nutritional potential of game meat, but also the prices that could be obtained and the potential markets to be targeted (Hoffman, 2000).

In Africa, the increased population and concurrent decrease in the per capita supply of high-quality protein has intensified the search for alternative sources of food protein (Onyango, Izumimoto & Kutima, 1998). In addition, the process of desertification in Africa has produced an environment that can no longer support increased numbers of domestic cattle economically. Although the consumption of game meat is an age-old practice in Africa (known as bush meat) and game meat is an important alternative to beef in many regions (Onyango *et al.*, 1998), not much research has been done on the different quality attributes and palatability traits of game meat, in particular black wildebeest (*Connochaetes gnou*), blue wildebeest (*Connochaetes taurius*) and mountain reedbuck (*Redunca fulvorufula*). According to Hoffman (2000), the last three decades have seen an increasing utilization of wildlife on private land throughout South Africa, although the production and consumption of game meat has been poorly documented.

Wildlife production can be seen as a quest for an efficient complementary alternative to conventional agricultural animals. The logic of livestock diversification using wildlife offers opportunities to use regional adopted species and to tap multiple niche markets. Most of the expansion of wildlife ranching and farming has occurred since 1970 (Hudson, 1999). In some areas it originated as a conservation initiative, but the main driving force has been the lucrative market for products and hunting opportunities created during a time of economic prosperity. Commercial wildlife production raises important issues of economic and ecological sustainability, welfare and social equity. There is an urgent need for more precise information on the status, dynamics and policy implications of this rapidly emerging industry (Hudson, 1999). Many cattle farmers are also changing over to game farming; during the past century game farming was the largest growing agricultural industry in the country. Commonly, large populations has been utilised for trophy hunting, as well as a source of animals for the live market and to explore tourism opportunities (Hearne, Lamberson & Goodman, 1996). This is leading to an overproduction of certain species and farmers need to look at options besides hunting, live sales and eco-tourism in an attempt to maximize their economic returns. On top of this, the prices of live game animals at auctions are decreasing. In an attempt to conserve these large mammal resources, more attention should be given to focusing on the optimum sustained use of these resources. This could lead to more meat utilisation and therefore production, and ultimately to more export opportunities. However, to sell or export meat, its exact nutritional content and composition must be known. Being young, the industry is not well organised and invests little in research programmes focussing on production and marketing.

There has been a rapid change in consumer trends over recent decades; consumers are more demanding and are very health conscious, especially in their choice of food products. Consumers are more attracted to "natural" or "organic" foods. Organic meat (or products) are perceived to be free of antibiotics, added hormones and GMO feed, and thereby safeguarded against "Mad Cow disease". Mad cow disease, also known as *bovine spongiform encephalopathy* (BSE), is a chronic degenerative disease that attacks the central nervous system of cattle, destroying brain tissue and eventually causing dementia and death. There is no known cure. Scientists believe the disease has spread among cattle primarily through so-called "animal recycling" - the use of bone meal and other ground animal parts in commercial feeds. At least 94 Europeans have died from a human variant of this disease, called new variant Creutzfeldt Jakob disease, probably contracted from eating infected meat products. The recent resurgence of the disease comes despite widespread beef import restrictions and other measures intended to protect the food supply (Anon., 2001). This causes a decline in the demand and supply of beef and beef-related products. The meat industry is one of the world's oldest and most important industries (Swatland, 1984), but because of the risks associated with beef consumption, consumers are now looking for alternative sources of red

meat. The South African game species live in a natural, pure and healthy environment, as opposed to the traditional meat types, which are affected by diseases and commercialised feeds. This creates a niche in the production, utilisation and even export market for other underdeveloped meat sources like game meat, which can be placed both under the organic and "Mad Cow safe" banner.

According to Stevenson, Seman and Littlejohn (1992) game meat is also promoted as a top-quality gourmet food item because of it nutritional profile (low fat and cholesterol) for health-conscious consumers. The consumer's demand for lean muscle with less fat has created an ideal niche for the utilization of game meat, as game meats are promoted on the basis of low fat, natural image and sensory attributes (Hudson, 1999). The main attraction factor for game meat will therefore probably be the product quality and consistency rather than price.

The health arguments have led to an increased interest in manipulating meat from domestic species so as to change its composition. Instead of changing the meat composition, why not replace meat from domestic animals with healthier alternatives? The meat industry must search for healthier alternative sources of red meat to provide lean alternatives, and start to label informatively to promote the positive virtues of game meat. In this way fat consumption can be controlled and the sensory pleasures of meat as a major food and nutrient source can be experienced (Harrington, 1994).

Furthermore, the factors that affect the biochemical quality of game meat, i.e. visual appeal, physical parameters and chemical composition, should be optimised. By determining all the ante-mortem factors influencing the meat quality and manipulating the post-mortem factors, optimum meat quality characteristics of the different South African game species are obtainable. The greatest difficulty with extensive systems is that animals cannot be easily monitored, capture can be traumatic and slaughter can be uncertain (Hudson, 1999). When animals are exposed to any unfamiliarity, they tend to become stressed which affects the rate and extent to which blood, and meat pH changes. The meat pH influences various meat quality parameters such as colour and the water binding capacity of the muscle, both important meat quality attributes. Little data is available on the effects of the cropping or shooting of wild ungulates on the quality of the meat (Hoffman, 2000).

This study will therefore investigate specific meat quality characteristics of black wildebeest, blue wildebeest and mountain reedbuck, and the changes in these caused by ante-mortem and post-mortem factors. Morphological characteristics of the carcass, the physical meat quality characteristics and the chemical composition, as well as the sensory quality attributes of the meat, will be investigated.

AIMS

The aim of this study is to determine the physical, chemical and sensory meat quality characteristics of three South African game species: black wildebeest (*Connochaetes gnou),* blue wildebeest (*Connochaetes taurinus)* and mountain reedbuck (*Redunca fulvorufula*). Figures 1 to 4 illustrate the research design of the three game species investigated in this research project.

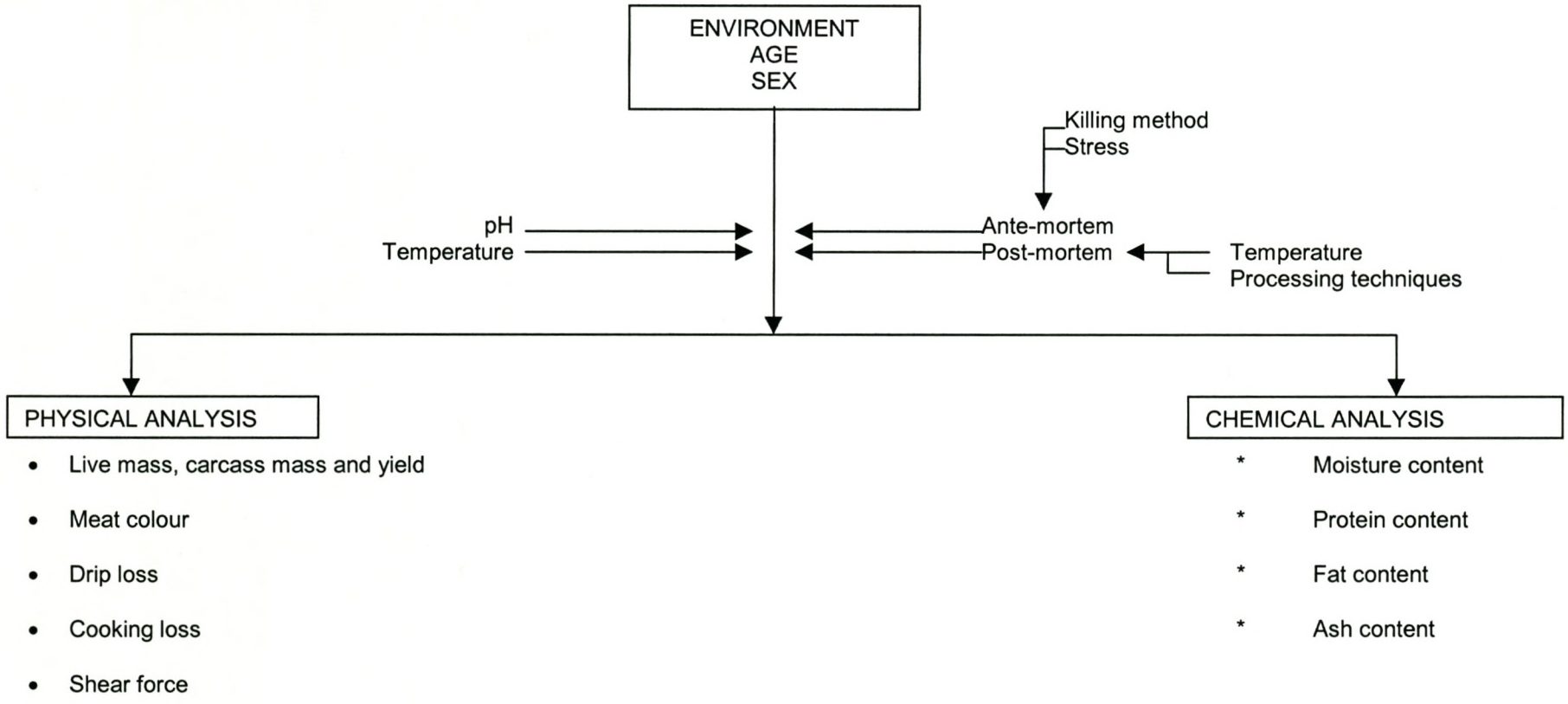

Figure 1

Research conceptual framework for the black wildebeest harvested during 2001 and 2003

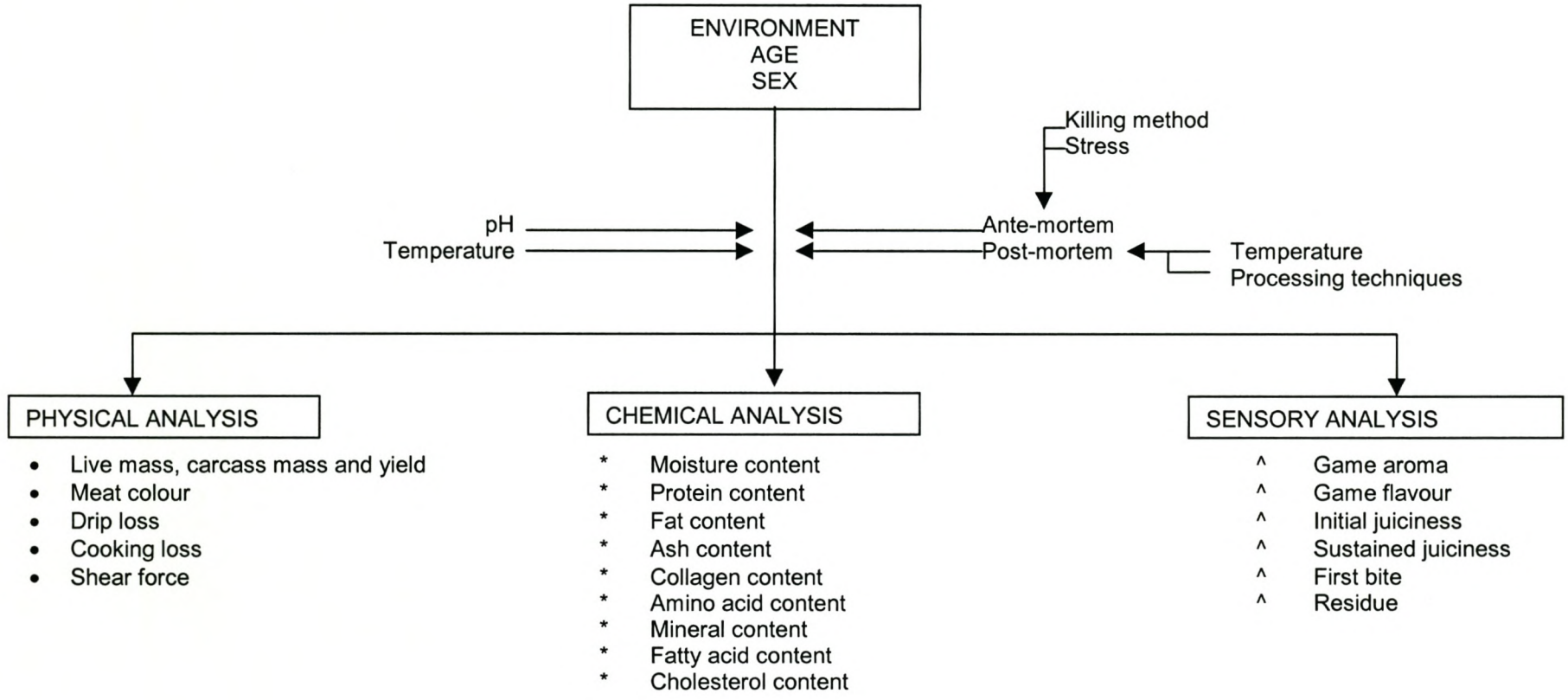

Figure 2

Research conceptual framework for the black wildebeest harvested during 2002

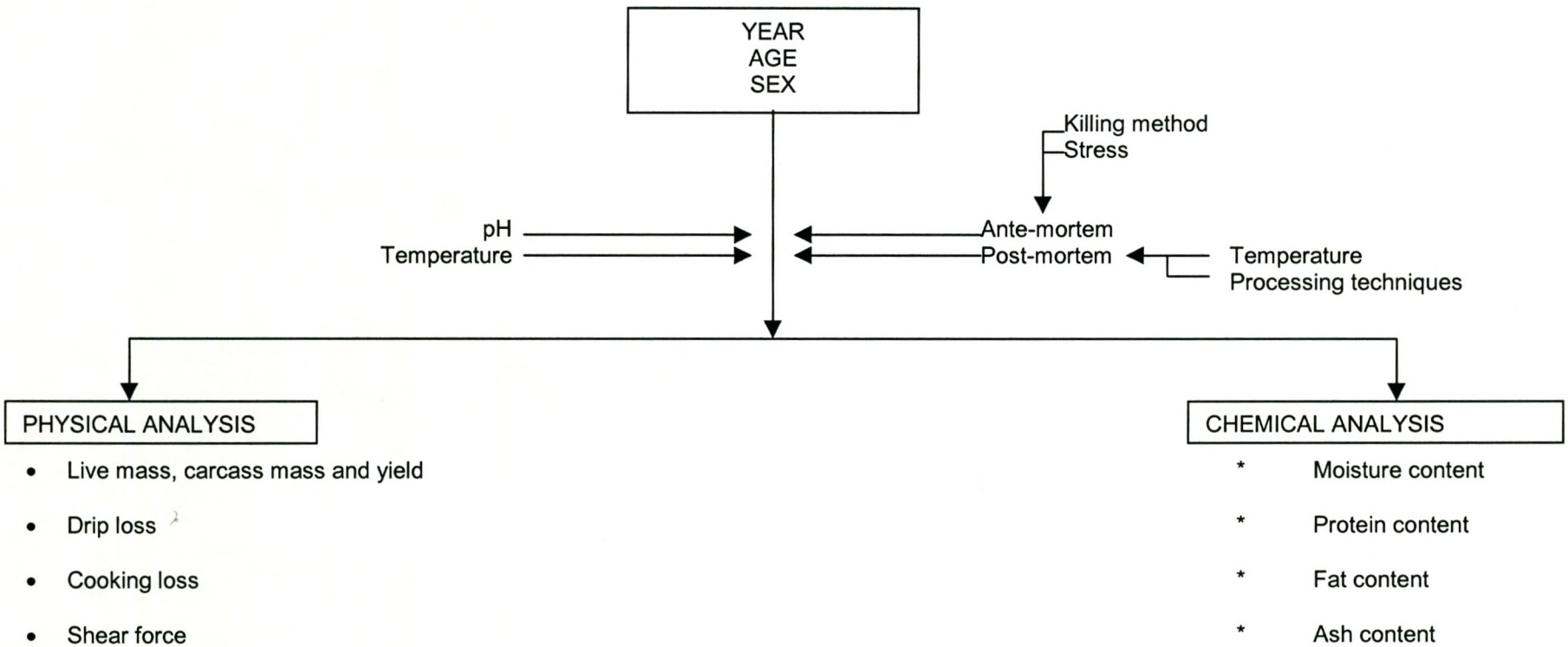

Figure 3

Research conceptual framework for the blue wildebeest harvested at Sandveld Nature Reserve during 2001 and 2003

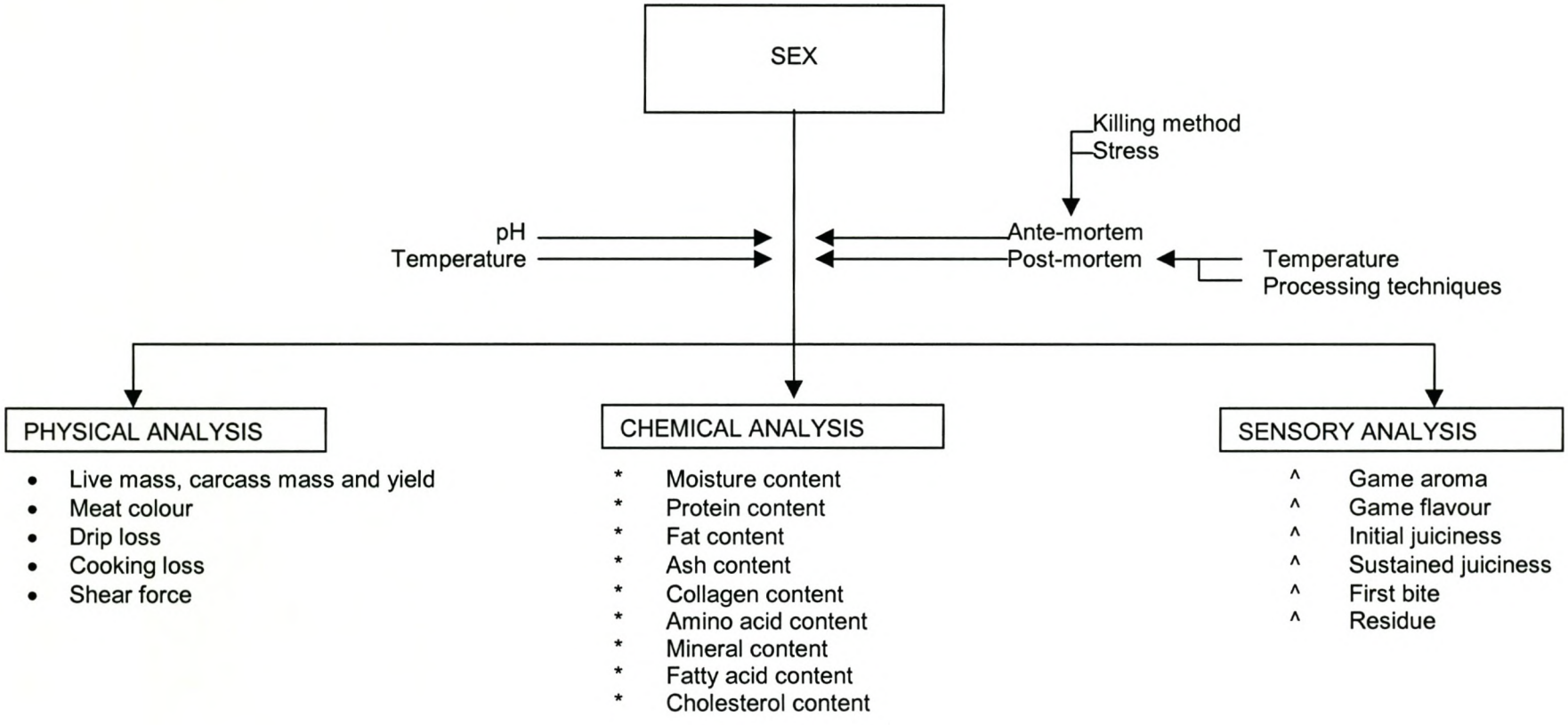

Figure 4

Research conceptual framework for the mountain reedbuck harvested at Tussen die Riviere Nature Reserve during 2002

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CHAPTER 2

LITERATURE REVIEW

1. INTRODUCTION

Muscle is a highly organised biological tissue with an intricate, complex structure, a unique composition and a very active biochemical capability. Knowledge of the composition, anatomy, development of rigor mortis and muscle functional properties is important in developing an understanding of the processing of meat (Anon., 2001). The term "meat" usually refers to the post-mortem animal muscle. Such tissue, however, is dependent on considerable inter- and intra-animal variation, while the structural, compositional and biochemical properties too vary considerably between different muscles on a particular carcass as well as within a particular muscle, both in relation to the type of action each muscle performs in the body and to induced effects arising from pre-slaughter and post-slaughter handling procedures (Jones, 1985). It is important to keep in mind that meat remains highly variable as a raw material, so that a proper understanding of the different properties will help achieve the best finished products, as animal variation due to species, age, sex, environment, and pre-slaughter handling affect the properties of its meat (Lawrie, 1985). This, in turn, affects the basic characteristics inherent to muscle, biochemical changes that occur in converting muscle to meat and the chemical properties of the most prevalent meat components (Anon., 2001).

In contrast to beef, mutton and pork, rather limited research on the consumer acceptability regarding meat quality and wholesomeness has been done on South African game meat, especially the palatability traits of different game species. When producing meat from wild ungulates, the same criteria apply as those applying to meat derived from domestic species (Hoffman, 2000). These criteria include characteristics such as yield, physical qualities, chemical composition and sensory profiles. Knowledge of these characteristics and parameters will indicate not only the nutritional potential and sensory properties, but also the potential markets to be targeted (Hoffman, 2000). This literature review will, therefore, discuss all the possible factors affecting game meat tenderness, juiciness and flavour, as well as the health issues and attributes associated with meat consumption. This will be followed by a species review of the three indigenous South African species, black wildebeest (*Connochaetes gnou*), blue wildebeest (*Connochaetes taurinus*) and mountain reedbuck (*Redunca fulvorufula*), followed by a regional review of the reserves where they are harvested.

Due to the scarcity of published material on game meat, general meat theory and correlations of beef, mutton and (where available) ostrich will be made.

Product features to a large extent determine the consumer demand. Each food product should meet its own set of distinctive standards to satisfy consumer requirements concerning these unique characteristics. According to Rywotycki (2003), contemporary consumers expect safe food of high nutritional quality and acceptable sensory features. An overview of all the factors that influence consumer choice and product acceptability, sensory properties of meat, and the way in which these are quantified by the use of different physical and chemical methods, as well as health issues associated with the consumption of meat, will now be discussed.

2. QUALITY CHARACTERISTICS

After the decision to purchase a food product, consumer acceptability will be determined by ascertaining the satisfaction experienced after consumption together with the nutritional fulfilment of the consumers' requirements. Meat products can be evaluated with both the human senses and instruments. The human senses measure the sensory properties by means of a trained taste panel and, when applicable, a consumer panel, whereas instruments are used to quantify the physical and chemical properties of meat.

2.1 Sensory properties

The acceptability of meat after purchase is determined almost exclusively by the satisfaction derived from its consumption (Jeremiah, Tong & Gibson, 1990). According to Stone and Sidel (1993), sensory analysis is defined as a scientific method used to evoke, measure, analyse and interpret the responses to products as perceived through the senses of sight, smell, touch, taste and hearing. It consists of a set of techniques for accurate measurement of human responses to foods and attempts to isolate the sensory properties of food for further enhancement (Lawless & Heymann, 1995). Sensory measurements offer the advantage of approximating the actual measurement of different meat characteristics as encountered under normal conditions of eating (Pearson, 1963). For this type of analytical testing, a group of trained panelists is used as an instrument to assess differences in tenderness, juiciness and flavour (Charley & Weaver, 1998). The sensory analysis of meat is of paramount importance, as meat and meat products contribute to one sixth of the proteins consumed by humans (Warris, 2000) and, therefore, form a large proportion of the human diet (Risvik, 1994). The three major palatability attributes of meat are tenderness, juiciness and flavour.

2.1.1 Tenderness

Tenderness is the most important palatability attribute of meat (Lawrie, 1985). The role of meat tenderness, tenderisation and ageing, and all the factors that influence the tenderness of meat, have been the subject of numerous studies. After consumption, meat tenderness is the property which will lead to the overall acceptability of the product by the consumer. Ouali (1990) states that tenderness is regarded as the most important sensory attribute affecting meat acceptability, while Koohmaraie (1988) mentions that tenderness is the predominant quality determinant and is probably the most important sensory characteristic of red meat. Consumers even state that, when meat is tough, it is unacceptable (Jeremiah *et al.*, 1990).

Lepetit and Culioli (1994) define meat tenderness as being the force needed to shear, compress and ground the meat during mastication and consumption, thus referring to the ease with which the consumer disorganises the meat structure. The sensation of tenderness is a complicated physical process, since chewing involves not only cutting and grinding, but also squeezing, shearing and tearing. Tenderness is extremely difficult to measure, because the chewing motions involve both vertical and lateral movements of the jaw. All these activities together produce the impression of tenderness (Pearson, 1963).

Meat tenderness or toughness is an extremely complex characteristic, because it is not caused by a single factor, but an acquisition and integration of many factors that influence, or are associated with, meat tenderness. Numerous variables have been related to tenderness, such as the amount of intermuscular fat, collagen content, even the post-mortem ageing. In a study on beef steaks Davis *et al.* (1979) included a percentage of expressible juice, fragmentation index, sarcomere length, cooking loss, and the percentage of soluble collagen as variables to predict and explain 68% of the variation in meat tenderness, while Hawkins *et al.* (1987) ascribed 51% of the variation in meat tenderness in their study to muscle traits, such as sarcomere length and the percentage of moisture and fat. Apart from the ante-mortem factors such as species, age, sex and nutritional status as well as post-mortem factors such as slaughtering methods, pre-slaughtering stress, handling, processing and cooking temperatures, which have all been identified as influencing meat tenderness, other factors such as the collagen content, level of enzymes (especially calpains) and glycogen content also play a vital role in the overall tenderness of meat. With this background it becomes important to discuss the factors that might have an effect on the overall tenderness of game meat.

2.1.1.1 Ante-mortem factors

The relationship between species, age, sex, muscle type and nutritional status is always the first fundamental variation when meat tenderness is discussed. Consumer choice is dependent on these ante-mortem factors, as they influence the commercial value and the manner in which the meat will be treated during post-mortem tenderisation and especially during the processing and preparation (Lepetit & Culioli, 1994). The species, age, sex, muscle type, and nutritional status of the animal are all multiple causes of toughness, for instance, the rate of ageing is dependent on the live mass, while live mass, in turn, varies considerably within all the latter factors (Ouali, 1990).

2.1.1.1.1 Species

Tenderness is heritable to an extent of over 60%, causing species to be one of the major factors affecting meat tenderness (Lawrie, 1985). Tenderness is influenced by many intrinsic and extrinsic factors (Lawrie, 1985) which exhibits considerable variation in muscle metabolism within different species (Swatland, 1984).

Species is a genetic aspect, and influences variables like muscularity, lifespan and gestation period. Every species has its own unique behaviour and survival techniques for unfavourable seasonal fluctuations that affect the growth and development of the animal. Seasonal changes affect the dietary energy intake and overall well-being of the animal and therefore the quality of the meat post-mortem. Species also affect muscle composition, because animal growth involves changes in shape and composition (Warris, 2000). Most species tend to have cumulative growth during the first years, depending of food availability, with a stasis or lack of growth during the winter and weight increase and growth during the summer. Figure 1 illustrates the normal growth curve, irrespective of season and food availability of animals (Warris, 2000).

Difference in chemical composition, especially the fat content, is one of the most common reasons or explanations for meat being classified as either tough or tender. The basic composition of all meat is generally the same, being water, protein, fat, carbohydrates and inorganic constituents (Forrest *et al.*, 1975). The content and percentage per mass differs, not only between different species, but also between different ages and sexes, even the nutritional status of the animal when slaughtered. Game meat tends to have a higher percentage of protein and ash compared to domestic animals. The fat content of game meat is very low as well. Onyango, Izumimoto and Kutima (1998) found less that 1% crude fat content in a comparative study between three game species, while Nieminin (1992) found the

fat content in reindeer meat to be between 2% to 3%. Game animals tend to deposit more fat around the visceral organs and have virtually no intramuscular fat (Talbot *et al.*, 1965).

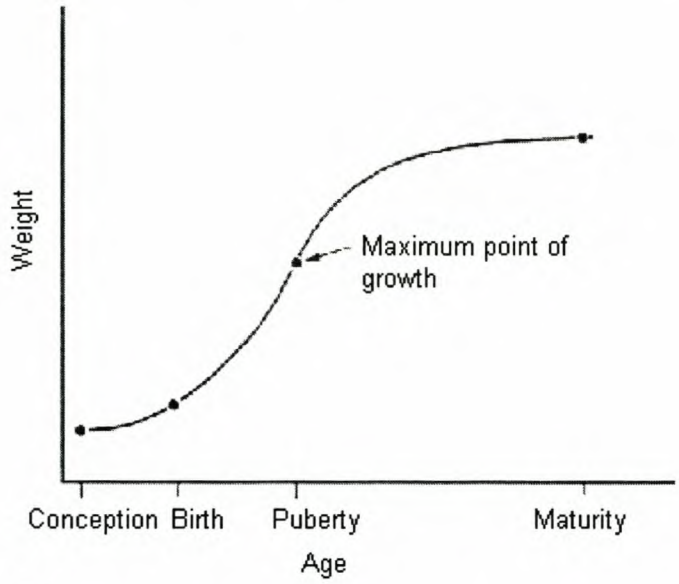

Figure 1
The relationship between the weight of an animal and its age (Warris, 2000)

Lawrie (1985) states that, apart from the chemical differences between species, there are more dynamic differences in a given muscle, for example, post-mortem enzymic activity. In addition, ultimate pH and muscle glycogen content varies between different species (Wiklund, Stevenson-Barry, Duncan & Littlejohn, 2001), which in turn affects the proteolytic enzyme levels and the ageing rate (Wiklund *et al.*, 1997). Dransfield (1994) also found that the rate of ageing differs between species, so that different species will have different post-mortem periods before optimum tenderness occurs.

2.1.1.1.2 Animal age

It is generally held that carcass maturity or age of the animal at the time of slaughter influences tenderness. Meat from more mature animals has repeatedly been found to be less tender than meat from younger animals. Therefore, evidence shows that tenderness decreases with advancing age (Palmer, 1963).

The composition of muscle varies with increasing animal age as well. As animals get older and heavier the proportion of fat in their carcasses increases, while the proportion of muscle and bone decreases (Warris, 2000). The protein content of young animals (calves/lambs) is 2% to 3% higher than those of adults (Nieminen, 1992). Other substances such as collagen

become less soluble with increased animal age, causing the meat to be less tender (Light, Champion, Voyle & Bailey, 1985).

2.1.1.1.3 Sex

Jeremiah *et al.* (1990) state that the proportions of tough and tender carcasses vary considerably among sex groups. It is commonly known that male animals are heavier and weigh more than female animals. In a study on impala (*Aepyceros melampus*), Hoffman (2000) found that even though the mean dressed weights differ significantly between the sexes, there are no significant differences ($P \leq 0.05$) when expressed in proportion of the body weight.

Sex has a major influence on fatness and conformation too. Female animals tend to display a greater tendency to accumulate fat, therefore causing them to be more tender (Diaz *et al.,* 2003). These sex differences in fatness are associated with variations in protein assimilation efficiency and the different composition of weight gain displayed by males and females throughout their growth (Diaz *et* al., 2003). Jeremiah *et al.,* (1990) found their results to be accordant with this – male animals are tougher than female animals. It is also interesting to note that even with wild ungulates (common eland bulls) the extremely low fat content could be raised by castrating the males and feeding them well and, therefore, enhancing their carcass qualities (Von La Chevallerie, Erasmus, Skinner & Van Zyl, 1971).

2.1.1.1.4 Nutritional status

Not a single known nutrient demonstrates any consistent and pronounced effect on meat tenderness (Palmer, 1963). In a study on the palatability and muscle properties of beef Fishell, Aberle, Judge and Perry (1985) established that cattle with restricted growth rates had lower tenderness ratings. In a review of the influence of nutrition on tenderness, Tatum (1981) concluded that there is substantial evidence that suggests that pre-slaughter nutrition has a pronounced effect on meat tenderness. The vastness of the data suggests that intensive feeding improves tenderness by increasing carcass weight and fatness, thereby reducing the susceptibility of cold-induced toughening. Diet and nutritional status of the animal, as well as other environmental factors and seasonal fluctuations such as drought, are responsible for changes in meat composition, especially in the percentages of intramuscular fat and moisture (Janicki, Kolaczyk & Kortz, 1969). Numerous reports have attributed variations in fat content to diet and geographical location. Fatness itself does not only influence the tenderness, quality and price, but also the slaughter weight (Diaz *et al.,* 2003). Diet varies considerably over the year and between the seasons, since the insufficient availability of nutrients causes weight loss (Wiklund, Pickova, Sampels & Lundström, 2001).

Winter live weight gains are thus considerably lower than summer live weight gains. Animals have been noted to undergo a 25% weight loss and lose more than 80% of their body energy over six weeks during a period of insufficient nutrition (Drew, 1985). The seasonal changes result in a considerable decrease in the chemical composition of the meat. Table 1 illustrates the weights of the muscle components in a study by Stevenson, Seman and Littlejohn (1992) as affected by the rutting season, where the male deer had less fat, protein and water after the rutting season.

Table 1
Weight of the muscle components of red deer stags pre- and post-rut

	Pre-rut	Post-rut
Moisture	2.15	1.86
Ash	46	39
Protein	703	586
Fat	79	10

Weights are in grams
Stevenson, Seman and Littlejohn (1992)

According to Hoffman (2000), the lower body lipid content during rutting is due to the strenuous activities in fighting for, and maintaining, a harem. The percentage of soluble collagen is also significantly greater in the pre-rut than the post-rut period. This causes post-rut samples to be less tender and to have lower flavour intensity than pre-rut samples (Stevenson *et al.*, 1992). Hammond (1932) also states that the general effects of different levels of nutrition on growth and development of animals are reflected in the composition of the different individual muscles. It is important to keep in mind that research has indicated that animal age, post-mortem carcass treatment and cooking method have a greater influence on the meat tenderness than the fat content (Stevenson *et al.*, 1992). This reveals that vast differences in the degree of fatness are necessary to produce significant changes in tenderness.

Pre-slaughter stress, handling and processing also greatly influence meat tenderness. An overview of the factors and the role they play in meat quality before and during processing will thus follow.

2.1.1.2 Pre-slaughter stress and post-mortem factors

Several significant changes occur in muscle before, during and immediately after slaughter. At the death of the animal the oxygen supply (as well as glucose and free fatty acids) to the muscles stops when the blood circulatory system fails (Warris, 2000). ATP continues to provide energy for vital functions through the anaerobic regenerated breakdown of glycogen

by glycolysis, since oxidative decarboxylation and phoshorylation will no longer operate. This causes the muscles to remain functional for quite some time (Warris, 2000). Since the blood no longer circulates the oxygen supply to the muscles, this results in an accumulation of lactic acid because the metabolic end products are not removed (Anon., 2001). This accumulation of lactic acid causes an increase in muscle acidity, so that the pH of the muscle decreases (Tarrant, 1981). Swatland (1994) states that this process can lead to the denaturation of muscle proteins, if the decline in pH is too low or if the carcass temperature is too high at even moderately low pH levels, which in turn may result in meat with poor water-holding capacity, which causes meat to be dry and tough.

However, it is often forgotten that the pH of the meat sample itself is temperature dependent. Jansen (2001) suggests an average pH-temperature dependence (?pH/?T) of about –0.011 pH units/°C. However, there is a considerable variation depending both on animal species and the type of tissue sampled. Although little work appears to have been done on the subject of the dependence of pH on temperature in post-rigor tissue, one can reasonably expect a difference between the pH-temperature interactions because of the differences between functioning cells and dead tissue which have been chilled (Jansen, 2001).

Various pre-slaughter stress factors are responsible for muscle glycogen depletion (Silva, Patarata & Martins, 1999). According to Andersen, Borggaard, Rasmussen and Houmøller (1999), the quality of the meat is greatly affected by the pH during the first 24 h after exsanguination, because of the anaerobic decomposition of the glycogen reserves. Both the ultimate pH and the rate of pH decline are important biochemical parameters that influence meat quality of the muscles after slaughter (Byrne, Troy & Buckley, 2000). According to Jansen (2001), tissue pH is widely used as a correlate in meat studies and frequently as a means of monitoring meat quality.

Bouton, Howard and Lawrie (1957) report a curvilinear relationship between ultimate pH and taste panel scores for tenderness between muscles with a maximum toughness at pH 5.9. The pH generally falls from ca. 7.0 in the living tissue to below 6.0 within 24 h after being slaughtered. The ultimate pH of individual muscles depends upon their metabolic state ante-mortem and the process of post-mortem glycolysis (Jones, 1985), but generally stabilises at pH ≅ 5.4. The relation between pH and tenderness could also be partly explained by the effect of pH on protease activities, as the calcium-activated protease activity is optimum close to a neutral pH of 7.0 (Purchas, 1990). Therefore, meat with a high ultimate pH is the most tender as a result of neutral proteases, while meat with a low pH is more tender than meat with an intermediate pH, due to the acidic degrading of the proteases (Jeremiah *et al.*, 1990), causing meat with pH values between 5.8 and 6.2 to be the toughest (Silva *et al.*, 1999).

Handling and processing conditions have a definite influence on tenderness, especially the temperature of meat conditioning (Byrne *et al.*, 2000). A high muscle temperature accelerates the rate of pH decline post-mortem (Busch, Parrish & Goll, 1967), as these conditions permit enzymatic activity to continue.

2.1.1.2.1 Dark, firm and dry meat

Dark, firm and dry (DFD) meat is a major quality problem in meat. DFD meat is caused by glycogen depletion prior to the animal's death and is normally caused by ante-mortem stress experienced by the live animal before and during slaughtering. DFD meat is dark in colour, firm in texture and dry when touched. The dark meat colour is caused by the higher activity of the cytochrome enzymes caused by the high ultimate pH. This causes the oxymyoglobin to be immediately reduced to myoglobin (Lawrie, 1985). As the pH is high, the muscle proteins are above their iso-electric point, resulting in the water within the muscle still being bound and thereby causing the firm texture. The tightly packed fibres that present a barrier to diffusion cause the dryness. The very low levels of carbohydrates in the muscle promote bacterial growth, because of the high pH causing high spoilage potential. Such meat, therefore, does not keep well and has a short shelf-life. DFD meat has poor processing characteristics with slow or uneven formation of cured meat pigment. Flavour development is poor in processed products and also in cooked meat (Lawrie, 1985).

2.1.1.2.2 Ageing

The chemical properties of living muscle or the post-mortem chemical and physical changes, which it undergoes during its phenomenal transformation to meat and subsequent ageing, are responsible, either singularly or jointly, for much of the variation in meat tenderness (Briskey, 1963). Ageing enhances meat tenderness. According to Ouali (1990), meat ageing is an extremely variable process, depending on a number of biological factors such as age, sex, muscle type, anabolic and repartitioning agents, and on electrical stimulation, temperature and the duration of storage. It is also defined as tenderising meat by storing the meat for longer than the normal time taken for setting and cooling (Dransfield, 1994). Since 24 h is usually the time taken for setting and cooling, ageing usually occurs after 24 h, post-mortem. Increasing the rate of rigor development and temperature, especially during the early stages after slaughter, can reduce the ageing time. The only two variables that can affect ageing are temperature and time. At a constant temperature, between 0°C and 40°C, the rates of ageing increases about 2.5-fold for every 10°C rise in temperature (Dransfield, Jones & MacFie, 1981). The pH is lowered as a result of the accumulation of lactic acid from glycolysis during the post-mortem storage (Honikel, 1992). The post-mortem pH decrease can also cause substantial changes to the myofibrillar or sarcoplasmic proteins, especially if the temperature remains at 37°C (Scopes, 1964).

2.1.1.2.3 Cooling

The indirect relationship between ultimate pH and toughness is related to differences in myofibrillar shortening and occurs in those muscles which are not restrained from shortening with cooling (Bouton, Harris, MacFarlane & Shorthose, 1982). Cooling of meat is essential to prevent the bacterial growth that causes meat spoilage. Initial cooling is extremely important within the first 24 h post-mortem, when the carcass temperature is reduced from 37°C to 4°C (Dransfield, 1994). Too low temperatures will inactivate the enzymes and this will reduce tenderness by slower rigor development (Wheeler *et al.*, 1990). Calculations of a study by Dransfield (1994) indicated that 50% of toughening could be overcome by effective and appropriate cooling.

2.1.1.2.4 Fast chilling

Fast chilling of carcasses may induce a rapid temperature decline, leading to cold shortening of the muscles and a resultant toughening. Cold shortening occurs when the pH is still above 6.2 and the muscle has already cooled down to temperatures below 10°C (Locker & Hagyard, 1963). The rate of post-mortem glycolysis is at its minimum at 17°C and increases with higher or lower temperatures (Dransfield, 1994). At lower temperatures calcium ions are released, causing muscle contraction, therefore in turn causing cold shortening (Dransfield, 1994). As rigor develops, the toughness caused by cold shortening becomes irreversible. Structural changes that prevent proteolysis by the enzymes cause maximum toughness when muscles are shortened by 40% (Dransfield, 1994).

2.1.1.2.5 Freezing

Freezing slows down the rate of ageing. Even though it stops the activity of the calpains, it does not destroy them, but only halts their activities throughout the storage period. Freezing prevents microbial growth and spoilage and is, therefore, a good method of preservation to keep the meat wholesome.

2.1.1.2.6 Cooking temperatures

Methods of preparation, cooking and processing are important factors in obtaining an acceptable product. Preparation, cooking and processing may well produce a palatable, tender product from meat that might normally be expected to be less tender (Vail, 1963). Many reports indicate that the cooking temperature influences the nature of the relationship between the ultimate pH and tenderness of the meat (Dransfield, 1981). The pH greatly affects the water content, which is an important factor affecting tenderness of cooked meat.

Slow cooking enhances tenderness (Dransfield, 1994). Bryce-Jones (1969) states that meat cooked at 80-90°C is found to be tougher than meat cooked at 50-60°C, which indicates that tenderness is also dependent on the cooking conditions. Higher water-holding capacity of meat with the high pH results in high tenderness (Bouton, Carrol, Harris & Shorthose, 1973). Cooking loss and juiciness are, therefore, correlated with tenderness (Silva *et al.*, 1999).

Consumers are mostly uneducated about the preparation and cooking methods of game meat. As stated above, the preparation methods can increase the toughness of meat. It is, therefore, important to establish guidelines to inform consumers of effective cooking and preparation methods to enhance meat tenderness, especially of game meat.

2.1.1.2.7 Collagen

Connective tissue can be subdivided into different levels of organisation, each having their own chemical and physical properties (Lepetit & Culioli, 1994). Collagen is the principal fibrous protein (Tarrant, 1998) and forms a structural matrix for the cellular components of muscle, providing the muscle with form and support, as well as a means of transmitting and absorbing forces generated by muscle contraction (McCormick, 1994). Collagen is synthesized intracellularly and is comprised of three genetically distinct types, all being stabilised by lysine-derived cross-links (Bailey & Sims, 1977). It is responsible for the development of force, tension, compression and toughening in cooked meat (McCormick, 1994).

When collagen fibres are exposed to heat (about 65°C), they contract to about one quarter of their original length and become rubber-like (Bailey & Sims, 1977). This thermal contraction causes a change in tension and generates more fluid to be exuded from the muscle, resulting in closer hydrophobic and ionic interactions of the denaturated myofilaments. This increases the toughness of the meat (Baily & Sims, 1977). With increased collagen cross-linkings, the heat-dependent solubility decreases and causes the perimysial collagen to remain as a resistant framework in the cooked meat (Baily & Light, 1989). The extent is determined by the thermal stability of the intermolecular cross-links (Bailey & Sims, 1977). Muscles that are rich in collagen therefore tend to be tougher (Dransfield, 1977), without being affected by any slaughtering conditions.

The age-related toughening of meat suggests that it is the quality of collagen, which is responsible for the progressive toughening of meat when animals grow older (Bailey, 1990). The increase in toughness in older animals is due to the greater thermal stability of the bonds (Horgan, 1991), resulting from a conversion of the labile reducible cross-links to stable non-

reducible bonds (Bailey & Sims, 1977). This causes collagen solubility to decrease with increased animal age.

There is a distinct correlation between total collagen concentration and collagen insolubility and the toughness of meat (Young & Braggings, 1993). The qualification of the total collagen will increase the understanding of factors influencing the toughness, although collagen solubility is generally regarded as the factor affecting meat tenderness (Light *et al.*, 1985). However, it has been suggested that the contribution of total collagen is more important in different muscles types than its content (Dransfield, 1994). Figure 2 illustrates the relationship of the collagen content and collagen concentration on the mean panel scores as it affects the overall tenderness of the meat.

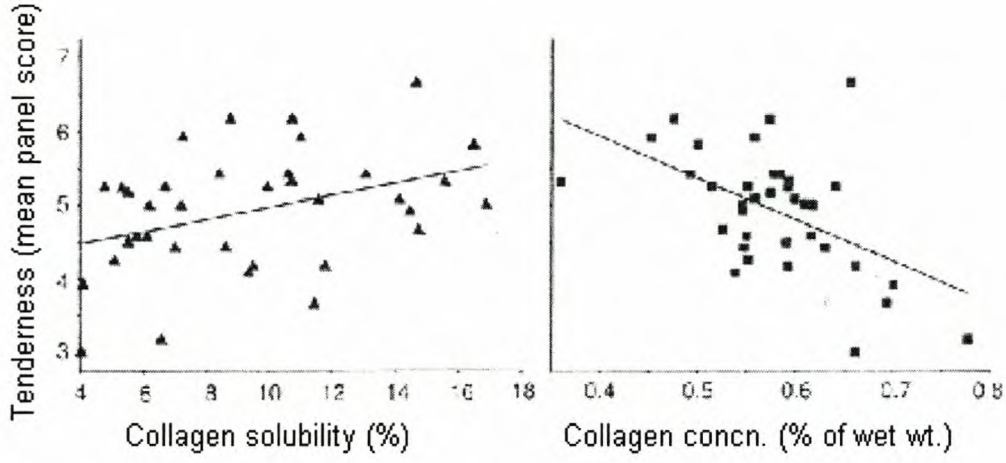

Figure 2

Mean panel tenderness scores for *M. semimembranosus* as a function of the collagen solubility and the collagen concentration. The linear regression coefficient for solubility was 0.38, significant at only $P<0.05$, whereas that for concentration was –0.53, significant at $P<0.001$ (Young & Braggins, 1993).

2.1.1.2.8 Level of calpains

Calpains are endogenous enzymes that gradually release calcium ions from the sarcoplasmic reticulum and the mitochondria to activate rigor development (Dransfield 1994). There are two calpains: calpain I which is activated first at pH 6.3, about 6 h post-mortem, when tenderisation starts, until about 16 h post-mortem, when calpain II is activated, causing further tenderisation. Calpains are unstable enzymes that become less active with storage and are destroyed by cooking (Dransfield, 1994). Calpain activity is maximal around neutral pH levels (Guignot *et al.*, 1994). Calpain levels increase with animal growth and are dependent on species (different species have different amounts of calpains), sex (males tend to have more

calpains) and nutritional status (the calcium status of the animal). Dransfield (1994) states that different geographical areas have an effect on calpain activity too. Heat, humidity as well as the species tolerance to certain environmental factors should be taken into account, especially when animals are being moved. In addition, muscle type greatly influences meat tenderness through calpain levels and amount of calpastatin, the calpain inhibitor.

2.1.1.2.9 Glycogen content

After an animal has been exsanguinated, muscle fibres may survive for some time by anaerobic glycolysis, but will run out of energy sooner or later. This can be because either glycogen, the primary source of carbohydrates, is depleted or because lactate, the end product of anaerobic glycolysis, has deactivated the biochemical systems by its acidity. However, a number of the enzymes in the biochemical pathways are still able to function for a prolonged time, even when the energy is no longer available and the muscle fibres have begun to lose their cellular integrity (Swatland, 1984).

Glycogen content is also an indicator of the nutritional status and the physical condition of the animal. The glycogen content is generally affected by stress caused by the pre-slaughtering conditions.

2.1.1.2.10 Sarcomere length

Sarcomere length is a very important factor that influences the tenderness of meat. The sarcomere length decreases as the pH increases (to pH 6.2), causing a higher level of toughness for meat with an intermediate pH (Silva *et al.*, 1999; Jeremiah *et al.*, 1990). Sarcomere length and pH combined account for nearly 66% of variations in shear force values (Purchas, 1990).

2.1.1.2.11 Instrumental determination of meat tenderness

The methods and interpretation of meat tenderness measurements are highly variable (Honikel, 1998). The objective method most widely (78%) used to determine meat tenderness mechanically is the Warner Bratzler shear test. This shear force test has an 80% satisfaction rate and remains the main reference (Lepetit & Culioli, 1994) for comparative studies and correlations between sensory analysis and determining meat tenderness instrumentally. By shearing the meat perpendicular to the muscles (Lepetit & Culoili, 1994) the configuration and myofibrillar component of the cooked meat can be closely related (Cross, Carpenter & Smith, 1973). Salè (1971) found that when myofibrils are rigid, simultaneous shearing of muscles and connective fibres would take place in cooked meat.

The shear force values will increase with increased animal age, as the force required to shear across the collagen grain rises as the collagen becomes less soluble (Young & Braggins, 1993).

2.1.2 Juiciness

Juiciness is another meat quality attribute that is particularly important to the consumer. Meat juiciness is firstly dependent on the inherent water-inding capacity (the ability of meat to retain its natural water content) and secondly on the amount of fat in the meat (Offer & Trinick, 1983).

Water is the largest component, comprising about 70% of lean tissue. About 10% of the water in living muscle is bound and another 5% to 10% located in the small channels between the muscle fibres in the extracellular space (Warris, 2000). Most of the water in muscle can be found in the spaces between the myosin and actin/tropomyosin. Only about 5% of the total water in muscle is directly bound to the hydrophilic groups of the proteins (Lawrie, 1985). The rest of the water molecules in the muscles are held by capillary forces between the thick and thin filaments, and is known as "free water". A high ratio of "bound water" to "free water" results in less moisture being lost during cooking and thus a more juicy impression. When measured by using descriptive sensory analysis, juiciness is composed of two sensory components. Firstly, it is the initial impression of juiciness which is the amount of fluid exuded on the cut surface when pressed between the thumb and forefinger and secondly, sustained juiciness, the impression that is formed after the first two to three chews between the molar teeth (AMSA, 1978).

Generally, the water content is about 3.5 to 7.7 times the amount of protein present. In living tissue, for every kilogram of protein the body synthesises, 3.5 to 3.7 kg of water is required to surround the proteins. Fat tissue commonly contains 7% to 8% water. Meat with a high fat content will have lower amounts of protein and water; therefore, water content varies inversely with the fat content of the meat. The retained water contributes to the juiciness and palatability of meat (Anon., 2000).

2.1.2.1 Drip loss

When carcasses pass into rigor there is a loss of water in the form of drip, which occurs mainly from the cut end of the meat (Offer & Trinick, 1983). The drip is formed from the extra cellular space content, which increases as the pH decline rate decreases, causing the amount of drip loss to be more dependent on the rate of pH decline than the ultimate pH (Guignot *et al.*, 1994). The muscle proteins tend to denature as the pH falls. The denaturation of the protein leads to a reduction in its power to bind water, causing the myofibrillar proteins to

reach their isoelectric point. This is when the protein molecules have no net electrical charge and tend to lose the water that is normally bound to them. Subsequently, this results in the exudation of fluid from the muscle fibres and moistness on the meat surface (Warris, 2000). This eventually causes water drip being exudated when hung for 24 h at 4°C, and is, therefore, the method for physical analysis of drip loss (Honikel, 1998). In a study by Kim and Lee (2003) the drip loss from the MLD muscles from Hanwoo beef increased at 14 days storage time, which demonstrates that significant changes in drip loss occur early during post-mortem ageing.

2.1.2.2 Cooking loss

A high water binding capacity leads to the surface of the meat appearing dry. It also results in less moisture being lost during the cooking of the meat and hence an unfavourable impression of juiciness during mastication. During cooking at varying temperatures (37°C to 75°C) the different meat proteins will denaturate (Honikel, 1998). This denaturation causes structural changes, which result in cooking loss. The loss of water during cooking is due simply to the shrinking of myofibrils caused by expansion of the filament lattice, thereby causing the water binding capacity of meat to be closely linked to the pH-value. According to Offer and Trinich (1983), shrinkage occurs rapidly under conditions of pH 5.5 and at temperatures of 40°C and above. With increased pH, the water retention will cause a decrease in cooking loss (Bouton *et al.*, 1973). Onyango, Izumimoto and Kutima (1998) also found that low cooking loss results in high water-holding capacity, and that the water-holding capacity is at its minimum at low ultimate temperatures. This denaturation causes structural changes such as the destruction of cell membranes, transverse and longitudinal shrinkage of muscle fibres the aggregation of sarcoplasmic proteins and shrinkage of the connective tissue (Honikel, 1998). All these changes, particularly the connective tissue changes, result in cooking losses in meat. The physical analysis of cooking loss is the difference in weight between the freshly cut meat sample and the sample after being cooked at 80°C for 1 h (Honikel, 1998).

2.1.2.3 Fat and moisture content

Juiciness in meat is directly related to the moisture content and intramuscular fat content (Lawrie, 1985). The water remaining in the meat after cooking is mainly responsible for the sustained juiciness, whereas the lipids in meat function as lubrication and ensure juiciness (Warris, 2000). It is well-known that game meat is lower in fat than meat derived from domestic species, causing game meat to be less succulent than beef. Von La Chevallerie (1972) reported the average moisture content of selected South African game species to be 75.5% and an average fat content below 2.5%. Although the fat content of meat contributes

to the overall juiciness, the higher moisture content of game meat make up for the lower fat content.

2.1.3 Game flavour and aroma

Flavour is a complex sensation involving odour, taste, temperature and pH (Pietersen, 1988). The flavour of meat is an important aspect in the sensory analysis that affects the overall acceptability of the meat and has been studied extensively during the past 30 years. Flavour and aroma are inherent qualities of a particular sample of meat, determined by both intrinsic and extrinsic factors (Lawrie, 1985). Intrinsic factors include pre-slaughter factors, as well as the fatty acid composition and mineral content (Sink, 1979), while the extrinsic factors mostly include the post-slaughtering conditions. Pre-slaughter factors include species, age, sex and diet, while post-slaughtering factors include slaughtering conditions, handling and storage. An overview of the intrinsic and extrinsic factors that influence meat flavour and aroma follows.

2.1.3.1 Intrinsic factors

2.1.3.1.1 Species, age and sex

Flavour is dependent on the genetics of the animal and the environmental influences on it (Melton, 1990). Species is the most important genetic factor, while feed source is the most important environmental factor (Shahidi & Rubin, 1986). There appears to be little doubt that the flavour of muscle foods is highly species dependent (Sink, 1979). According to Shahidi and Rubin (1986), the meaty flavour of red meats develops during cooking through degradation and reactions of water-soluble compounds. The species flavour originates in the fatty tissue and both lipids and water-soluble components are necessary to develop a species' characteristic flavour and aroma (Wasserman & Spinelli, 1972). Formation and deposition of fats in ruminants start after a certain age and also depend on sex, physiological state and feeding conditions (Banskalieva, 1996). According to Lawrie (1985), increased animal age is normally associated with increased intensity of flavour; therefore natural meat flavour is not fully developed until the animal reaches maturity. Ford and Park (1980) found that with increased animal age, the meat gained more flavour and aroma.

2.1.3.1.2 Fatty acid composition

Fatty acid composition plays an important role in the definition of meat quality and is related to differences in sensory properties of the meat, especially flavour (Wood & Enser, 1997). The effect of fatty acid composition on meat flavour is due to the production of volatile, odorous, lipid oxidation products during cooking and the involvement of these with Maillard reaction

products to form other volatiles which contribute to odour and flavour (Wood *et al.,* 2003). Fatness itself affects the flavour and aroma, since the triacylglycerols in the fatty acid composition of the total lipid is less unsaturated than phospholipids in the muscle membranes, and with increased fatness the triacylglycerols will increase (Enser *et al.*, 1998). The role of fat has been studied intensively, suggesting that the basic meat aroma is derived from a water-soluble fraction of muscle, while fatty acids provide the characteristic species aroma and flavour (Mottram & Edwards, 1983). Both lipids and water-soluble components are, therefore, necessary for aroma development (Wasserman & Spinelli, 1972). The lipids undergo thermal oxidative changes when cooked, which contributes to the desirable flavour, but can also react with other components to add more flavour (Mottram & Edwards, 1983). A study by Cameron and Enser (1991) found that saturated and mono-unsaturated fatty acids were positively associated with the eating quality traits, while negative correlations with eating quality were made with polyunsaturated fatty acids (PUFA).

A large number of factors in production affect the adipose tissue and fatty acid composition. These factors include species, age of weaning, sex, diet and body weight (Sanudo *et al.,* 2000).

2.1.3.1.2.1 Species

According to Sink (1979), there is little doubt that the flavour of muscle food is highly dependent on the species. Within the muscle foods from animal origin, beef and pork are the easiest to identify and most preferred. A study by Enser *et al.* (1998) found that the muscles obtained from lamb carcasses were higher in stearic acid (C18:0) and PUFA concentrations, especially the n-3 PUFA, compared to those of beef.

2.1.3.1.2.2 Age

After the weaning period, myristic acid (C14:0) and palmitic acid (C16:0) content decrease, while stearic acid (C18:0) and oleic acid (C18:1) increase, regardless of the energy value of the diet and depot fat studied. With advanced age, changes in fatty acid level followed the same trend, i.e. a decrease in saturation of lipids in adult animals. Girolami *et al.* (2003) found that an increase in animals' age of blue neck ostriches (*Struthio camelus australis*) causes a significant increase ($P<0.01$) in the palimitic acid (C16:0) and oleic acid (C18:1n-9) concentrations, whereas stearic acid (C18:0) decreases. Older ostriches also showed a significant decrease in linoleic acid (C18:2n-6) and α-linolenic acid (C18:3n-3). The results of a study by Zembayashi and Nishimura (1996) indicate that leaner or younger steers have greater proportions of saturated fatty acids. Other studies have shown higher values for PUFA as a percentage of total fatty acids in bulls compared to steers. These results can be

attributed to differences in the phospholipid:triacylglycerol ratio associated with the differences in carcass fatness (Hood & Allen, 1971). In a study by Eichorn, Bailey and Blomquist (1985), bulls had a two-fold higher percentage of linoleic acid (C18:2) as well as α-linolenic acid (C18:3), both proportional to their higher ratio of phospholipids to triacylglycerols.

2.1.3.1.2.3 Sex

In a study by Diaz *et al.* (2003), it was found that the subcutaneous fat of female lambs (Manchego-breed lambs) contained more linolenic acid as well as higher proportions of poly-unsaturated fatty acids, while the intramuscular fat of females also displayed lower proportions of saturated fatty acids than that of the males. Kemp *et al.* (1981) observed that the lipids from ram lambs contained greater quantities of unsaturated fatty acids than the lipids from wether lambs. Crouse *et al.* (1972), in turn, noted that castration had no detectable effect on the fatty acid composition of lambs.

2.1.3.1.2.4 Body weight

According to Enser *et al.* (1998), the effects of diet on the fatty acid composition and the effect of this on meat flavour have been studied. Fatness affects the fatty acid composition of the total lipids, because the triacylglycerols, which increase with fatness, are less unsaturated than the more constant phospholipids in the muscle membranes (Marmer, 1990). The results of a study on the effect of age, physiological state and nutrition on fatty acid composition in depot fat and ruminal volatile fatty acids in sheep also indicated that the ratio of PUFA to saturated fatty acids (P:S) is affected by diet, being lower in grass-fed sheep because the rumen hydrogenates the unsaturated fatty acids (Enser *et al.,* 1998). The differences in fat composition are thus partly responsible for the characteristic flavours of the meat (Melton, 1990).

2.1.3.1.3 Mineral and vitamin content

Thiamin appears to be an important precursor of meat aroma, as the thermal degradation of thiamin produces at least eight volatile compounds that have been identified as cooked meat aroma (Lawrie, 1985).

2.1.3.2 Extrinsic factors

Many extrinsic factors can cause variability in flavour. These include diet (Lawrie, 1985), post-slaughter handling and processing, as well as cooking and preparation methods.

2.1.3.2.1 Diet

The nutritional status and diet of the animal also greatly affect the flavour and aroma of the meat. Many authors have reviewed and studied the effect of animals' diets on the flavour of beef and mutton (Ford & Park, 1980; Field *et al.,* 1978). These analyses show that the type of feed affects the concentration of a large number of flavour volatile components (Melton, 1990). The effects of diet ingredients on red meat flavour are dependent on the type of diet (Melton, 1990). In general, high-energy grain diets produce a more acceptable or more intense flavour than a low-energy forage or a grass diet. According to Field *et al.* (1978), any feed that influences the concentration of the flavour deposits or precursors' unique components in fat will affect the cooked meat flavour, although the extent of the influence is dependent on the species which can refer to relatively undesirable features derived from specific components (Lawrie, 1985) as well. Grass and forage or grass-based diets lead to changes in the saturation of the meat, despite the hydrogenating action of the rumen. A grass-based diet leads to higher concentrations of n-3 PUFA in body tissues, while grain diets lead to a higher concentration of n-6 PUFA. These reflect differences in the composition of dietary oils, grass being high in the n-3 series precursor fatty acid a-linolenic acid (C18:3) and grains higher in the n-6 series precursor fatty acid linoleic acid (C18:2) (Marmer *et al.,* 1984). With increasing dietary energy content the properties of C18:1 and C18:2 increase, while C18:0 decreases, which induces higher unsaturation of the reserve lipids (Banskalieva, 1996). Certain grass and shrub species add flavour, while different areas have different vegetation types with different plant species. In any study it is, therefore, important to build different areas into the descriptive sensory analysis to quantify the possible effects that different areas could have on game meat flavour and aroma.

2.1.3.2.2 Post-slaughtering conditions, handling and storage

Pre-slaughter and post-slaughter variables cannot be mentioned without mentioning pH changes before, during and after slaughtering. Bouton, Howard and Lawrie (1957) state that the desirability of flavour decreases as muscle pH increases, causing the meat flavour intensity to be lower with a higher ultimate pH. This is supported by Ford and Park (1980), who confirm that the meaty character of cooked beef diminishes progressively as the ultimate pH increases, causing the cooking meat to have a different flavour. Thus, the higher the ultimate pH, the lower the flavour intensity, because of the swollen structure that interferes

with substances' access to the palate (Lawrie, 1985). Silva, Patarata and Martins (1999) state that meat with a high ultimate pH tends to be dark and is thus more susceptible to bacterial growth, which causes spoilage to the meat and reduced flavour. Therefore, attempts should be made to control and take note of factors and also to study the behaviour patterns of the animals and their meat, to improve pre-slaughter and post-slaughter conditions to optimise the flavour and aroma.

Ageing of meat also tends to add flavour, due to the changes in free fatty acids that occur during ageing.

2.1.3.2.3 Cooking and preparation procedures

A large number of types of heat-induced reactions lead to the production of meat flavours (Lawrie, 1985), while the volatile compounds of cooked meat determine the aroma attributes and contribute most to the characteristic flavours of meat (Shahidi, 1998). A wide range of these volatile components have been isolated and identified, which shows that both lipids and the water-soluble components of the depot adipose tissue are necessary to develop a characteristic aroma to distinguish between species (Wasserman & Spinelli, 1972). Mottram and Edwards (1983) found that lipids contribute to desirable flavour of cooked meat, either through changes in the thermal oxidative producing compounds, which can also react with components from lean tissue to form other flavour compounds or can act as a solvent of aroma for the compounds accumulated during cooking, or even in the processing and production stages. This indicates the importance of the interaction between lipid and lean-based precursors for meat flavour development.

2.1.4 Colour

Meat colour is another important meat quality attribute as it determines the consumer's initial decision to buy the meat (Hood & Riordan, 1973). Meat colour can be measured as a sensory attribute or physically with a colour meter. Although appearance and meat colour are important sensory attributes to consumers, Stevenson *et al.* (1989) concluded that the three component equation in an evaluation of venison colour by an objective method by using the CIELab values can be used in place of a trained panel with the L* values indicating lightness, a* the red-green range and b* the blue-yellow range. The a* and b* values are used to calculate the chroma value and hue angle according to the following equations: chroma = $\sqrt{(a^{*2}+b^{*2})}$, and the hue angle (°) = $\tan^{-1}(b^*/a^*)$. As b* rotates towards a*, there is an increase in the hue angle, which results in more redness. High a* and b* values result in higher saturation and cause muscle to appear bright with greater colour purity, which is desirable (Onyango *et al.*, 1998).

Colour is often the basis for product acceptability (Stevenson, Seman, Weatherall & Littlejohn, 1989). According to Honikel (1998), there are three sources responsible for colour variation in meat. Firstly, myoglobin (the red pigment), which is dependent on production factors such as species, age and nutritional status; secondly, the colour is influenced by the pre-slaughtering period, the slaughtering (cropping) as well as the pH and temperature decline; thirdly, the colour and colour changes occurring during handling and storage, which cause oxygenation and oxidation of myoglobin.

Fresh meat colour is limited to the surface accumulation of the brown-coloured pigment metmyoglobin (Madhavi & Carpenter, 1993). This initially forms a layer underneath the meat surface and spreads towards the surface, eventually affecting the overall meat appearance (Madhavi & Carpenter, 1993). The metmyoglobin accumulation is affected by environmental factors such as temperature, relative humidity, light, oxygen partial pressure, and microbial load, as well as inherent factors such as pH, lipid oxidation (in particular fatty acids) and oxygen consumption rates. Boccard *et al.* (1981) state that colour should not be measured, either on the carcass or on excised muscles, until the pH has reached its final value. Therefore, the colour readings should be taken after rigor mortis and after blooming the meat until the surface myoglobin is fully oxygenated (Honikel, 1998). In a study Stevenson *et al.,* (1989) determined that for venison and other game species only three observations per sample are necessary.

The colour is brighter when the ultimate pH is lower (Swatland, 1985), which means that a high ultimate pH causes the meat to appear dark (Swatland, 1990). Oxygen consumption rates, in the early post-mortem period, define colour stability, but once the oxygen consumption is reduced metmyoglobin-reductase will dominate the ageing activity.

2.2 Consumer health benefits

Throughout the developed world consumers have become concerned about certain aspects of meat consumption and production to such an extent that demand has been or is in danger of being affected adversely (Harrington, 1994). Although meat provides nutrients, energy and building materials, and countless substances that are essential for normal human growth, development and survival, the risks associated with meat consumption are probably the most commonly acknowledged reason for reducing meat consumption (Richardson, MacFie & Shepherd, 1994). Meat quality includes nutrition properties such as protein, fat, minerals, essential sub-constituents; the appropriate proportions of the bioactive compounds; sensory characteristics such as tenderness, juiciness and flavour; healthiness of the meat, such as fatty acid composition; and the views or perceptions about the production conditions and food

safety (Zotte, 2002). Zotte (2002) also states that people are becoming increasingly concerned about the quality and safety of the food they are consuming. According to Warris (2000), the wholesomeness of meat has two components: firstly it should be safe to eat and, secondly, meat should be positively beneficial to human health.

2.2.1 Meat safety

Meat should be safe to eat. According to Snijders and Van Knapen (2002), food safety is a key issue for consumers and the public expects safe and wholesome food produced under hygienic and animal-friendly conditions.

The microbiological safety of the food supply, particularly meat, has become an increasingly important concern to the public and is affecting international trade. Meat can act as a vector for foodborne diseases, although most foodborne diseases are transmitted through poultry, eggs, shellfish and milk, rather than through meat (Sanders, 1998). Meat products have very high protein contents, which make them susceptible to possible contamination with pathogenic microorganisms, such as *Salmonella* and *Campylobacter* (Mulder, 1996). Specific food safety requirements should be formulated to minimize the risk of exposure to potential human pathogens. One of the systems for the control of foodborne pathogens that is being recommended is the implementation of hazard analyisis of critical control points (HACCP). HACCP is an integrated approach, assuring microbial safety and preventing the possible contamination of food products. Such measures include inspection systems, specific personnel hygiene regimens, as well as possible contamination of carcasses during the slaughter and further processing, storage and handling. In an integrated quality control system, information about the facility is an essential element to ensure safe meat and proper slaughterhouse inspection and management (Snijders & Van Kanpen, 2002). This information is needed because hazards and their potential negative health impact vary within and between production systems, regions and countries. In an attempt to guarantee the safety of the game meat, from whichever source, species or region, appropriate safety procedures should be applied in order to maintain hygiene and safety in all the activities and processing methods.

Meat safety does not only imply freedom from parasites and microbiological pathogens, but also from hazardous chemicals from previous veterinary medication or growth-promoting agents (Warris, 2000). Harrington (1994) mentions that the concern that is most widespread in the developed world relates to residues and contaminants. The fear that substances administered to animals to promote growth, or to prevent or treat diseases, or pesticides, could leave residues in the meat that are often harmful to the consumer's health is common in the developed world (Zotte, 2002). Consumer confidence in the approval, regulatory and

control process is vital in a challenge to reduce biological residues and contamination to overcome lower meat consumption because of environmental problems. Residues and safety tend to fluctuate in response to specific incidents. However, game animals are bound to wildlife sanctuaries and normal biological diversity, as well as a sustained ecological environment and are thus not exposed to vaccinations and treatment for diseases. This indicates that their survival is strictly dependent on natural healing. Consumers are also increasingly concerned about the environment and are, therefore, interested in free-ranging animals and organic meat, as well as products produced by natural production methods (Wierenga *et al.,* 1997). The worldwide tendency towards natural food products and the fact that the South African game species are bound to free-range environments can create lucrative opportunities for our game meat industry.

However, additional research is needed to reduce possible risks of contamination and to develop health systems that are appropriate and practicable to implement at the different game-slaughtering units and reserves.

2.2.2 Wholesomeness

Growing concerns about the healthiness of meat increasingly influence consumer demands, since good eating habits are based on a variety of factors contributing to good health. Good nutrition emphasizes the importance of maintaining wellness and the prevention of diseases. Consumers, therefore, prefer foods with positive health benefits, which will contribute the minerals, vitamins and high-value protein, and possibly essential fatty acids, to their diet.

Most of the prevailing chronic diseases in the world have important nutritional components through directly causing a specific disease, enhancing the risk, exerting a beneficial effect in decreasing the risk or even preventing a disease (Weisburger, 2000). Several health arguments have been advanced for reducing red meat consumption because of the association with high intakes and the risk of cancer and heart disease, despite the fact that red meat makes important contributions to essential nutrients (Sanders, 1998).

2.2.2.1 Minerals and vitamins

Meat is a major source of iron, copper, zinc and selenium (Warris, 2000). The amount of minerals such as calcium, magnesium, potassium and trace elements such as iron, copper and selenium has also been found to be higher in game meat than in the meat of domestic animals (Nieminen, 1992).

Iron deficiency anemia is the world's most common nutritional deficiency. Since the functions of iron result from its ability to participate in oxidation and reduction reactions, it is an integral part of the human diet (Mahan & Escott-Stump, 2000). Iron in meat has high bioavailability, the main reservoir being the component of haem protein, myoglobin.

The mineral composition of najdi-camel meat shows significant variation in slaughtering ages between the concentration of minerals such as magnesium, potassium, sodium, zinc, and iron (Dawood & Alkanhal, 1995). Less variability was found in tissue mineral contents when the results were expressed on a dry-weight, fat-free basis (Dawood & Alkanhal, 1995).

2.2.2.2 Protein and amino acids

Meat is a very concentrated source of protein and contains all the amino acids essential for human health; it also contributes one sixth of the proteins consumed by humans (Warris, 2000). The biological value of meat is that it is a very concentrated source of protein, because its composition matches closely with human proteins. Table 2 illustrates the different protein contents in meat of different species.

Table 2
Protein values in meat of selected game species compared to domestic species

Species	Protein (mg/100g)	Reference
Beef	20.1	Paleari *et al.* (1998)
Mutton	13.9	Sayed, Frans and Schönfeldt (1999)
Pork	13.9	Sayed *et al.* (1999)
Ostrich	22.2	Paleari *et al.* (1998)
Reindeer	22.5	Nieminen (1992)
Kongoni	22.4	Onyango *et al.* (1998)
Oryx	20.3	Onyango *et al.* (1998)
Impala	23.8	Hoffman (2000)
Camel	20.4	Dawood and Alkanhal (1995)

Lawrie (1985) also states that meat is a very good source of essential amino acids, although the amino acid content (i.e. lysine) can be affected by processing and cooking. The protein of najdi-camel meat tended to have a higher percentage of the amino acid proline than the literature values for other red meats, and lower values of tryptophan, aspartic acid and tyrosine (Dawood & Alkanhal, 1995). In a study by Hoffman, Fisher and Sales (2000) on the nile crocodile (*Crocodylus niloticus*), all the amino acids analysed, except glycine, histidine and arginine were more concentrated in cooked meat samples than in raw meat samples.

Although the amino acid content of meat protein is quite constant, regardless of the species or type of cut, possible differences between regions and sexes will be investigated in this study.

2.2.2.3 Fat, fatty acids and cholesterol

The fat type or fatty acid composition of meat is an important diet or health concern to consumers (Rhee, Waldton, Ziprin & Rhee, 2000). High levels of fat consumption and particularly of saturated fatty acids are considered to enhance several so-called "Diseases of Western Civilisation" (Scollan *et al.* 2001). Interest in meat fatty acid composition originated mainly from the need to find ways to produce healthier meat (Wood *et al.* 2003). Knowledge about the fatty acid and cholesterol content of food will serve as a reliable standard of reference to all concerned with the nutrient content of food, and will also provide a valuable tool for those engaged in research on the possible relevance of dietary lipids to heart diseases and arteriosclerosis (Weihrauch, Posati, Anderson & Excler, 1977).

Fatty acid composition does not only play an important role in the differences between the sensory attributes of meat, but also in the nutritional value of the fat for human consumption (Santos-Silva, Bessa & Santos-Silva, 2002). Fatty acids with double bonds are vulnerable to oxidative damage, because humans and other warm-blooded organisms predominantly store fat as saturated palmitic acid (C16:0) and stearic acid (C18:0) (Mahan & Escott-Stump, 2000). It is generally known that red meats contain more saturated and less unsaturated fatty acids. Saturated fatty acids are known to increase plasma lipids and excess consumption of saturated fatty acids, together with the oxidation of cholesterol, can lead to their accumulation in the veins, blocking the normal blood flow. Therefore, the first step when recommending a healthier nutritional diet is the reduction of dietary intake of saturated fat and cholesterol (Ortega *et al.*, 1998), namely less than 30% of energy as fat, less than 10% of energy as saturated fat, and less than 300 mg of dietary cholesterol per day.

In a comparative study with a limited sample size on different game meats, Onyango *et al.*, (1998) found that beef had more than 50% saturated fatty acids, while oryx (*Oryx beisa*) had 68%, kongoni (*Alcelaphus buselaphus*) 74%, and zebra (*Equus burchellii*) 40% saturated fatty acids. The data obtained from a comparative study by Paleari *et al.* (1998) reveal that the total fatty acid composition of the ostrich was similar than that of turkey and beef, but the ostrich presented quantities of highly unsaturated fatty acids. Paleari *et al.* (1998) also indicated that the breeding, feeding and slaughtering of the animal can influence the data of different tests, while variations can occur due to the animals' place of origin, sex and age. The ratio between polyunsaturated and saturated fatty acids (P:S) and the ratio between n-6 and n-3 fatty acids are considered as two important indexes for nutritional evaluation of fat

(British Department of Health, 1994) as well. The recommended figure for the P:S ratio is 0.45 for the British diet as a whole (British Department of Health, 1994), with lower values indicating less healthy food that increases the risk for cardiovascular diseases (Enser *et al.*, 1998). Although ruminant meats normally have a low ratio of polyunsaturated fatty acids (PUFA) compared to saturated fatty acids (SFA), the muscle contains a series of C20 and C22 PUFA of both the n-6 and n-3 series, which may be of potential significance in human health and nutrition (Enser *et al.,* 1998). Humans have the capacity to syntheses the C20 PUFA, eicosapentaenoic acid (C20:5n-3) and, to a lesser extent, docosahexaenoic acid (C22:6n-3), from C18:3n-3. The British Department of Health (1994) thus recommends ratios below four conjugated with an increase in the consumption of these n-3 fatty acids to overcome the imbalance in the ratio of n-6:n-3 (Scollan *et al.,* 2001).

The membranes throughout the body as well as the human brain and central nervous system, require n-3 fatty acids for optimal function. The long-chain poly-unsaturated essential fatty acids must, therefore, be obtained from the diet, either preformed or from dietary precursors (Mahan & Escott-Stump, 2000). The precursor for the n-3 series is a-linolenic acid (C18:3n-3) (Scollan *et al.,* 2001). It must be kept in mind that the long-chain C20 and C22 PUFA in ruminants are found mainly in the phospholipids and not in the triacylglycerol fraction of the muscle and adipose tissue. Since phospholipids constitute a relatively constant proportion of tissues, increased deposition of n-3 PUFA can only occur through displacement of another similar fatty acid, usually from the n-6 series (Ratnayake, Ackman & Hulan, 1989). The recommended daily consumption of n-3 fatty acids is, therefore, 100 to 200 mg/d, mainly as eicosapenataenoic acid (C20:5n-3) and docosahexaenoic acid (C22:6n-3) (Department of Health, 1994). However, in the USA, the consumption of 1 g/d of n-3 fatty acids is recommended with 300 to 400 mg/d of n-3 fatty acids (Scollen *et al.* 2001). A comparison of the P:S and n-6:n-3 ratios of beef, mutton and pork (Warris, 2000) is presented in Table 3.

Table 3
A comparison of the P:S and n-6:n-3 ratio of beef, mutton and pork

Species	P:S	n-6:n-3
Beef	0.11	2.11
Mutton	0.15	1.32
Pork	0.58	7.22

Data obtained from Warris (2000)

Limitations in fat and cholesterol intakes are thought to be important measures to prevent obesity and hypercholesterolaemia, conditions that are considered to predispose humans to various chronic diseases of the circulatory system. The negative image associated with cholesterol overwrites the fact that cholesterol has positive functions in the human body as well. Dietary cholesterol is strictly linked with foods of animal origin, since cholesterol is an

essential constituent of animal cells (Chizzolini, Zanardi, Dorigoni & Ghidini, 1999). Meat, particularly red meat, is commonly identified as a major source of dietary cholesterol and it is often the first food that medical doctors advise should be reduced in the diets of hypercholesterolemic patients. The mean content of cholesterol in meat for selected species is presented in Table 4.

Table 4

Mean cholesterol content in meat for selected animal species

Species	Cholesterol content in mg/100g
Beef	69
Lamb	87
Pork	71
White tailed deer	113
Mule deer	85

Data obtained from Anger (1990)

Although all the values mentioned in Table 4 seem high, consumers need to understand that cholesterol is an integral part of the cell membrane of animals. The cholesterol content in meat is thus more closely tied to the membranes of muscle cells than to the fat content of the muscles.

2.2.3 Nutritional claims

According to the Regulations relating to labelling and advertising of foodstuffs (Department of Health, 2002), no claim that describes the level of a nutrient contained in a foodstuff and a nutritional supplement can be made on a label or in an advertisement of a foodstuff, unless it complies with the conditions.

The Department of Health (2002) defines "claim" in relation to a foodstuff or nutrient supplement as any written, pictorial, visual or other descriptive matter or verbal statement, communication, representation or reference brought to the attention of the public in any manner, including a trade name or brand name and referring to the characteristics of a product, in particular to its nature, identity, nutritional properties, composition, quality, durability, origin or method of manufacture or production.

2.2.4 Recommended daily allowance

To ensure good eating habits based on a variety and moderation contributing to good health a set of guidelines exists to satisfy the normal nutritional requirements for our daily needs. The Recommended Daily Allowance (RDA) is the amount of a nutient needed to meet the requirements of nearly all (97% to 98%) of the healthy population (Mahan & Escott-Stump, 2000). Table 5 illustrates the Food and Nutrition Board, National Academy of Sciences – National Research Council Recommended Daily Allowances, designed for the maintainance of food nutrition.

Table 5
Recommended Daily Allowance for male and female adults

Nutrient	Male	Female
Protein (g)	63	50
Phosphorus (mg)	700	700
Potassium (mg)	2000	2000
Calcium (mg)	100	100
Magnesium (mg)	420	320
Sodium (mg)	500	500
Iron (mg)	10	15
Copper (mg)	1.5-3.0	1.5-3.0
Zinc (mg)	15	12

Mahan and Escott-Stump (2000)

3. SAMPLE SELECTION

In an attempt to conserve Africa's biological diversity and wildlife estate, the focus should be on the optimum sustained use of large mammal resources by government agencies, as well as private and commercial land-owners (Cumming, 1991 as cited by Hearne, Lamberson & Goodman, 1996).

Manipulation of the age and sex ratios leads to improved productivity of the game animals. Fairall (1983) calculated in a study on impala (*Aepyceros melampus*) that changing the sex ratios from 1:3 to 1:10 increases the productivity by 30%, and for a population with no predators, the most complex manipulation, achieved by harvesting all the animals older than three years, gives an increase of 138%.

The sample selection includes a review of the species, a review of all the areas and their vegetation types where the animals were harvested, associated diseases with black and blue wildebeest as well as the harvesting methods used to cull the animals.

3.1 Species review

The black wildebeest, blue wildebeest and mountain reedbuck are all indigenous South African antelopes, which create a niche in the game meat export market out of Africa, especially because of the low fat content of game meat. Black and blue wildebeest are fairly large mammals with an average dressing percentage of between 55% and 58%. This increases the profitability for large-scale production purposes. Mountain reedbuck are known to have some of the tenderest game meat, while also having a fairly high dressing percentage of 55%.

A description of the animal, as well as general species' behaviour and the areas where the animals were sampled follows.

3.1.1 Black wildebeest *(Connochaetes gnou)*

The black wildebeest or white-tailed gnu is an endemic South African species that grazes in herds with a social organisation. These groups include territorial bulls, cowherds and younger bull herds (Skinner & Smithers, 1990). Black wildebeests are often referred to as the "clown of the field", "beast" even as being "the most bizarre creature", with a mane and tail like a horse, a head like a bovine and delicate legs like an antelope (Furstenburg, 2002a).

Black wildebeest are dark brown mammals that appear black over a distance. The older bulls tend to be darker, while the females are shorter and lighter. They have an area of longer, dark hair between their forelegs, covering the chest, and another patch of bristly black hair along the bridge of the nose. The young have shaggy, fawn-coloured coats. The characteristic feature of the black wildebeest in the field is the tail, which is dark at the base, the remainder with long, off-white hair reaching nearly to the ground. They are rather ungainly looking beasts because the back slopes from the massive humped shoulders to the slender, lightly built hindquarters. Their manes are high and upstanding and they have a distinct-looking beard with long hair as well. Both the male and female species carry paired horns that curve down, forward and then up. The base of the horns is widened and flattened to form a protective shield. The horns of the females are lighter and thinner (Mills & Hes, 1997). The calves have horns that rise straight up from the head and only start to curve when the animals are about a year old.

The males have a shoulder height of about 1.20 m and weigh between 147 kg and 193 kg, while the females are 1.10 m and weigh between 120 kg to 160 kg (Furstenburg, 2002a). Black wildebeest are predominantly grazers and prefer short grassveld and open grass planes without trees or shrubs (Furstenburg, 2002a), whereas areas with tall, mature grass

are avoided (Von Richter, 1971). They utilise a wide variety of grasses during the summer, while the karooid bushes (in Afrikaans *karoo-bossies*) are grazed during winter. They are highly selective grazers, on plant species as well as which part of the plant is consumed. They do eat lucern, a phenomenon that can be very beneficial especially during a drought, to keep meat production rates constant. During the summer their feeding activities are highest in the early morning, late afternoon and night, while they prefer to graze throughout the day during the cooler months (Van Hoven & Boomker, 1981).

Black wildebeest are strictly seasonal breeders. Mating is usually in autumn (between March and April), although mating activity has also been documented in the winter (July) in some areas (Skinner & Smithers, 1990). The cows give birth during the summer (December/January) (Skinner, Van Zyl & Oates, 1974), after a gestation period of approximately 8.5 months. Calves can stand within nine minutes after parturition and are able to graze (at least part time) within one month. Weaning takes place after four months, but the calves stay with their mother until the next calf is born. The males will reach social maturity after 36 months and the females after 18 months, while both sexes will reach sexual maturity after only 16 months. They have an average life span of approximately 18 years.

In the past black wildebeest were confined to the central open plains of South Africa, especially the grass-veldt and Karoo regions of the central and Northern Cape Province, the Free State Province, the highveld regions of North West Province, and the grass-veldt along the Drakensberg foothills in Kwazulu Natal Province (Von Richter, 1971). After almost becoming extinct, they are currently widely distributed throughout the central plateaus and open plains of South Africa (Skinner & Smithers, 1990). Since black wildebeest are mostly territorial and tend to stay in the same area (Van Hoven & Boomker, 1980), their specific territorial restraint and feeding behaviour can result in serious over-grazing (Von Richter, 1971).

Their annual population growth is 28% to 33%, including deaths (Furstenburg, 2002a). No literature could be found on places where the population growth rate was increased by means of manipulating age and sex ratios within a closed population as has been done successfully for impala (Fairall, 1983) and warthog (Somers, 1997). This aspect warrants further research. This production growth rate could be advantageous for meat production purposes.

Black wildebeest are difficult to hunt, since they prefer to graze on open planes and most shots are fired from a distance of more than 100 m from the herd. They also tend to get anxious and start running fearlessly when any form of danger approaches or endangers their lives. For this reason only professional or qualified marksmen should be used during culling.

Black wildebeest are also known to be very aggressive and will attack and even kill if threatened.

3.1.2 Blue wildebeest *(Connochaetes taurinus)*

The blue wildebeest, also known as the brindled gnu, is one of the most common bushveld mammal species in South Africa. Both black wildebeest and blue wildebeest belong to the subfamily *Alcelaphinae* and genus *Connochaetes*. The blue wildebeest has rudimentary pedal glands on the hind feet, which is only one of many differences found between the black wildebeest and blue wildebeest, as this particular gland is absent on the black wildebeest (Skinner & Smithers, 1990).

Blue wildebeests are dark blue-grey to silver-grey, sometimes with a brown tinge (Skinner & Smithers, 1990). This beastly looking mammal has a series of dark-coloured bars on the neck and shoulders, extending back to about the middle of the body, which gives them a brindled appearance (Skinner & Smithers, 1990). The front part of its body is heavier and more sturdily built, with humped shoulders and deep necks, in contrast with the far less developed hindquarters (Furstenburg, 2002b). The legs look slender compared to the size of the body (Skinner & Smithers, 1990), and its longer forelegs and sloping back allow it to progress easily from a walk to a slow loping movement; this helps it to conserve energy when travelling over long distances (Mills & Hes, 1997). Their heads are massive and elongated, broadening out at the nostrils and lips (Skinner & Smithers, 1990), while the animal's large mouth also inhibits its ability to select succulent grass leaves and to browse, hence its need to move in search of better food patches (Mills & Hes, 1997). Blue wildebeest have manes of long black hair which droop over their shoulders, long whisks of black hair on the ends of their tails, which nearly touch the ground, and a fringe of long black hair down their throats, with a distinct beard of long black hair on their chins. Both the male and female have horns and, when one is facing the wildebeest head-on, the male has a complete black frontal section, while the female is brownish on the forehead and between the horns (Estes, 1976). The unrigged horns, which rise from swollen bosses, sweep outward and slightly downward and then rise upward to the inwardly pointed tips, which are often directed slightly backward (Skinner & Smithers, 1990). The horns of the juveniles rise straight up from the head and only show the start of the outward curve at the age of about eight months.

The males have a shoulder height of 1.30 m to 1.50 m and weigh between 210 kg and 260 kg, while the females are 1.22 m to 1.35 m high and weigh between 170 kg and 200 kg (Furstenburg, 2002b). They have ridged teeth, and the jaw moves from side to side, when chewing cud. They eat the softer or middle layer of the grass and are particularly partial to fresh sprouting grass on burnt areas or fresh green grass sprouting after the rain (Skinner &

Smithers, 1990). They graze for approximately the same percentage of time during both seasons (Ben-Shahar & Fairall, 1987).

The peak of the mating season is between autumn and winter (May and June), and cows are pregnant for eight to nine months (250 days), after which one calf of approximately 22 kg is born. The calving season peaks in summer (mid-November to the end of December). The calves, which are light brown in colour, are suckled for seven to eight months, but will eat grass earlier. The young stay close to their mothers, lying down as the opportunity permits. The blue wildebeest longevity is 16 to 20 years (Furstenburg, 2002b).

Blue wildebeest are particularly associated with savannah woodland and shade, while drinking water is an essential habitat requirement. They occur in two widely separated areas (Skinner & Smithers, 1990). The northern area extends from south-western Kenya to north-western Mozambique, while the southern area stretches from Zambia marginally into South Africa (Skinner & Smithers, 1990). The wide distribution of the blue wildebeest makes it possible to satisfy production demands, especially with an annual population increase of 28% to 33% (Furstenburg, 2002b). Similarly to black wildebeest, no details could be sourced about the manipulation of the annual population increase.

3.1.3 Mountain reedbuck *(Redunca fulvorufula)*

The mountain reedbuck is closely related to the reedbuck (*Redunca arundinum*), but not related to the grey rhebuck (*Pelea capreolus*), as the Afrikaans name *rooiribbok* could easily imply. They are the smallest of the three species under the genus *Redunca* and live together in small herds of three to eight animals, increasing up to about 40 animals in certain seasons (Furstenburg, 1999).

The mountain reedbuck is predominantly grey, the head and shoulders being reddish-brown. These animals have striking white underparts, while the head and neck are yellowish (Skinner & Smithers, 1990). The coat is soft and woolly, with long oval body hair (Skinner & Smithers, 1990). The tail is bushy and the same colour as the upper parts of the body on top and pure white underneath (Skinner & Smithers, 1990) with the tail held up as it runs away in alarm (Mills & Hes, 1997). This species has large ears and a long snout. Only the ram has horns, which are short and heavily ridged, and rise from the top of the head, hook forward at about the level of the top of the long, narrow ears and end in smooth rather blunt points (Skinner & Smithers, 1990). When alarmed, it utters a "whisking" sound and has the habit of running with a rocking horse motion, with their tails upright (Anderson & Koen, 1993). The "whisking" sound is a sharp, shrill whistle almost like that of the reedbuck, and is often repeated many times if it is uncertain of the danger.

The mountain reedbuck is a medium-sized antelope, with the adult males standing about 0.76 m at the shoulder and weighing between 24 kg and 36 kg, while the females have a shoulder height of about 0.70 m and weigh between 18 kg and 34 kg (Furstenburg, 1999). They have a large subdivided rumen with keratinised mucosa that is adapted to digesting a low-quality, coarse grass diet during the dry season or droughts (Hoffman & Stewart, 1972), although they can still lose about 20% of their body weight during this period (Furstenburg, 1999). They are grazers, especially selecting young green shoots when available. They are most active during the early mornings, late afternoons and at night, while they rest in the cover of bushes in the late mornings and early afternoons (Skinner & Smithers, 1990).

Mating can take place throughout the year, peaking in autumn (April/May) (Skinner & Smithers, 1990). A single lamb is usually born in early summer (October to January) (Mills & Hes, 1997), after a gestation period of eight months (236 to 251 days), with a mass of approximately 3 kg, although some are born at other times of the year. Lambs are hidden for two to three months after birth, the mother's visiting once or twice a day to suckle and clean them (Skinner & Smithers, 1990). They reach adult body weight at two years, and ewes reach sexual maturity after only 15 months. Ewes produce one young per year for the rest of their lives (Furstenburg, 1999). They have a life span of approximately 14 years.

These mountain antelopes are found on the lower sunny slopes and in the bushy gullies and drainage lines where bushes or scattered trees can provide cover (Mills & Hes, 1997). They are dependent on drinking water (Nortan, 1989) and drink more often during dry weather than during cold, cloudy weather. They tolerate a wide range of climatic conditions. Their distribution is mostly restricted to areas 100 to 1600 m above sea level with an average rainfall of about 400 to 900 mm (Furstenburg, 1999). In South Africa they are commonly found in the Eastern Cape province, Eastern Free State province, Mpumulanga province, as well as in some parts of the Kruger National Park (Furstenburg, 1999). The cropping of mountain reedbuck is difficult, because they inhabit stony slopes of hills and mountains, so that this process needs specialized four-wheel drive vehicles.

Mountain reedbuck have a high productivity rate and many people believe that their potential as a game-farm and meat-production species has not yet been fully realised.

3.2 Area review

For the purpose of this study the species were harvested at different provincial reserves in the Free State Province, South Africa. The different reserves have different vegetation types and habitats and, therefore, different species for biodiversity.

3.2.1 Areas where black and blue wildebeest were harvested

The areas where the black wildebeest were harvested in this investigation were Sandveld Nature Reserve and Maria Moroka Nature Reserve, all in the Free State Province, South Africa.

The Sandveld Reserve encompasses the north-west area of the large peninsula created by the 23 035 ha Bloemhof Dam in the northwestern Free State Province (*Reader's Digest*, 1983). This reserve is 14 700 ha in size and is characterised by a grassy ground layer and a distinct upper layer of woody plants, also described as Kalahari mountain bushveld or Kalahari thornveld. This vegetation type forms part of the savanna biome. The Sandveld Reserve has a summer rainfall of 400 to 500 mm per year, while the temperature varies between -8°C and 41°C, with an average of 19°C (Low & Rebelo, 1998). It is an open savanna with Umbrella Thorn (*Acacia tortilis*) and Camel Thorn (*A. erioloba*) as the dominant tree species; there is a grass layer that is fairly well developed and grasses such as Redgrass (*Themeda triandra*), Common Nine-awn Grass (*Enneapogon cenchroides*) and Lehmann's Lovegrass (*Eragrostis lehmanniana, Elionurus muticus* and *Cymbopogon plurinodis*) are conspicuous. The shrub layer is poorly to moderately developed (Low & Rebelo, 1998).

Maria Moroka is a 5 880 ha Nature Reserve near Thaba Nchu, 60 km east of Bloemfontein. This reserve is situated on a plateau, with rocky slopes and grassy plains and has a rainfall of 700 to 800 mm, also occurring in summer (Low & Rebelo, 1998). In winter the region experiences severe frost, but little snow. The temperatures vary between -13°C and 35°C, with an average of 14°C. The moist cold highveld grassland has deep, yellow and grey sandy-loam soil, with the land and soil type having less influence on plant distributions than terrain form and associated soil depth, soil moisture (clay content), rockiness of the soil surface, and grazing. The moderately dense grassland is dominated by Bushveld turpentinegrass (*Cymbopogon plurinodis*), Redgrass (*Themeda triandra*) and Small creeping foxtail (*Setaria sphacelata, Eloinurus muticus* and *Eragrostis curvula*). Invasion of Karoo bushes, such as Bitterkaroo (*Pentzia globosa*) and Bloublommetjie (*Felicia muricata*), may occur in some areas (Low & Rebelo, 1998).

3.2.2 Areas where mountain reedbuck were harvested

All the mountain reedbuck for this study were harvested at Tussen die Riviere Nature Reserve. Tussen die Riviere is a 21 000 ha game farm, west of Bethulie, at the confluence of the Orange and Caledon Rivers (*Reader's Digest*, 1983). The Reserve's western tip, where the two rivers converge, is a flood plain, but otherwise high rocky ridges with occasional

plateaus and lower-lying grassy plains separate the rivers. The rainfall, soil type and vegetation are very similar to that of Maria Moroka Nature Reserve, containing both sweet and sour grasses. Sweet grasses have a lower fibre content, maintain their nutrients in their leaves in winter and are therefore palatable to stock (Low & Rebelo, 1998). Sour grasses have a higher fibre content and tend to withdraw their nutrients from the leaves during winter, so that they are unpalatable to stock. Because of the keratinised mucosa of the mountain reedbuck's stomach they are well adapted to live in this particular area (Low & Rebelo, 1998).

3.3 Diseases associated with wildebeest

Black and blue wildebeest are carriers of the virus that causes *snotsiekte* (bovine malignant catarrhal fever) (Monnig & Veldman, 1989). It is an acute and usually deadly viral disease affecting cattle and some other ruminants. The virus is found permanently in populations of both types of wildebeest. Virtually all the wildebeest in South Africa that have been tested were serologically positive for *snotsiekte*. However, infection with the virus does not produce clinical signs of the disease in either black or blue wildebeest (Bothma, 2002).

3.4 Harvesting and cropping of the animals

Integration between species, their feed utilization and vegetation availability are vital management functions in wildlife areas. To prevent over-utilization of vegetation and habitat degradation, effective methods must be used to harvest animals. A seasonal game census as well as an analysis of the field condition and vegetation as well as a census of species populations, age and sex ratio should be taken into account before harvesting should take place (Densham & Tomkinson, 1979). Cropping of the animals can be used to manipulate the sex ratios for the most effective breeding productivity.

To cause the least possible stress to the animal and ensure an immediate, "painless" death, the best possible method should be used to harvest the animals. This will also ensure optimum meat quality, especially in terms of meat tenderness, as stress causes glycogen depletion and thus a high ultimate pH (Silva *et al.*, 1999).

According to Lewis, Pinchin and Kestin (1997) and Veary (1991), shooting the animals during the night is the best method of harvesting game. It causes the least stress to the animals, before and after shooting, while also causing the least damage and wastage to the carcass (Hoffman & Ferreria, 2000). During culling or cropping, the animals should be shot through the head or neck as the traditional shot through the shoulders or rib results in a high percentage of carcass damage (Von La Chevallerie & Van Zyl, 1971).

Other observations during cropping that influence the ultimate meat quality and tenderness include approximate distance covered by the animal before being shot, time of shooting, distance travelled after first hit, duration between kill and bleeding, onset of rigor mortis and location of bullet wound (Von La Chevallerie & Van Zyl, 1971).

4. CONCLUSION

Since meat is an important part of our daily food intake, researchers should have a thorough knowledge of its composition, nutritive value, quality, storage life and physical properties in order to make intelligent decisions in terms of the selection, purchasing, preservation, preparation and the serving of all the various meats. It is evident from this literature review that there are still many aspects of game meat that need to be investigated. Although studies have been done on all the factors and properties affecting the sensory, physical and chemical properties of meat from domestic species, there is a definite lack of proven scientific research on South African wild ungulates and game species. The limited research available indicates that the many health-attributing and sensory characteristics of game meat can be used to further promote the utilisation of the meat. However, the existing literature was published in the late 1960s and early 1970s, and needs to be reviewed thoroughly.

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CHAPTER 3

EFFECTS OF THE HARVESTING REGION, AGE AND SEX ON THE CARCASS TRAITS AND CHEMICAL COMPOSITION OF BLACK WILDEBEEST (*CONNOCHAETUS GNOU*) MEAT

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Abstract

Nineteen black wildebeest were analysed to determine carcass yield and to evaluate the effects of the harvesting region, animal age and sex on the carcass composition and meat quality traits. The animals harvested at Maria Moroka Nature Reserve (MM) had a significantly higher ($P \leq 0.05$) live mass (137.55 kg ± 6.26), as well as carcass mass (70.52 kg ± 3.14) than the animals harvested at Sandveld Nature Reserve (SV), which had a live mass of 112.22 kg ± 10.86 and carcass mass of 54.91 kg ± 5.59. The black wildebeest had a mean carcass mass of 62.40 kg ± 7.02 and dressing percentage of 50.10% ± 3.04. Overall, the morphological measurements indicated that the animals harvested at MM were physically larger than the animals harvested at SV. Although the animals harvested at MM were significantly heavier and larger, the animals from SV (1.20% ± 0.07) had a significant higher ($P \leq 0.05$) percentage of fat compared to those harvested at MM (0.96% ± 0.09). There were no significant differences in the proximate chemical composition between the different age groups. The females (20.73% ± 0.29) had a significant higher ($P \leq 0.05$) protein content than the males (19.42% ± 0.29), and also tended ($P > 0.05$) to have a higher percentage of fat (1.13% ± 0.07) and moisture (75.21% ± 0.34), than the 0.97% ± 0.11 fat and 74.69% ± 0.56 moisture of the males. There were no significant differences ($P > 0.05$) in any of the minerals or amino acids analysed for any of the main effects investigated. The chemical composition, mineral and amino acid content of black wildebeest determined in this study can serve as a reference standard for future studies.

Keywords: black wildebeest, carcass yield, chemical analysis, collagen, mineral, amino acid

Introduction

There seems to be a general acknowledgement by the vast majority of environmentally aware humans that the increased demand on the resources of our planet is unsustainable (Ledger, 2003). In Africa the increased population and a concurrent decrease in the per capita supply of high-quality protein have intensified the search for alternative sources of food protein. In addition, the process of desertification in Africa has produced an environment that can no

longer support increased numbers of domestic cattle economically. However, these regions are suitable for the production of indigenous game species. In spite of the recent economic recessions and frequent droughts, game farming is increasingly growing in popularity in Southern Africa (Ebedes, 2002). The consumption of game meat is an age-old practice in Africa and an important alternative to beef in many regions (Onyango, Izumimoto & Kutima, 1998).

The black wildebeest, one of Africa's largest mammal species, is only one of many species that can be exploited for possible game meat production purposes. The black wildebeest or white-tailed gnu is an endemic South African species that grazes in herds with a social organisation (Furstenburg, 2002). Black wildebeest are dark brown mammals that appear black over a distance with a long, off-white tail reaching nearly to the ground. They are rather ungainly looking beasts; the back slopes from the massive humped shoulders to the slender, lightly built hindquarters; they also have paired horns that curve down, forward and then up. The males have a shoulder height of about 1.20 m and weigh between 147 kg and 193 kg, while the females are approximately 1.10 m and weigh between 120 kg and 160 kg (Furstenburg, 2002). Black wildebeest are predominantly grazers and prefer short grassveld and open grass plains without trees or shrubs (Furstenburg, 2002), whereas regions with tall, mature grass are avoided (Von Richter, 1971). The size and browsing habits of the black wildebeest make them an excellent source of meat to supply the increasing demand for game meat for production purposes.

Due to the emphasis placed on the nutritive value of food by consumers, there is a great need for information on the nutritional composition of different meat products. In relation to food products the exact nutrient composition must be known, not only to meet nutritional needs, but also to comply with regulations concerning the labelling of food products for local and overseas markets. However, limited research has been conducted on the carcass and chemical properties of game meat. This study was, therefore, undertaken in an attempt to gain some information on the carcass yield of black wildebeest and the proximate, mineral and amino acid composition of the meat.

Materials and Methods

Animals

A total of 19 black wildebeest (*Connochaetus gnou*) were included in this study. The animals were harvested during 2002 at the Maria Moroka Nature Reserve (MM) and Sandveld Nature Reserve (SV) in the Free State Province, South Africa. MM, 60 km east of Bloemfontein, near Thaba Nchu, is a 5 880 ha reserve situated on a plateau with a grassy plain (Low & Rebelo, 1998). SV encompasses the north-west region of the large peninsula created by the Bloemhof Dam in the northwestern Free State (*Reader's Digest*, 1983). This 14 700 ha

reserve is characterised by a grassy ground layer and a distinct upper layer of woody plants (Low & Rebelo, 1998).

Table 1 and Table 2 illustrate the lay-out of age and sex according to the different regions where the animals were harvested. The animals in Table 1 were measured for their morphological sizes and weights and used to determine the proximate chemical composition, while the animals in Table 2, a sub-sample of the animals in Table 1, were used to determine the amino acid and mineral content of the meat. Age was estimated on the basis of tooth eruption and wear, as well as horn size and length. Adult refers to a reproductive animal, while sub-adult refers to young animals that have not yet reached maturity.

Table 1

Distribution of age groups and sex according to the region where the black wildebeest were harvested for the determination of carcass yield and proximate composition of the meat

	Region						
	Maria Moroka			Sandveld			
	Sub-adult	Adult	Total	Sub-adult	Adult	Total	Total
Male	1	4	5	1	1	2	7
Female	0	5	5	2	5	7	12
Total	1	9	10	3	6	9	19

Table 2

Distribution of sub-samples of male and female black wildebeest of different age groups according to the region where they were harvested for the determination of mineral and amino acid content

	Region						
	Maria Moroka			Sandveld			
	Sub-adult	Adult	Total	Sub-adult	Adult	Total	Total
Male	0	3	3	1	1	2	5
Female	0	4	4	1	3	4	8
Total	0	7	7	2	4	6	13

Harvesting

The culling at MM was done at night, while at SV it was done during the day. The animals that were culled at night (MM) were culled according to the method described by Lewis, Pinchin and Kestin (1997), which consists of driving slowly in four-wheel drive vehicles and immobilizing the animals with spotlights prior to shooting them. At SV, two hunting vehicles drove to opposite ends of the herd of black wildebeest, creating an angle to trap the wildebeest. Shooting of the animals at both reserves was done using either a .270 caliber or .243 caliber rifle fitted with a telescopic sight. The huntsmen aimed for the head or upper neck, as this method causes the least damage and wastage to the carcass (Von La Chevallerie & van Zyl, 1971).

The cropped animals were exsanguinated by cutting the throat, approximately 2 min post-mortem, and then loaded onto the back of the culling vehicle. After the targeted number of animals had been harvested, they were taken to the reserve's skinning shed. Live mass was recorded on the hot carcasses after being bled, approximately 60 min post-mortem. The animals were then eviscerated, skinned and cleaned, followed by the removal of the head, gut and other edible and non-edible parts of the body. These included the kidneys, liver, lungs, internal fat as well as the leg from the hoof to the knee. The carcasses at SV were moved into a cooling facility (set at 4°C) approximately 18 h post-mortem, while the carcasses at MM were moved into a mobile cooling unit (set at 4°C) at 22 h post-mortem. The dressed carcasses were removed from the cooler 24 h post-mortem and weighed; thereafter they were re-placed in the cooler and the dressing percentage calculated.

Morphological measurements

The morphological measurements to obtain the length, width and depth of the carcass as well as carcass circumferences were also taken on the cold eviscerated carcasses. The carcass length was measured from the base of the neck to the base of the tail at the juncture of the pelvis. The depth of the carcass was measured from the spine to the sternum, just posterior to the forelegs, while the width of the carcass was measured between the widest points of the rib cage just posterior to the forelegs. The circumferences included the maximum chest circumference and the leg (buttock) circumference. The length of the leg was measured from the base of the leg to the end. The chest circumference was measured around the chest also posterior to the forelegs and the leg circumference at the top of the leg at the juncture with the abdomen, posterior to the thigh. The carcass length, width and depth were taken with a steel slide yardstick, while the circumferences were taken with a standard tape measure.

For the chemical analysis the *M. longissimus dorsi et lumborum* (MLD) was removed from between the 12^{th} and 13^{th} rib to between the 4^{th} and 5^{th} lumber vertebra, 24 h post-mortem. The lean meat samples were placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further analyses could be carried out.

Proximate chemical analysis

Proximate analysis was conducted on the MLD samples. After removing the subcutaneous fat and superficial connective tissue, the frozen muscle samples were cut into smaller portions, minced three times through a 2 mm sieve to ensure homogeneity, and analysed chemically. Total percentage moisture, protein and ash were determined according to standard AOAC methods (AOAC, 1997). The moisture content was analysed by drying a 2.5 g sample at 100°C for a period of 24 h. The protein (N x 6.25) content was determined by the block digestion method (AOAC, 1997), while ashing was done at 500°C for a period of 5 h.

The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee, Trevino & Chaiyawat, 1996).

Total collagen analysis

Hydroxyproline is quantitavely determined as a measure of the collagen in meat and was determined according to the method of Kolar (1990). A 4 g meat sample was hydrolysed in 3.5 M H_2SO_4 at 100°C for 12 to 14 h, filtered and diluted. Hydroxyproline was oxidised with choloramine-T and the colour reagent, 4-dimethylaminobenzaldehyde added. After calibration the absorbance was measured spectrometrically at 560 nm.

Amino acid analysis

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 centrifuged (15 krpm for 5 min) samples were dried under vacuum for 1.5 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 1.5 to 2 h. The resulting sample was derivatized by adding 20 µl of 7:1:1:1 ethanol:water:triethylamine:phenylisothiocyanate derivatizing solution. This was allowed to react at room temperature for 10 min prior to drying under vacuum (minimum of 3 h). 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 5000ppm 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).

Mineral analysis

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

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

Statistical analysis

A three-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were two regions (MM and SV), two age groups (adult and sub-adult) and two sexes (male and female). 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, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998). Correlations were made using the Pearson product moment correlation coeffisient.

Results and Discussion

There were no interactions between any of the main effects investigated in the present study; therefore, only the significant differences ($P \leq 0.05$) and tendencies toward differences ($P > 0.05$) of the main effects will be discussed.

Morphological attributes

The mean live and carcass mass, as well as the morphological measurements of the harvested animals, are presented in Table 3.

Table 3

The mean live mass, carcass mass, yield and morphological measurements of the MLD from black wildebeest harvested at two regions, devided into two age groups and sexes

	Region			Age			Sex		
	MM n = 10	SV n = 9	LSD	Adult n = 15	Sub adult N = 4	LSD	Male n = 7	Female n = 12	LSD
Live mass (kg)	137.55[a]	112.22[b]	7.03	138.91[a]	75.48[b]	8.61	130.08	122.91	7.27
Carcass mass (kg)	70.52[a]	54.91[b]	6.03	70.05[a]	37.18[b]	7.39	64.90	62.09	6.24
Dress out (%)	51.35	48.91	3.04	50.49	49.09	3.72	50.10	50.25	3.15
Length (cm)	113.71[a]	99.60[b]	7.67	114.09[a]	93.50[b]	8.45	122.32	108.21	7.23
Width (cm)	34.87[b]	38.34[a]	2.59	38.08[a]	30.65[b]	3.17	37.19	36.13	2.68
Depth (cm)	47.21	45.13	3.11	47.82[a]	40.25[b]	3.81	46.20	46.24	3.22
Chest circumference (cm)	122.16	118.41	5.99	125.20[a]	99.23[b]	7.73	120.58	120.63	6.47
Leg circumference (cm)	73.60[a]	64.52[b]	4.55	72.09[a]	58.83[b]	5.58	69.93	68.93	4.71
Leg length (cm)	65.32	60.02	3.64	65.79[a]	56.15[b]	4.46	65.50	62.74	3.77

LSD, Least Significant Difference, $P=0.05$

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

The mean live and carcass mass of animals from MM was significantly heavier ($P \leq 0.05$) than those of SV and, although it did not differ significantly, the dressing percentage of MM was also higher than that of the animals harvested at SV. This may be due to the fact either that the animals harvested at MM only included one sub-adult animal, while the animals harvested at SV included three sub-adults, or to the different types of vegetation at the different reserves. Black wildebeest, like most other animal species, increase in animal size and weight with an increase in animal age. Due to the uneven distribution of age groups at the harvesting regions, the significantly higher ($P \leq 0.05$) live and carcass mass of MM could be ascribed to more adult animals being included in the sample size. Nutritional level will also undoubtedly influence growth rate and mature size and may well have been a major factor in determining the size of the animals (Von La Chevallerie, 1971).

The black wildebeest were harvested during the winter (July to August), when they have specific feeding behaviour, making use of karooid shrubs as a major food source (Von Richter, 1971). SV is an open savannah with Umbrella thorn (*Acacia tortilis*) and Camel thorn (*A. erioloba*) as the dominant tree species. The grass layer at SV is fairly well-developed, and grasses such as Redgrass (*Themeda triandra*), Common Nine-awn grass (*Enneapogon cenchroides*) and Lehmann's lovegrass (*Eragrostis lehmanniana, Elionurus muticus* and *Cymbopogon plurinodis*) are plentiful. The shrub layer is poorly to moderately developed (Low & Rebelo, 1998). MM has moderately dense grassland and the moist cold highveld grassland has deep, yellow and grey sandy-loam soil, while the land and soil type have a lesser influence on plant distributions than terrain form and associated soil depth, soil moisture (clay content), rockiness of the soil surface, and grazing do. The dominating grass species at MM are Bushveld turpentinegrass (*Cymbopogon plurinodis*), Redgrass (*Themeda triandra*) and Small Creeping Foxtail (*Setaria sphacelata, Eloinurus muticus* and *Eragrostis curvula*) (Low & Rebelo, 1998). The vegetation at MM is, therefore, more favourable for black wildebeest during the winter months due to the higher availability of karooid shrubs.

The animals at both MM and SV had lower dressing percentages then those noted by Hitchins (1966) who reported a mean dress percentage of 56% for males and 55.7% for female black wildebeest harvested at Hluhluwe Game Reserve. The higher dressing percentages reported by Hitchins (1966) could most probably be attributed to his method of calculating dressing percentage, as he reported the carcass weight with the kidneys and kidney fat still attached. The significant differences between the adult and sub-adult black wildebeest as pertaining to the yield, as well as the differences in morphological sizes, were as expected, with an increase in animal age causing an increase in animal size and therefore an increase in animal weight (Lawrie, 1985). Although not significantly, the mean weight for the males were heavier than those of the females, but when the live and carcass mass were expressed as a proportion of total body weight the dressing percentages were similar.

Hoffman (2000) obtained a similar result between male and female impala (*Aepyceros melampus*) with no significant differences in the dressing percentage between the sexes. According to Von la Chevallerie (1971) the dressing percentages of wild ungulates are supposed to be the same or even more than those of domestic species. Although the dressing percentages and carcass yield reported on impala (58%) were higher (Hoffman, 2000) than that of black wildebeest (50%), the latter were similar to those of beef, being 51% (Onyango *et al.*, 1998). The morphological measurements taken indicated that the black wildebeest harvested at MM were larger in size and circumferences than those harvested at SV. The morphological measurements on the dressed carcass also indicated that the male black wildebeest are larger than the female black wildebeest.

Proximate chemical composition

The mean values for the proximate chemical composition of the black wildebeest are presented in Table 4. Limited data were found on the chemical composition of different South African game species, making it difficult to draw comparisons between different wild ungulates.

Table 4

Mean proximate composition and collagen content from the MLD of the black wildebeest harvested in two regions and classified according to age and sex

	Region			Age			Sex		
	MM n = 10	SV n = 9	LSD	Adult n = 15	Sub-adult n = 4	LSD	Male n = 7	Female n = 12	LSD
Moisture (%)	75.26	74.75	1.35	75.26	74.10	1.65	74.69	75.21	1.40
Protein (%)	20.23	20.27	0.07	20.41	19.63	0.09	19.42^{b}	20.73^{a}	0.07
Fat (%)	0.96^{b}	1.20^{a}	0.98	1.03	1.23	1.20	0.97	1.13	1.01
Ash (%)	1.27	1.26	0.24	1.26	1.29	0.29	1.29	1.25	0.24
Total Collagen (%)	0.71^{a}	0.49^{b}	0.31	0.65^{a}	0.39^{b}	0.33	0.56	0.65	0.17

LSD, Least Significant Difference, P=0.05

^{a,b}Means in rows, within effects, with different superscript letters are significantly different, $P \leq 0.05$

In this study the moisture and ash content did not differ ($P>0.05$) significantly between the regions, age groups or male and female black wildebeest. In a study on najdi-camel meat (*Camelus dromedaries*) Dawood and Alkanhal (1995) found older animals to have lower moisture content due to their higher fat content. Although the older animals in this investigation did not have a lower moisture content, there were only inversely related tendencies ($P>0.05$) between the moisture and fat content for all the main effects studied. The female black wildebeest had a significantly higher ($P \leq 0.05$) protein content in their MLD than the males. The animals harvested at SV had a significantly higher intramuscular fat content. But according to Table 3 the SV black wildebeest were significantly ($P \leq 0.05$) lighter and smaller than the animals harvested at MM. The significantly higher percentage of fat,

therefore, indicates that, although the animals harvested at SV were lighter and smaller, they were not famished or in a worse condition than the animals harvested at MM. In addition, the females tended to have a higher fat content compared to the males. The lower fat content of the males can be due to the excitable stage of black wildebeest bulls during the mating or rutting season. During this period the bulls can be very wary and probably spend less time feeding. Hoffman (2000) made similar findings in a study on male and female impala.

Collagen content

Collagen is the major connective tissue protein and is, therefore, an integral constituent of muscle (McCormick, 1994). There were significant differences ($P \leq 0.05$) in the collagen content between the animals harvested at MM and those harvested at SV, as well as the adult and sub-adult animals. Tarrant (1998) states that collagen is the principal fibrous protein. The adults tended ($P > 0.05$) to have a higher protein content, and it is also well-known that changes occur in meat as animals grow and mature and is most directly correlated to the progressive maturation of muscle collagen. The significant difference ($P \leq 0.05$) in the collagen content between the regions can thus be ascribed to the uneven distribution of the animal age as the sample size at MM included no sub-adults. The sub-adults had a significant ($P \leq 0.05$) lower content of total collagen than the adults, this emphasized the age effect of collagen.

Amino acid content

The amino acid content of the three main effects in mg/100 g meat sample is presented in Table 5. There were no significant differences ($P > 0.05$) present between any of the three main effects for the amino acids analysed. Glutamic acid contributed the highest content to the total amino acid composition, followed by aspartic acid, alanine and lysine. According to Sales and Hayes (1996), beef and ostrich meat is characterized by a high content of lysine, leucine, aspartic acid, and glutamic acid. In the latter study the meat from the ostriches had higher content of phenylalanine and a lower content of histadine compared to beef and chicken. In comparison to ostrich and beef (Sales & Hayes, 1996), black wildebeest had a higher content of threonine (ostrich 3.90 mg/100 g, beef 4.64 mg/100 g), leucine (ostrich 7.78 mg/100 g, beef 8.00 mg/100 g), aspartic acid (ostrich 9.79 mg/100 g, beef 9.60 mg/100 g), serine (ostrich 3.02 mg/100 g, beef 4.48 mg/100 g), glycine (ostrich 4.22 mg/100 g, beef 5.60 mg/100 g), and alanine (ostrich 5.46 mg/100 g, 6.40 mg/100 g), all indicating black wildebeest meat to be a good source of amino acids, as would be expected because of the high protein content.

Table 5

Mean amino acid content in g/100 g of meat sample from the MLD of the black wildebeest

	Region			Age			Sex		
	MM n = 7	SV n = 6	LSD	Adult n = 11	Sub-adult N = 2	LSD	Male n = 5	Female n = 8	LSD
Alanine	2.55	2.74	0.50	2.58	2.97	0.69	2.58	2.67	0.51
Arginine	1.39	1.45	0.22	1.39	1.60	0.31	1.41	1.43	0.23
Aspartic acid	2.85	3.04	0.43	2.85	3.43	0.59	2.95	2.93	0.44
Cystine	0.21	0.23	0.04	0.21	0.25	0.05	0.20	0.23	0.04
Glutamic acid	3.18	3.30	0.42	3.18	3.53	0.58	3.27	3.22	0.43
Glycine	1.91	1.92	0.31	1.88	2.12	0.42	1.95	1.89	0.31
Histidine	0.62	0.66	0.10	0.63	0.72	0.13	0.60	0.66	0.10
Isoleucine	1.14	1.21	0.18	1.14	1.35	0.25	1.17	1.18	0.19
Leucine	2.30	2.48	0.50	2.32	2.77	0.69	2.32	2.43	0.51
Lysine	1.99	2.09	0.33	1.99	2.28	0.45	2.01	2.05	0.34
Methionine	0.69	0.75	0.14	0.60	0.82	0.19	0.68	0.74	0.14
Phenylalanine	0.50	0.91	0.16	0.85	1.00	0.22	0.85	0.89	0.17
Proline	1.34	1.39	0.25	1.34	1.53	0.35	1.36	1.37	0.26
Serine	1.82	1.95	0.32	1.83	2.14	0.44	1.86	1.90	0.33
Threonine	1.71	1.83	0.31	1.72	2.05	0.43	1.75	1.78	0.32
Tyrosine	0.73	0.77	0.12	0.73	0.86	0.17	0.74	0.76	0.12
Valine	1.44	1.51	0.24	1.44	1.67	0.33	1.47	1.47	0.24

LSD, Least Significant Difference, P=0.05

Aspartic acid = aspartic acid + aspartine and Glutamic acid = glutamic acid + glutamine

Table 6

Mean amino acid content in g/100 g of protein from the MLD of the black wildebeest harvested in two regions and classified according to age and sex

	Region			Age			Sex		
	MM n = 7	SV n = 6	LSD	Adult n = 11	Sub-adult N = 2	LSD	Male n = 5	Female n = 8	LSD
Alanine	9.94	10.23	1.93	9.99	10.54	2.71	9.72	10.29	2.01
Arginine	5.40	5.42	0.86	5.36	5.68	1.19	5.29	5.49	0.88
Aspartic acid	11.06	11.33	1.66	11.02	12.13	2.30	11.08	11.25	1.71
Cystine	0.81	0.88	0.15	0.84	0.86	0.21	0.77	0.89	0.16
Glutamic acid	12.35	12.31	1.50	12.30	12.50	2.07	12.27	12.37	1.53
Glycine	7.41	7.15	1.12	7.25	7.50	1.54	7.32	7.28	1.14
Histidine	2.42	2.47	0.40	2.43	2.56	0.56	2.27	2.56	0.41
Isoleucine	4.43	4.53	0.72	4.42	4.78	1.00	4.39	4.53	0.74
Leucine	8.97	9.29	2.03	8.98	9.83	2.81	8.75	9.34	2.08
Lysine	7.71	7.80	1.23	7.69	8.09	1.70	7.56	7.87	1.26
Methionine	2.67	2.78	0.56	2.69	2.90	0.71	2.55	2.83	0.57
Phenylalanine	3.30	3.93	0.66	3.30	3.57	0.91	3.20	3.43	0.68
Proline	5.21	5.20	0.92	5.17	5.43	1.28	5.11	5.27	0.95
Serine	7.09	7.28	1.27	7.10	7.58	1.75	6.99	7.29	1.30
Threonine	6.66	6.84	1.22	6.65	7.24	1.69	6.57	6.85	1.25
Tyrosine	2.83	2.89	0.47	2.82	3.06	0.65	2.78	2.90	0.48
Valine	5.60	5.62	0.93	5.55	5.91	1.29	5.50	5.67	0.96

LSD, Least Significant Difference, P=0.05

Aspartic acid = aspartic acid + aspartine and Glutamic acid = glutamic acid + glutamine

Mineral content

Table 7 presents the mean mineral and trace element content of the MLD for the main effects investigated. There were no significant differences ($P \leq 0.05$) between any of the minerals or trace elements analysed for either the regions, age groups or male and female black wildebeest. The minor differences ($P > 0.05$) between the different regions, MM and SV, can possibly be ascribed to the different vegetation types and feeding regimes of the black wildebeest at the different reserves, or due to the production levels as De Bouwer *et al.* (2000) stated that the mineral requirements increase as the level of production increases. Cronje (1990) stated that the nutritional value of the vegetation (veld) decrease after the month of maximum rainfall. Although not significantly ($P > 0.05$), the males tended to have a higher content of all the minerals investigated, which includes phosphorus, potassium, calcium, and magnesium. In comparison to ostrich (Sales & Hayes, 1996), black wildebeest had a higher content of iron and copper than ostrich, namely 2.3 mg/100g and 0.10 mg/100g, respectively. Overall, black wildebeest meat had a high content of phosphorus and iron, and low content of sodium, and all of these are definite health-promoting attributes that can be used in the marketing of the meat to the health conscious consumer.

Table 7

Mean mineral content in mg/100g from the MLD of the black wildebeest harvested in two regions and classified according to age and sex

	Region			Age			Sex		
	MM n = 7	SV n = 6	LSD	Adult n = 11	Sub-adult n = 2	LSD	Male n = 5	Female n = 8	LSD
Phosphorus	159.37	178.00	74.52	164.54	186.83	102.96	194.43	151.43	76.36
Potassium	164.20	159.25	48.99	170.78	113.18	67.69	189.72	144.54	50.20
Calcium	6.65	6.69	2.04	6.60	7.03	2.83	6.98	6.47	2.10
Magnesium	18.15	21.77	8.19	19.59	21.07	11.32	22.04	18.43	8.39
Sodium	14.52	14.43	4.87	14.19	16.07	6.73	14.48	14.48	4.99
Iron	3.18	2.96	1.02	3.17	2.59	1.41	3.64	2.73	1.04
Copper	0.13	0.08	0.12	0.11	0.08	0.16	0.11	0.11	0.12
Zinc	1.24	1.21	0.77	1.15	1.61	1.07	1.00	1.37	0.79

LSD, Least Significant Difference, $P=0.05$

Conclusion

The aim of this study was to determine the effects of the production and harvesting region, animal age and sex on the yield, proximate composition, amino acid and mineral content of black wildebeest meat. The animals harvested at MM were significantly heavier and larger, while the animals harvested at SV contained significantly more fat in the MLD. The MLD of the females had a significantly higher content of protein and tended to have a higher moisture and fat content as well. For the main effects investigated no significant differences were found between any of the amino acid and minerals investigated. This indicates that the amino acid and mineral content does not vary considerably between harvesting region, age groups

and sex of the animal and future studies only need to analyse the proximate composition of the meat.

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CHAPTER 4

PHYSICAL PROPERTIES, FATTY ACID AND CHOLESTEROL CONTENT, AND SENSORY ATTRIBUTES OF BLACK WILDEBEEST (*CONNOCHAETUS GNOU*) MEAT AS INFLUENCED BY REGION, AGE AND SEX

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Abstract

The *M. longissimus dorsi et lumborum* (MLD) of nineteen black wildebeest, harvested during 2002, was analysed to investigate the influence of production region (Maria Moroka Nature Reserve and Sandveld Nature Reserve), animal age (adults and sub-adults) and sex (male and female) on the physical attributes, fatty acid content and sensory properties of the meat. The pH, cooking loss and shear force did not differ significantly ($P>0.05$) between any of the main effects investigated, while a lower temperature at 24 h post mortem (T_{24}) of 4.82°C (± 0.87) at Sandveld Nature Reserve (SV) compared to the 7.30°C (± 0.22) of Maria Moroka Nature Reserve (MM) caused a significantly lower ($P\leq0.05$) percentage drip loss for SV, namely 2.44% (± 0.23) compared to the 5.45% (± 0.74) of MM. Differences pertaining to the meat colour proved the females (14.85 ± 0.58) to have a significantly higher ($P\leq0.05$) mean a* value than males (13.32 ± 0.32), while the sub-adults (10.96 ± 1.47) had a significantly higher ($P\leq0.05$) mean b* value compared to the adults (10.96 ± 0.50). A total of 13 animals consisting of five males and eight females were used to determine the fatty acid and cholesterol content. The black wildebeest harvested at SV had a significantly higher ($P\leq0.05$) content of total fatty acids, saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and n-3 PUFA due to the significantly higher ($P\leq0.05$) contents of α-linolenic acid (C18:3n-3), eicosapentaenoic acid (C20:5n-3), and docosapentaenoic acid (C22:5n-3), than those animals harvested at MM. The mean cholesterol content of black wildebeest was 47.00 ± 1.34 mg/100g and did not differ between the main effects. Generic descriptive sensory analysis was used to evaluate the differences in game aroma intensity, overall game flavour, initial impression of juiciness, sustained juiciness, tenderness and residue on 13 black wildebeest meat samples. The animals harvested at MM (6.00) had a significantly stronger ($P\leq0.05$) game meat flavour than the animals harvested at SV (5.58). The latter had a significantly higher ($P\leq0.05$) rating for the initial juiciness of the meat. There were no significant differences ($P\leq0.05$) between the male

and female black wildebeest for either flavour or initial juiciness. Region x Sex interactions indicated that the males harvested at MM (6.38) had a stronger game meat aroma than the males and females harvested at SV (5.86 and 5.70 respectively). Samples from females harvested at MM (6.13) were proved ($P \leq 0.05$) more juicy than the males harvested at SV (5.14). The meat from the females harvested at SV were significantly ($P \leq 0.05$) more tender (6.27) and had the highest rating for residue (6.54), while the males harvested at MM had the lowest ratings (4.88; 5.61 respectively) for both the tenderness and residue sensory attributes. These results indicate that both production region and sex influence sensory quality attributes of black wildebeest meat and need to be borne in mind during the marketing of game meat.

Keywords: game meat, physical characteristics, fatty acid content, cholesterol content, sensory attributes

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Introduction

Game meat is becoming increasingly popular among consumers all over the world, especially with the recent interest in organic foods and meat with a low fat content. However, limited research has been done on the physical attributes, fatty acid composition, cholesterol content and sensory attributes of game meat, particularly of that derived from animals found in Southern Africa.

In recent years there has been an increased interest in manipulating the fatty acid composition of meat (Wood *et al.*, 2003). Meat is seen as a major source of fat, especially saturated fatty acids, which contribute to various diseases, such as heart disease and cancer. According to Wood *et al.* (2003), the interest in the fatty acid composition of meat originated mainly from the need to find ways to produce healthier meat. This increased an awareness amongst consumers of the fatty acid composition of meat and a minimal figure of 0.45 for the ratio of polyunsaturated (PUFA) to saturated acids (SFA) (P:S) for British diets (Department of Health, 1994) as a whole (where higher values indicate healthier food especially in relation to cardiovascular diseases) has been recommended (Enser *et al.*, 1998). Several investigations seeking suitable methods on how to manipulate the fatty acid composition of meat to get higher ratios of PUFA to SFA fatty acids and a more favourable balance between the n-6 and n-3 PUFA have been conducted (Wood *et al.,* 2003).

Meat, particularly red meat, is commonly identified as a major source of dietary cholesterol. It is often the first food component that medical doctors advise should be reduced in the diets of hypercholesterolemic patients (Anger, 1990). Consumers need to understand that cholesterol is an integral part of the cell membrane of animals, and that the cholesterol content of meat is closely tied to the membranes of muscle cells. From a cholesterol point of view, the meat

from wild ungulates generate leaner meat with a lower cholesterol content, due to the low fat and high protein content (Hoffman, 2000). However, this has not yet been determined for all the different South African ungulate species.

Sensory attributes are of great importance in consumer preference (Risvik, 1994). After appearance and tenderness, flavour is the most important sensory characteristic of meat quality as perceived by consumers (Campo *et al.*, 2003). Consumer demands are increasingly influenced by growing concerns about the healthiness of the meat and the impact that modern methods of production could have on the wellbeing of consumers (Zotte, 2002).

The black wildebeest is an endemic African species, with an annual population growth of between 28% and 33% (Furstenburg, 2002). Black wildebeest are large mammals distributed widely in natural sanctuaries throughout South Africa. All the latter factors make the black wildebeest a suitable game species for meat production purposes, not only locally but internationally as well. It is well-known that the production region has an influence on the quality of the meat, due to different temperatures, water availability and vegetation types. Other ante-mortem factors also known to influence the physical quality of the meat as well as the fatty acid composition and sensory attributes include breed, the age of the animal at slaughter and sex. Therefore, this study investigated the possible influences of region, animal age and sex on the physical properties, fatty acid profile and sensory attributes of black wildebeest meat.

Materials and Methods

Animals

A total of 19 black wildebeest (*Connochaetus gnou*) were used to determine the physical parameters. Thereof a sub-sample of 13 was used to determine the fatty acid profile, cholesterol content and to evaluate the sensory attributes of the meat using a trained panel. The animals were harvested during 2002 at Maria Moroka Nature Reserve (MM) and Sandveld Nature Reserve (SV) in the Free State Province, South Africa. MM, approximatly 60 km east of Bloemfontein, near Thaba Nchu, is a 5 880 ha reserve situated on a plateau with grassy plains (Low & Rebelo, 1998). SV encompasses the north-west region of the large peninsula created by the Bloemhof Dam in the northwestern Free State (*Reader's Digest*, 1983). This 14 700 ha reserve is characterised by a grassy ground layer and a distinct upper layer of woody plants (Low & Rebelo, 1998). Table 1 and Table 2 illustrate the lay-out of age and sex according to the different reserves (regions) where the animals were harvested.

The animals in Table 1 were used for the physical analysis of the meat, which includes pH and temperature readings, colorimetric measurements, drip loss and cooking loss, as well as determining of the meat tenderness instrumentally. Age was estimated on the basis of tooth

eruption and wear, as well as horn size and length, and verified according to their live mass and carcass mass. Adult refers to a reproductive animal while sub-adult refers to young animals.

Table 1

Distribution of age groups and sex according to the region where the black wildebeest were harvested for the determination of the physical characteristics of the meat

	Region						
	Maria Moroka			Sandveld			
	Sub-adult	Adult	Total	Sub-adult	Adult	Total	Total
Male	1	4	5	1	1	2	7
Female	0	5	5	2	5	7	12
Total	1	9	10	3	6	9	19

Table 2

Distribution of sub-samples of male and female black wildebeest of different age groups according to the region where they were harvested for the determination of the fatty acid and cholesterol content and to evaluate the sensory attributes of the meat

	Region						
	Maria Moroka			Sandveld			
	Sub-adult	Adult	Total	Sub-adult	Adult	Total	Total
Male	0	3	3	1	1	2	5
Female	0	4	4	1	3	4	8
Total	0	7	7	2	4	6	13

Harvesting

The culling at MM was done at night, while at SV it was done during the day. The animals that were culled at night (MM) were culled according to the method described by Lewis, Pinchin and Kestin (1997), which consists of driving slowly in four-wheel drive vehicles and immobilizing the animals with spotlights prior to shooting them. At SV, two hunting vehicles drove to opposite ends of the herd of black wildebeest, creating an angle to trap the wildebeest. Shooting of the animals at both reserves was done using either a .270 caliber or .243 caliber rifle fitted with a telescopic sight. The huntsmen aimed for the head or upper neck, as this method causes the least damage and wastage to the carcass (Von La Chevallerie & van Zyl, 1971).

The cropped animals were exsanguinated by cutting the throat, approximately 2 min post-mortem, and they were then loaded onto the back of the culling vehicle. After the targeted number of animals had been harvested, they were taken to the reserve's skinning shed. The animals were then eviscerated, skinned and cleaned, followed by the subsequent removal of the head, gut and other edible and non-edible parts of the body. These included the kidneys, liver, lungs, internal fat as well as the leg from the hoof to the knee.

Physical measurements

Forty-five minutes post-mortem the initial muscle pH (pH_{45}) and temperature were taken and after 24 h the ultimate pH (pH_{24}) and temperature were measured. These measurements were taken on the *M. longissimus dorsi et lumborum* (MLD) between the 4th and 5th lumbar vertebrae counting from the caudal end. The pH was measured with a penetrating glass electrode on a hand-held Crison pH/mV-506 meter. The pH meter consisted of an automatic temperature compensator to ensure the adjustment of the pH for temperature. The pH meter was calibrated after every four readings with pH 4.01 and pH 7.02 buffers and cleaned with distilled water after every reading.

For the physical and chemical analyses, both the MLD were removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra, and trimmed of all visible subcutaneous fat. For the determination of the drip loss, 1.0 cm thick meat samples weighing ca. 30 g, cut perpendicular to the longitudinal axis of the muscle on the caudal side of the MLD, were weighed. The samples were placed in netting and suspended in an inflated plastic bag. After a storage period of 24 h at 4°C, the samples were blotted with absorbent paper, weighed again and the drip loss was calculated as weight loss expressed as a percentage of the original mass of the sample (Honikel, 1998). For the cooking loss determination, freshly cut MLD samples (1.0 cm thick) were weighed and placed in thin-walled plastic bags in a water-bath at 80°C. After 1 h the samples were removed from the water-bath, cooled in cold water, blotted dry and weighed. Cooking loss was calculated as the difference in sample weight before and after cooking, expressed as a percentage of the initial sample weight (Honikel, 1998).

Three cylindrical cores were cut from each cooked sample (after determining cooking loss) using a 1.27 mm diameter bore. Samples were randomly removed from the centre of each MLD with a temperature of approxamitely 9°C. Maximum Warner Bratzler shear force values required to shear a cylindrical core of cooked muscle, perpendicular to the longitudinal orientation of the muscle fibers at a crosshead speed of 299 mm/min, were recorded for each sample and the mean was calculated for each muscle. A larger value indicates greater shear force and therefore tougher meat (Honikel, 1998).

The MLD was used for the determination of fresh meat colour. Three readings were taken per sample after blooming for 20 min. Colour was evaluated according to the method described by Honikel (1998) using a Colorgard System 2000 colorimeter (Pacific Scientific, Silver Spring, MD, USA) to determine L*, a* and b* values, with L* indicating lightness, a* the red-green range and b* the blue-yellow range. These values were also used to calculate the chroma value and hue angle according to the following equations, chroma = $\sqrt{(a^{*2}+b^{*2})}$, and the hue angle (°) = $\tan^{-1}(b^*/a^*)$.

The remaining lean meat samples were homogenised, placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further analyses could be carried out.

Fatty acid analysis

The fatty acid content was determined using the same method described by Tichelaar, Smuts, Van Stuihvenber, Faber and Benade (1998). After thawing the meat, the lipids in a 2 g sample was extracted with choroform/methanol (CM 2:1; v/v) according to a modified method of Folch, Lees and Sloane-Stanley (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 tude 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 a 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 in the total lipids were identified by comparison of the retention times to those of standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Cholesterol analysis

From the same lipid extraction used for the fatty acid determination, a sub-sample was used for cholesterol determination. After drying the sub-sample under nitrogen Stigmasterol (3-B-hydroxy-24-ethyl-5.22-cholestadiene; Sigma Chemical Co., St Louis, MO, USA) was added as internal standard and 6% Ethanolic KOH used to saphonifise the extraction for 2 h at 70°C in a heating block. After cooling, distilled water and hexane were added and the resultant extraction was analysed by GLC (Varian Model 3700, equipped with flame ionization detection). A 1.2 m glass column of 2 mm internal diameter packed with 3% SP2401 on 100/120 mesh Supelcoport (Supelco Inc., Bllefonte, PA, USA) was used. Gas flow rates were: hydrogen, 20 ml/min; air, 200 ml/min and nitrogen (carrier gas), 25 ml/min. Temperatures were: injector temperature 280°C; column temperature 255°C and detector temperature 290°C.

Sensory analysis

The vacuum-packed meat samples taken from the left side of the MLD were defrosted at a temperature of 4°C to 6°C for a period of 24 h prior to cooking on their pre-assigned sensory analysis dates. The meat samples were roasted in cooking bags placed on a wire-rack covered in foil on an open roasting pan to an internal temperature of 72°C. The temperature changes were monitored using thermocouples connected to hand-held digital recorders until the ultimate temperature of 72°C was reached. The samples were cooked at 160°C in two Defy 835 electric ovens connected to a computerised temperature control system (Viljoen, Muller, De Swardt, Sadie & Vosloo, 2001). Immediately after cooking the samples were cut into 1 cm x 1 cm cubes, wrapped in aluminium foil, placed in preheated glass ramekins marked with random three-digit codes and placed in a preheated oven at 100°C (until evaluated 10 min later) and were served to the panel.

Descriptive sensory analysis was performed on the black wildebeest meat. The panelists were selected and trained in accordance with the guidelines for the sensory evaluation of meat of the American Meat Science Association (AMSA, 1978) and the generic descriptive analysis technique (Lawless & Heymann, 1998). A trained, and test-re-tested, six-member panel evaluated the black wildebeest samples for the following sensory attributes: game aroma and flavour, juiciness and tenderness. An 8-point structured scale was used to evaluate the latter sensory attributes. Table 3 depicts the definitions of the attributes used in the sensory analyses.

Table 3

Definitions of the attributes used in the sensory analysis of the MLD muscle of black wildebeest

Characteristic	Description	Score
Game aroma intensity	Take a few short sniffs as soon as you remove the foil	8 Extremely intense 1 Extremely bland
Overall game flavour	This is a combination of taste and flavour experienced prior to swallowing	8 Extremely intense 1 Extremely bland
Initial impression of juiciness	The amount of fluid exuded on the cut surface when pressed between your thumb and forefinger	8 Extremely juicy 1 Extremely dry
Sustained juiciness	The impression that you form after the first two to three chews using the molar teeth	8 Extremely juicy 1 Extremely dry
First bite	The impression of tenderness after the first two to three chews using the molar teeth	8 Extremely tender 1 Extremely tough
Residue	The amount of residue left in the mouth after the first fifteen to twenty chews, using the molar teeth	8 None 1 Abundant

The panelists were seated in individual booths in a temperature (21°C) and light-controlled (artificial daylight) room (AMSA, 1978). Distilled water, apples and crackers were given to the panelists between 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 two regions (MM and SV), two age groups (adult and sub adult) and two sexes (male and female). 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, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998). Correlations were made using the Pearson product moment correlation coeffisient.

Results and Discussion

In the present investigation there were no interactions between the three main effects studied for the physical characteristics, fatty acid content, and cholesterol content determined. Therefore, only the significant differences ($P \leq 0.05$) and tendencies ($P > 0.05$) toward differences of the main effects will be discussed.

Physical characteristics

The mean values for the different effects of the physical attributes investigated are presented in Table 4. The night cropping of the black wildebeest at MM proved to be more efficient than the day cropping method used at SV. At SV all the animals ran approximately 4 km before the first gun shot was fired due to the anxious nature and antagonistic behaviour of the animals towards humans. Although all the animals at SV ran a distance before being shot, the meat, according to the pH and meat colour (Table 4), had no indication of dark, firm and dry meat (DFD). DFD meat is usually caused when an animal experiences severe ante-mortem stress (Lawrie, 1985; Hoffman, 2000).

There were no significant differences between the initial pH and temperature readings taken 45 min post-mortem for any of the main effects tested. The animals harvested at SV tended ($P > 0.05$) to have a slightly higher mean pH_{45} and $temperature_{45}$ than those harvested at MM; this can be ascribed to the different culling techniques. At SV culling was conducted during the day and all the animals ran at least 4 km before the first shot was fired. The running caused the ante-mortem body temperature of the animals to rise and this caused a higher mean temperature 45 min post-mortem. The females tended to have a higher initial pH, although not significant ($P > 0.05$). The higher pH_{45} of the females in the present study was an

Table 4

Physical characteristics of the MLD for the black wildebeest harvested at different regions according to their age and sex

	MM n = 10	SV n = 9	LSD	Adult n = 15	Sub-adult n = 4	LSD	Male n = 7	Female n = 12	LSD
pH_{45}	6.05	6.35	0.66	6.25	6.42	0.57	6.12	6.36	0.57
$Temperature_{45}$ (°C)	36.80	37.40	5.62	37.90	35.67	4.86	37.37	37.26	4.86
pH_{24}	5.54	5.54	0.11	5.52	5.63	0.13	5.54	5.54	0.11
$Temperature_{24}$ (°C)	7.30[a]	4.82[b]	1.89	6.29	5.53	2.32	5.89	6.26	1.96
Drip loss (%)	5.45[a]	2.44[b]	1.74	4.24	3.21	2.13	5.56[a]	3.13[b]	1.80
Cooking loss (%)	39.69	39.94	2.29	39.88	39.54	2.80	40.32	39.51	2.37
Shear force (kg/1.27 cm F)	3.42	4.43	1.45	3.84	4.10	1.77	3.23	4.28	1.50
L* value	35.24	32.99	2.87	33.51	36.65	3.51	35.98	33.12	2.97
a* value	14.43	13.28	1.47	14.15	12.88	1.80	14.85[a]	13.32[b]	1.52
b* value	7.88	9.45	1.86	8.01[b]	10.96[a]	2.28	9.24	8.27	1.93
Hue angle (°)	28.85[b]	35.11[a]	4.14	30.15[b]	38.05[a]	5.07	30.21	32.75	4.28
Chroma	16.55	16.40	1.91	16.35	16.95	2.33	17.64	15.80	1.97

LSD, Least Significant Difference, P=0.05

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

inverse result to that of Hoffman (2000) in a study on another South African ungulate, the impala (*Aepyceros melampus*), where the males had a significantly higher ($P \leq 0.05$) pH_{45}. MM had a significantly higher ($P \leq 0.05$) mean ultimate temperature, taken 24 h post-mortem. The higher temperature of MM was because the animals were moved into the mobile cooling unit only approximately 22 h post-mortem, while the animals at SV were moved into the cooling facility 18 h post-mortem. Due to unforeseen circumstances, and because culling at MM was done at night, the culled animals were only exsanguated without being skinned after being shot, while at SV, where the animals were cropped during the day, all the animals were skinned after being culled and left overnight in the skinning shed until the next morning, when the animals were moved into the cooling facility. The skinning shed at SV had a mean ambient temperature of 4.2°C during the period when the samples were collected.

There were significant differences ($P \leq 0.05$) between the harvesting region as well as male and female black wildebeest for percentage drip loss. The significant differences in drip loss between MM and SV can be due to the different ultimate temperatures and cooling rates as the ultimate temperature influences a variety of meat quality parameters. The higher percentage drip loss of the females was similar to that of Diaz *et al.* (2003) in a study on Manchego-breed suckling lambs, where females also expelled a higher percentage of liquid. There were no significant differences ($P > 0.05$) in cooking loss for any of the three main effects studied. Hoffman and Fisher (2001) found similar results in a study on ostriches, with no differences in cooking loss between age groups or sex. Although the sub-adults and

females tended to have higher shear force values, there were also no significant differences (P>0.05) in the shear force for any of the effects investigated. Huff and Parrish (1996) state that, among all the factors that influence meat tenderness, the most notable are the age and sex of the animal. Meat from more mature animals has been found to be less tender than the meat from younger animals. The tendency (P>0.05) towards an inverse finding in the present study, where the younger animals were less tender, could possibly be ascribed to the lower ultimate meat temperature of the younger animals, because muscle temperature post-mortem has been cited as an important factor in the development of meat tenderness (Lee, 1986). A high muscle temperature accelerates the rate of pH decline in muscle, presumably because such a physiological temperature permits enzymatic activity to continue (Busch, Parrish & Goll, 1967). It is, therefore, of vital importance that reserves should give attention to proper cooling facilities, not only to ensure meat of a better and consistant physical quality, but also to prevent microbial spoilage.

The colour-related parameters of the MLD showed significant differences (P≤0.05) between the age groups for the b* values and the hue angle. The higher b* value and wider hue angle of the sub-adults were due to the rotation of b* towards a*, causing an increase in the hue angle, which results in more redness. The sub-adults also tended to have a higher (P>0.05) mean reflectance value (L*), which is similar to the results of Hoffman and Fisher (2001) in their comparative study of the meat quality characteristics of young and old ostriches. Although not significant (P>0.05), the higher L* value of the sub-adults indicates that the meat from black wildebeest also becomes darker with increased animal age, just like that of beef, pork and ostrich (Lawrie, 1985; Hoffman & Fisher, 2001). In general, game meat has lower L* values than meat from domestic species and is, therefore, perceived to be darker. Although black wildebeest meat is darker than that of beef, the latter having a mean L* value of 39.24 (Kim & Lee, 2003), it is not as dark as the meat from ostriches (L* = 27.34) and impala (L* = 29.22). Swatland (1984) explains in detail why meat colour is brighter when the ultimate pH is lower, which means that a high ultimate pH causes meat to appear darker. However, this is not true for the present study, where there was no similar correlation between ultimate pH and L* values of the adult and sub-adult animals. The latter tendency (P>0.05) could be a result of the fact that colour intensity is not only dependent upon ultimate pH, but also on the myoglobin concentration (Kim, Yoon, Song & Lee, 2003).

Fatty acid content

The fatty acid composition of meat samples (g/100 g) from the different regions, age groups and male and female black wildebeest is presented in Table 5, while the percentage contribution to the total fatty acids is presented in Table 6. The MLD meat samples from the animals harvested at SV had a significantly higher (P≤0.05) content of fatty acids than the animals from MM. The significant higher (P≤0.05) content of total fatty acids of the SV

animals can be ascribed to the higher percentage of fat (1.20% than the 0.96% of MM) found in the MLD samples.

The significantly higher content of fatty acids in samples of the SV animals caused a significantly higher ($P \leq 0.05$) content of saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and desirable fatty acids (DFA), as well as a higher content of the n-3 fatty acids compared to those of animals harvested at MM. The significantly higher ($P \leq 0.05$) content of SFA can be attributed to the tendency towards a higher ($P > 0.05$) content of palmitic acid (C16:0) and stearic acid (C18:0). The significantly higher ($P \leq 0.05$) content of MUFA, in turn, can be ascribed to the significantly higher content of oleic acid (C18:1n-9). This regionally significant difference ($P \leq 0.05$) in oleic acid could be due to the different grass species being consumed by the black wildebeest at the different reserves. Oleic acid was found to be 1.6 times higher in grass-fed steers in a study by Enser *et al.* (1998) than in the steers that were fed concentrates. The significantly higher ($P \leq 0.05$) content of PUFA of the animals harvested at SV is due to the significantly higher content of α-linolenic acid (C18:3n-3), eicosapentaenoic acid (C20:5n-3) and docosapentaenoic acid (C22:5n-3), as well as the tendency ($P > 0.05$) towards a higher content of arachidonic acid (C20:4n-6). The percentage contribution of each fatty acid (Table 6) towards the total fatty acids also shows that the significantly higher content of PUFA of the meat derived from the SV animals has a tendency ($P > 0.05$) towards a higher percentage of linoleic acid (C18:2), α-linolenic acid (C18:3n-3), γ-linolenic acid (C18:3n-6), and eicosapentaenoic acid (C20:5n-3). The significantly higher ($P \leq 0.05$) content in mg/100 g meat of the MLD from the animals harvested at SV in α-linolenic acid (C18:3n-3), and a tendency ($P > 0.05$) towards a higher content of γ-linolenic acid (C18:3n-6), than the black wildebeest harvested at MM, can also be ascribed to the different vegetation types and grass species at the different reserves. Linolenic acid (C18:3) is the major fatty acid in grass. If a high proportion of linolenic acid is biohydrogenerated in the rumen, it may lead to a higher concentration of C18:0 in grass-fed animals (Sanudo *et al.,* 2000). The animals from SV, as mentioned above, had significantly higher ($P \leq 0.05$) concentrations of eicosapentaenoic acid (C20:5n-3) and docosapentaenoic acid (C22:5n-3). This may also be due to the different feeding regimes and food availability at the different reserves. Although not present in significant biological quantities, the significantly higher ($P \leq 0.05$) content of docosapentaenoic acid (C22:6n-3) of the sub-adult black wildebeest were similar to findings by Hoffman and Fisher (2001) in a comparative study on young and old ostriches. They found that an increase in animal age causes a decrease in docosapentaenoic acid. The significantly higher ($P \leq 0.05$) content of MUFA and PUFA of the SV animals consequently caused a significantly higher ($P \leq 0.05$) TUFA content. The animals harvested at MM had a significantly lower ($P \leq 0.05$) content of the long chain polyunsaturated n-3 fatty acids.

Table 5

Fatty acid composition (mg/100 g meat sample) and cholesterol content (mg/100 g meat sample) of the *M. longissimus dorsi et lumborum* of black wildebeest derived from two regions, two age classes and two sexes

	Region			Age			Sex		
	MM n = 7	SV n = 6	LSD	Adult n = 11	Sub-adult n = 2	LSD	Male n = 5	Female n = 8	LSD
Total fatty acids	4.61[b]	6.34[a]	1.10	5.29	6.06	1.52	5.15	5.57	1.12
Saturated									
C16:0	0.63	0.78	0.19	0.68	0.83	0.26	0.68	0.71	0.19
C18:0	1.33	1.47	0.15	1.40	1.37	0.21	1.35	1.42	0.15
C20:0	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.01
C22:0	0.02	0.02	0.00	0.02	0.02	0.01	0.02	0.02	0.00
C24:0	0.04	0.03	0.01	0.03	0.04	0.02	0.04	0.03	0.01
Mono-unsaturated									
C16:1n-7	0.00[b]	0.01[a]	0.00	0.00[b]	0.02[a]	0.00	0.01	0.00	0.00
C18:1n-9	0.68[b]	1.24[a]	0.01	0.88	1.26	0.43	0.74[b]	1.07[a]	0.32
C20:1n-9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
C24:1n-9	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02
Polyunsaturated									
C18:2	0.90	1.20	0.43	1.02	1.13	0.59	1.08	1.01	0.44
C18:3n-6	0.00	0.05	0.01	0.00	0.01	2.37	0.00	0.01	0.01
C18:3n-3	0.18[b]	0.33[a]	0.09	0.24	0.31	0.13	0.23	0.26	0.10
C20:2n-6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
C20:3n-9	0.04	0.06	0.02	0.05	0.05	0.03	0.04	0.04	0.02
C20:4n-6	0.43	0.58	0.20	0.50	0.49	0.28	0.51	0.51	0.21
C20:5n-3	0.12[b]	0.24[a]	0.06	0.16	0.23	0.09	0.16	0.16	0.06
C22:4n-6	0.02	0.03	0.01	0.02	0.03	0.02	0.03	0.03	0.01
C22:5n-3	0.16[b]	0.27[a]	0.09	0.22	0.21	0.13	0.19	0.23	0.09
C22:6n-3	0.02[b]	0.04[a]	0.01	0.02[b]	0.05[a]	0.01	0.03	0.03	0.01
SFA	2.02[b]	2.31[a]	0.25	2.14	2.27	0.34	2.10	2.19	0.25
MUFA	0.71[b]	1.29[a]	0.32	0.91	1.32	0.45	0.78	1.10	0.33
PUFA	1.88[b]	2.74[a]	0.83	2.24	2.48	1.14	2.27	2.28	0.85
TUFA	2.59[b]	4.03[a]	1.09	3.16	3.80	1.50	3.05	3.38	1.11
DFA	3.92[b]	5.50[a]	1.03	4.55	5.17	1.43	4.40	4.80	1.06
P:S	0.94	1.21	0.43	1.06	1.09	0.59	1.09	1.04	0.44
n-6	1.36	1.81	0.61	1.56	1.65	0.85	1.63	1.54	0.63
n-3	0.48[b]	0.88[a]	0.22	0.64	0.79	0.31	0.61	0.70	0.23
n-6:n-3	2.86[a]	2.09[b]	0.55	2.58	2.11	0.76	2.82	2.31	0.56
Cholesterol	46.51	47.37	7.27	44.87	50.17	7.45	46.05	51.63	10.04

LSD, Least Significant Difference, P=0.05

[a,b]Means, in rows, within groups, with different superscript letters are significantly different, P= 0.05

Abbreviations: SFA, Saturated Fatty Acids; MUFA, Mono-unsaturated Fatty Acids; PUFA, Polyunsaturated Fatty Acids; TUFA, Total Unsaturated Fatty Acids, DFA, Desirable Fatty Acids (C18:0 + TUFA); P:S, Polyunsaturated, Saturated fatty acid ratio; n-6 consists of C18:2, C18:3, C20:2, C20:4, C22:4; n-3 consists of C18:3, C20:5, C22:5

Table 6

Fatty acid composition (molar %) of the *M. longissimus dorsi et lumborum* of black wildebeest derived from two regions, two age classes and two sexes

	Region			Age			Sex		
	MM n = 7	SV n = 6	LSD	Adult n = 11	Sub-adult n = 2	LSD	Male n = 5	Female n = 8	LSD
SFA	45.05	36.61	9.96	41.81	37.52	13.76	42.58	40.26	10.21
C16:0	0.84	0.56	0.80	0.74	0.59	1.11	0.69	0.73	0.82
C18:0	4.20	5.90	1.63	4.78	6.14	2.25	4.41	5.35	1.67
C20:0	0.02	0.03	0.03	0.01	0.08	0.05	0.01	0.03	0.03
C22:0	0.25	0.45	0.18	0.35	0.31	0.25	0.28	0.38	0.19
C24:0	0.81	1.79	0.49	1.19	1.69	0.68	1.07	1.38	0.51
MUFA	14.86[b]	20.24[a]	3.44	16.54[b]	21.80[a]	4.76	14.28[b]	19.26[a]	3.53
C16:1n-7	7.79	8.28	5.08	7.46	11.07	7.02	6.16	9.17	5.20
C18:1n-9	0.00	0.05	0.00	0.00	0.16	0.00	0.04	0.02	0.00
C20:1n-9	1.24	2.45	0.68	1.71	2.27	0.94	1.48	2.00	0.70
C24:1n-9	0.15	0.20	0.09	0.17	0.18	0.13	0.19	0.16	0.09
PUFA	40.09	43.15	8.58	41.65	40.69	11.85	43.14	40.48	8.79
C18:2	8.91	11.49	2.64	9.88	10.42	3.65	8.85	10.66	2.71
C18:3n-6	4.63	9.40	2.20	6.34	9.53	3.04	4.82	8.09	2.26
C18:3n-3	6.19	8.86	3.49	7.26	8.36	4.82	7.11	7.62	3.57
C20:2n-6	0.12	0.13	0.05	0.12	0.15	0.07	0.12	0.13	0.05
C20:3n-9	0.04	0.08	0.04	0.05	0.08	0.06	0.04	0.07	0.04
C20:4n-6	0.05	0.08	0.01	0.06	0.07	0.06	0.06	0.06	0.05
C20:5n-3	2.90	4.31	1.57	3.53	3.66	2.17	3.34	3.69	1.61
C22:4n-6	0.12	0.14	0.05	0.13	0.18	0.07	0.13	0.14	0.05
C22:5n-3	0.23	0.24	0.08	0.23	0.26	0.11	0.25	0.22	0.08
C22:6n-3	0.15	0.18	0.11	0.16	0.20	0.15	0.18	0.15	0.11

LSD, Least Significant Difference, P=0.05

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

According to Saňudo *et al.* (2000), a higher n-6 PUFA content in meat is derived from animals fed on concentrates, while a grass diet is associated with a higher content of n-3 PUFA. Therefore, the fatty acid composition, in the present study, having no interactions between the main effects investigated; indicate that region, age and sex had a limited effect. These results are consistent with other reports in the literature, such as that of Kemp *et al.* (1981) in their study on the effect of feeding systems, slaughter weight and sex on the fatty acid composition of lamb.

The mean P:S ratio of the three main effects studied were all well above the recommended 0.45 advocated by the British Department of Health (Enser *et al.*, 1998). The n-6:n-3 PUFA ratio of black wildebeest was also well below the British Department of Health's recommended figure of 4.0. These results compare very favourably with meat from domestic species. However, it is important to remember that the total fat content of this game species is extremely low and the positive fatty acid results must be viewed in the context.

Cholesterol content

There were no significant differences between the three main effects investigated for the cholesterol content of the meat. The mean content of cholesterol in black wildebeest meat (47 mg/100 g ± 1.34) was lower than the cholesterol content of domestic species, such as beef (69 mg/100 g), lamb (87 mg/100 g) and pork (71 mg/100 g), and even lower than specific venison species, such as the white-tailed deer (113 mg/100 g) and mule deer (85 mg/100 g; Anger, 1990).

Sensory attributes

The results from the descriptive sensory analysis are presented in Table 7 and Table 8. Table 7 illustrates the effects of region (Maria Moroka Nature Reserve, MM and Sandveld Nature Reserve, SV) and sex (male and female), whereas Table 8 presents the interactions between the two factors (region x sex) investigated.

Table 7

Mean panel scores for the sensory analysis of the MLD for two different regions, and male and female black wildebeest

	Region			Sex		
	MM n = 7	SV n = 6	LSD	Males n = 5	Females n = 8	LSD
Flavour[c]	6.00[b]	5.58[a]	0.212	5.71	5.62	0.212
Initial juiciness[d]	6.24[a]	5.96[b]	0.233	6.14	6.10	0.233

LSD, Least Significant Difference, P=0.05

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

[c]1 = extremely bland; 8 = extremely intense

[d]1 = extremely dry; 8 = extremely juicy

For the attributes where there were no interactions (Table 7), the animals harvested at MM had a significantly ($P \leq 0.05$) stronger game meat flavour. Sink (1979) states that there is little doubt that the type of diet and nutrient source significantly influences the flavour of muscle foods. Therefore, the significant difference in flavour of the animals harvested at the different reserves can be ascribed to the different feeding regimes and vegetation types, indigenous to the different habitats at the reserves. It would be interesting to find out whether consumers would be able to distinguish between the meats originating from these two regions on the basis of the flavour and to ascertain which they find more pleasing. The animals harvested at MM had a significantly higher ($P \leq 0.05$) rating for initial juiciness. Differences in the juiciness of meat can be attributed to the amount of water in the muscle, or the intramuscular fat content of the meat sample. Although there were no significant ($P > 0.05$) correlations between either the moisture content or total intramuscular fat content and juiciness in this investigation, many authors have found positive correlations between juiciness and intramuscular fat content (Kim & Lee, 2003; Wheeler *et al.*, 1996). In the present study the

higher impression of juiciness can possibly be attributed to the rate of cooling and higher carcass temperature, 24 h post-mortem, of the animals harvested at MM (Table 4).

Table 8

Sensory interactions between the harvesting region and animal sex of the MLD for the sensory attributes investigated on black wildebeest meat

	MM Male n = 3	MM Female n = 4	SV Male n = 2	SV Female n = 4	LSD
Aroma[d]	6.38[a]	6.05[ab]	5.86[b]	5.70[b]	0.378
Sustained juiciness[e]	5.70[b]	6.13[a]	5.14[c]	5.70[b]	0.370
First bite[f]	4.88[c]	5.91[ab]	5.77[b]	6.27[a]	0.435
Residue[g]	5.61[b]	6.41[a]	6.54[a]	6.54[a]	0.389

LSD, Least Significant Difference, P=0.05
[a-c]Means, in rows, with different superscript letters are significantly different, 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

The sensory attributes of aroma, sustained juiciness and impression of tenderness (first bite and residue) all had region x sex interactions (Table 8). As far as aroma is concerned, the males from MM had a more intense smell, which differed from that of the females from MM. The aroma of the latter two did not differ significantly. As far as sustained juiciness is concerned, the females harvested at MM had a significantly ($P \leq 0.05$) higher sustained juiciness rating, while the males from SV were perceived to be only "moderately juicy", while the males from MM and females from SV had the same score. Meat tenderness is the most important palatability attribute and differences may be attributed to both ante- and post-mortem factors. It is clearly demonstrated that the female meat collected at SV had the highest scoring for first bite, i.e. the impression of tenderness after the first two to three chews between the molar teeth. The males harvested at MM had the lowest rating for first bite and for residue. There was also a negative correlation between the temperature taken 45 min post-mortem (Table 3) and the meat first bite ($r = -0.954$; $P \leq 0.046$), which indicates that an increase in $temperature_{45}$ will, therefore, cause a decrease in meat tenderness. Factors that causes ante-mortem stress to animals, like spotting the hunting vehicle or running after shots have been fired, should be limited as they subsequently cause an increase in body temperature and ultimately a decrease in meat tenderness.

Conclusion

The aim of this study was to determine the physical properties, fatty acid content and sensory characteristics of black wildebeest as influenced by the harvesting region, animal age and sex. Of the three main effects investigated the harvesting region had the largest impact on the attributes studied. Carcass temperature, taken 24 h post-mortem, had an impact on the

percentage drip loss. This suggests a need to formulate regulations regarding standard procedures for the time:temperature control of carcasses in order to ensure game meat of consistant physical quality. Different vegetation types, found in the different regions, had a significant effect on the fatty acid composition of the meat samples in contrast with the minor differences in fatty acid composition between animal age and sex. Interactions between four of the six sensory attributes proved that harvesting region and animal sex can be contributing factors in aroma, sustained juiciness, tenderness and residue of black wildebeest meat. An aspect that warrents further research is whether the consumers will be able to differentiate between meats representing these main effects.

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CHAPTER 5

THE EFFECT OF SEASON ON THE PHYSICAL AND CHEMICAL COMPOSITION OF BLACK WILDEBEEST (*CONNOCHAETUS GNOU*) MEAT

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Abstract

The aim of this study was to investigate the effect of different seasons, age groups and sex on the physical and chemical composition of black wildebeest (*Connochaetus gnou*) meat. Eighteen black wildebeest were harvested at Maria Moroka Nature Reserve, in the Free State province, South Africa during the winter, spring and autumn. Average live and carcass mass indicated lighter weights and lower dressing percentages after the winter months. Expected morphological mean differences were present between the different age groups, with significant interactions between age and sex for the dressing percentage ($P \leq 0.05$), carcass length ($P \leq 0.03$) and chest circumference ($P \leq 0.01$). The ultimate pH of the *M. longissimus dorsi et lumborum* (MLD) tended ($P > 0.05$) to be inversely related to meat tenderness, while higher ultimate muscle temperatures caused lower shear values. The animals harvested during spring (5.45% ± 0.74) had a significantly higher ($P \leq 0.05$) drip loss compared to those harvested in winter (2.38% ± 0.16) and autumn (3.30% ± 0.55), as well as cooking loss, spring showing a value of 39.69% ± 0.68 compared to a value of 34.71% ± 0.71 for winter and 33.44% ± 0.62 for autumn. The males (3.37 kg/1.27 cm F ± 0.24) were also found to be significantly tougher ($P \leq 0.05$) than the females (2.82 kg/1.27 cm F ± 0.23). The colour of the meat became increasingly darker with an increase in animal age (as indicated by the L* values). Season also had an effect on the muscle colour with the a* values for spring (14.43 ± 0.38) being significantly higher than those for autumn (12.98 ± 0.55). These differences in L* and a* values caused the hue and chroma values of the meat also to differ significantly for the main effects. The proximate composition of the MLD had significant season x sex interactions for both the percentage protein ($P=0.03$) and the percentage fat ($P=0.03$), where the males harvested in spring had a lower protein content (19.36% ± 0.41), and the females harvested during the winter had the higher percentage of fat (1.56% ± 0.27). It is clear that the seasonal changes affected both the physical and chemical composition of black wildebeest muscle.

Keywords: game meat, seasons, yield, physical parameters, chemical composition

Introduction

The diet and nutritional status of many game species vary considerably between the seasons of the year, which can cause weight loss or lack of growth in winter because of insufficient availability of nutrients (Wiklund, Pickova, Sampels & Lundström, 2001). These changes in food availability ultimately lead to changes in the chemical composition of the meat. Since game meat samples are usually only available during the South African hunting season (May to August), limited research has been done on the chemical changes in game meat composition between the seasons.

The black wildebeest or white-tailed gnu is an endemic South African species, which has an annual population growth of 28% to 33% and adapts easily to different environments. This makes it suitable for meat production purposes. The growth and development of black wildebeest from birth to adulthood are cumulative and consist of a rapid mass increase during summer followed by a mass loss or stasis during winter (Skinner & Smithers, 1990). During the summer (December to February), when food is in abundance, the diet of the black wildebeest consists mainly of green vegetation and forage, which is rich in cellulose, proteins and minerals, causing them to grow and to store fat. Their diet during the winter months (June to August) consists mainly of lichens, an abundant source of complex carbohydrates (Nieminen, 1992). The forced starvation during the winter causes the animals to rely on their lean tissue and fat reserves for energy (Wiklund *et al.* 1997). According to Drew (1985), the winter live mass of game animals is considerably lower than the summer live mass, since these animals can undergo a 25% mass loss and lose more than 80% of their body energy reserves. Food availability is also reliant on the rainfall. Finally the biochemical changes of the meat is not only dependent on the animals' food requirements, but also on the seasonal behaviour of the animals.

Black wildebeest, unlike blue wildebeest (*Connochaetes taurinus*), do not migrate over long distances during winter. However, their meat quality is highly influenced by the mating season (peak mating season March/April). According to Hoffman (2000), impala (*Aepyceros melampus*) rams lose body mass (lower lipid content) during the breeding and rutting season because of the strenuous activities of fighting, which result in the males spending less time feeding. The possible differences in meat quality and content that can occur due to an annual natural cycle that affects the normal growth and development of the animals due to different environmental conditions and seasonal behaviour of the black wildebeest must therefore be determined. This study was thus conducted to determine and compare the effects of seasonal changes, animal age and sex on the physical and chemical meat quality attributes of black wildebeest.

Materials and Methods

Animals

A total of 28 black wildebeest were shot during 2001 to 2003 at Maria Moroka Nature Reserve. Maria Moroka is a 5 880 ha Nature Reserve near Thaba Nchu, 60 km east of Bloemfontein in the Free State province, South Africa. This reserve is situated on a plateau with rocky slopes and grassy plains. The size and vegetation of this reserve result in a carrying capacity of 250 black wildebeest, with approximately 120 black wildebeest being culled every two years (Personal communication, 2 August 2003, Morne Pretorius, Nature Conservationist, Maria Moroka Nature Reserve). The actual black wildebeest population during August 2003 was 400, a clear indication that the numbers need to be reduced.

The annual rainfall of Maria Moroka Nature Reserve during the period of this study is presented in Table 1, which reveals that it is a summer rainfall region (Personal communication, 21 February 2004, Morne Pretorius, Nature Conservationist, Maria Moroka Nature Reserve).

Table 1

The annual rainfall of Maria Moroka Nature Reserve in mm

	2000	2001	2002	2003
January	132	78	187	79
February	59	78	89	44
March	86	94	19	129
April	73	127	64	15
May	37	22	81	10
June	4	33	4	0
July	2	2	0	0
August	5	29	108	7
September	53	23	38	17
October	29	55	23	1
November	63	173	12	42
December	80	113	95	57
Total mm/year	623	827	720	401

The animals were harvested during the winter in 2001 (July/August), spring in 2002 (September) and autumn in 2003 (March). The age and sex of the animals harvested during this period are illustrated in Table 2. The age was estimated on the basis of tooth eruption and wear, as well as horn size and length. Adult refers to a reproductive animal, while young refers to an animal that has not yet reached maturity.

Table 2

Distribution of the black wildebeest harvested at Maria Moroka Nature Reserve

	Winter		Spring			Autumn			
	Adult	Total	Adult	Young	Total	Adult	Young	Total	Total
Male	5	5	4	1	5	3	1	4	14
Female	3	3	5	0	5	5	1	6	14
Total	8	8	9	1	10	8	2	10	28

Harvesting

The culling at Maria Moroka Nature Reserve was done at night according to the method described by Lewis, Pinchin and Kestin (1997), which consists of driving slowly with four wheel drive vehicles and immobilizing the animals with spotlights prior to shooting them. Shooting of the animals was done using either a .270 calibre or .243 calibre rifle fitted with a telescopic sight. The huntsman aimed for the head or upper neck, as this method causes the least damage to and wastage of the carcass (Von La Chevallerie & Van Zyl, 1971).

The cropped animals were exsanguinated by cutting the throat, approximately 2 min post-mortem, and then loaded onto the back of the culling vehicle. After the targeted number of animals had been harvested, they were taken to the reserve's skinning shed. Live mass was recorded on the hot carcasses after being bled, approximately 60 min post-mortem. The animals were then eviscerated, skinned and cleaned, followed by the subsequent removal of the head, gut and other edible and non-edible parts of the body. This included the kidneys, liver, lungs, internal fat as well as the leg from the hoof to the knee. The carcasses at MM were moved into a mobile cooling unit (set at 4°C) 22 h post-mortem. The dressed carcass were weighed, 24 h post-mortem, and the dressing percentage calculated.

Morphological measurements

The morphological measurements to obtain the length, width and depth of the carcass as well as carcass circumferences were also taken on the cold eviscerated carcasses. The carcass length was measured from the base of the neck to the base of the tail at the juncture of the pelvis. The depth of the carcass was measured from the spine to the sternum, just posterior to the forelegs, while the width of the carcass was measured between the widest points of the rib cage just posterior to the forelegs. The circumferences included the maximum chest circumference and the leg (buttock) circumference. The length of the leg was measured from the base of the leg to the end. The chest circumference was measured around the chest also posterior to the forelegs and the leg circumference at the top of the leg at the juncture with the abdomen, posterior to the thigh. The carcass length, width and depth were taken with a steel slide yardstick, while the circumferences were taken with a standard tape measure.

For the chemical analysis, the *M. longissimus dorsi et lumborum* (MLD) was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra, 24 h post-mortem.

The lean meat samples were placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further analyses could be carried out.

Physical measurements

Forty-five minutes post-mortem the initial pH was taken (pH_{45}) and after 24 h the ultimate pH (pH_{24}) was measured. The pH measurements were taken on the *M. longissimus dorsi et lumborum* (MLD) between the 4th and 5th lumbar vertebrae counting from the caudal end. The pH was measured with a penetrating glass electrode on a hand-held Crison pH/mV-506 meter. The pH meter consisted of an automatic temperature compensator to ensure the adjustment of the pH for temperature. The pH meter was calibrated after every four readings with pH 4.01 and pH 7.02 buffers and cleaned with distilled water after every reading

For the physical and chemical analyses, both the MLD was removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra, and trimmed of all visible subcutaneous fat. For the determination of the drip loss 1.0 cm thick meat samples weighing ca. 30 g, cut perpendicular to the longitudinal axis of the muscle on the caudal side of the MLD, were weighed. The samples were placed in netting and suspended in an inflated plastic bag. After a storage period of 24 h at 4°C, the samples were blotted with absorbent paper, weighed again and the drip loss was calculated as weight loss expressed as a percentage of the original weight of the sample (Honikel, 1998). For the cooking loss determination, freshly cut MLD samples (1.0 cm thick) were weighed and placed in thin-walled plastic bags in a water-bath at 80°C. After 1 h the samples were removed from the water-bath, cooled in cold water, blotted dry and weighed. Cooking loss was calculated as the difference in sample weight before and after cooking, expressed as a percentage of the initial sample weight (Honikel, 1998).

Three cylindrical cores were cut from each cooked sample (after determining cooking loss) using a 1.27 mm diameter bore. Samples were randomly removed from the centre of each MLD. Maximum Warner Bratzler shear force values required to shear a cylindrical core of cooked muscle, perpendicular to the muscle grain at a crosshead speed of 3.8 mm/sec, were recorded for each sample and the mean was calculated for each muscle. A larger value indicates greater shear force and therefore tougher meat (Honikel, 1998).

The MLD was used for the determination of fresh meat colour. Three readings per sample were taken after blooming for 20 min. Colour was evaluated according to the method described by Honikel (1998) using a Colorgard System 2000 colorimeter (Pacific Scientific, Silver Spring, MD, USA) to determine L*, a* and b* values with L* indicating lightness, a* the red-green range and b* the blue-yellow range. These values were also used to calculate the

chroma value and hue angle according to the following equations: chroma = $\sqrt{(a^{*2}+b^{*2})}$, and the hue angle (°) = $\tan^{-1}(b^*/a^*)$.

The lean meat samples were placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until the proximate chemical analysis could be carried out.

Proximate chemical analysis

Proximate chemical analysis was conducted on the MLD samples. After removing the subcutaneous fat and superficial connective tissue, the frozen muscle samples were cut into smaller portions, minced three times through a 2 mm sieve to ensure homogeneity, and analysed chemically. Total percentage moisture, protein and ash were determined according to standard AOAC methods (AOAC, 1997). The moisture content was analysed by drying a 2.5 g sample at 100°C for a period of 24 h. The protein (N x 6.25) content was determined by the block digestion method (AOAC, 1997), while ashing was done at 500°C for a period of 5 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee, Trevino & Chaiyawat, 1996).

Statistical procedures

A three-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were three seasons (winter, spring and autumn), two age groups (adult and young) and two sexes (male and female). 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, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998). Correlations were made using the Pearson product moment correlation coeffisient.

Results and Discussion

Morphological attributes

The mean values of the yield and morphological sizes obtained from the black wildebeest are presented in Table 3, while Table 4 presents the age x sex interactions between the dressing percentage, carcass length and maximum chest circumference. The mean body mass (live mass) and carcass mass of the black wildebeest harvested during 2002 and 2003 did not differ significantly ($P>0.05$) between the seasons, although there was a tendency for the animals harvested during autumn to be slightly heavier than the animals harvested during the winter. This can be due to food availability and selected seasonal vegetation types. Seasonal differences in mass have also been reported in a study on adult blesbok (*Damaliscus dorcas phillipsi*) males, where the live mass of the animals harvested during

Table 3

Mean values for live mass, carcass mass and the morphological measurements of black wildebeest

	Season				Age			Sex		
	Winter n = 8	Spring n = 10	Autumn n = 10	LSD	Adult n = 25	Young n = 3	LSD	Male n = 14	Female n = 14	LSD
Live mass (kg)	NE	137.55	139.98	17.35	151.15a	68.57a	24.29	138.41	139.06	17.43
Carcass mass (kg)	NE	70.52	73.81	10.87	78.34a	37.20b	15.22	73.79	70.84	10.93
Dressing (%)	NE	51.35	52.76	2.16	SI	SI	.	SI	SI	.
Length (cm)	NE	113.71	112.89	4.22	SI	SI	.	SI	SI	.
Width (cm)	NE	34.87	33.78	3.73	36.03a	24.67b	5.23	34.33	34.32	3.75
Depth (cm)	NE	47.21	48.23	2.76	49.25a	39.03b	3.86	47.54	47.86	2.77
Chest circumference (cm)	NE	122.16	122.35	3.58	SI	SI	.	SI	SI	.
Leg circumference (cm)	NE	73.6	77.88	7.21	78.03a	62.77b	10.09	74.52	76.74	7.24
Leg length (cm)	NE	65.32b	72.83a	4.08	71.12a	57.47b	5.71	71.11	67.41	4.10

LSD, Least Significant Difference

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

NE, Not Executed

SI, Significant Interaction between main effects, $P \leq 0.05$

Table 4

Age x Sex interactions between the dressing percentage, carcass length and chest circumference of the MLD of black wildebeest harvested at Maria Moroka Nature Reserve

	Adult Male n = 10	Adult Female n = 7	Young Male n = 2	Young Female n = 1	LSD	*P*
Dressing (%)	53.09^{ab}	50.65^{b}	53.60^{ab}	55.71^{a}	3.35	0.05
Length (cm)	119.84^{a}	115.75^{a}	89.35^{b}	90.90^{b}	8.81	0.03
Chest circumference (cm)	131.14^{a}	124.63^{a}	94.70^{b}	91.40^{b}	7.48	0.01

LSD, Least Significant Difference, P=0.05

$^{a-b}$ Means, in rows, with different superscript letters are significantly different, $P \leq 0.05$

spring was significantly ($P \leq 0.01$) lighter compared to the animals harvested during the other seasons (Kroon, Van Rensburg & Hofmeyr, 1972). Although the adult females in the present study had a heavier live mass, they had a lighter cold carcass mass than the adult males. The fact that the adult females were pregnant and the mass of the fetuses were included in the live weight caused a significant interaction ($P \leq 0.05$) between the animal sex and age for the dressing percentage (Table 4). The mean dressing percentage (irrespective of season, age and sex) for the black wildebeest (52.05% ± 1.66) compared favourably with other wild ungulates like blesbok (*Damaliscus dorcas phillipsi*) with a dressing percentage of 52.90% (Huntley, 1971). The significant interaction ($P \leq 0.05$) for the dressing percentage between the adult females and young females could either be ascribed to the adult females being pregnant, or to a sampling factor, because the sub-group of the young females consisted only of one animal. There were also significant interactions between the carcass length ($P \leq 0.03$) and chest circumferences ($P \leq 0.01$), where the young males and young females were significantly smaller than the adult males and adult females. It is generally accepted that an increase in animal age causes an increase in animal size, and that males are larger than females (Lawrie, 1985). The significant differences ($P \leq 0.05$) in live and carcass mass, as well as the morphological measurements between the age groups and the size differences between the males and females were as expected. The sampling factor, caused by the harvesting methodology, caused the females to be larger than the males for most of the morphological measurements taken, although it is known that black wildebeest males are larger than the females (Skinner & Smithers, 1990).

Physical characteristics

In the present investigation there were no interactions between the main effects and physical characteristics studied, therefore only the significant differences and, where applicable, the tendencies of the main effects will be discussed. The mean values for the physical meat quality parameters between the seasons, age groups and male and female black wildebeest are illustrated in Table 5.

In the present study the animals harvested during the colder months, winter and autumn, as well as the black wildebeest bulls (males) had significant higher ($P \leq 0.05$) mean pH_{45}. Similar results were obtained by Hoffman (2000) in a study on impala (*Aepyceros melampus*), where the male impala had a significantly higher ($P \leq 0.05$) pH_{45} compared to the female impala. In the present investigation the temperature measured at 24 h post-mortem differed significantly ($P \leq 0.05$) between the seasons, as well as the age groups. These temperature differences were most probably due to the different ambient temperatures, indicating potential differences in the chilling rates. The pH_{24} values were significantly lower ($P \leq 0.05$) during the winter or colder months. Kim *et al.* (2003) likewise observed the seasonal differences in pH_{24}, where the warmer months caused higher ultimate pH values. The effect of season on the physical qualities of the meat was also illustrated in the different ambient temperatures causing the animals harvested during the autumn to have a significantly higher ultimate temperature than the animals in spring, which in turn was significantly higher than that of the animals harvested in winter. The significant differences subsequently caused significant differences between the water-holding capacity of the meat, illustrated through the drip loss and cooking loss, and may well be attributed to protein denaturation and the effect of the post-mortem pH/temperature ratio thereof (Guignot, Vignon & Monin, 1994). Numerous studies, such as that of Onyango, Izumimoto and Kutima (1998) on selected game meats, have found relations between an increased pH, which causes an increase in the WHC of the meat. Similar findings were present in this study. The differences in drip loss between the male and female black wildebeest were similar to those of Diaz *et al.* (2003), who also found that WHC was lower in females compared to males. The animals harvested during winter and spring were significantly tougher than the animals harvested in autumn. Carcasses may have undergone cold-shortening or cold-toughening upon subjection to the colder ambient temperatures during the winter and spring, directly after slaughter. The differences in drip loss can also be as a result of the cooling rate of the carcass, where the decline in temperature in smaller carcasses is more rapid than that of larger carcasses. The differences between the shear values of the two age groups can be ascribed to collagen solubility, where the collagen cross-links become less soluble with increased animal age (Bailey, 1990). The significantly higher ($P \leq 0.05$) shear force value of the males (3.37 kg/1.27 cm F ± 0.24) could possibly be as a result of the slightly higher ultimate pH of 5.53. This result was similar to findings on beef carcasses by Jeremiah, Tong and Gibson (1990). Shear force or meat tenderness is greatly influenced by the rate of carcass temperature decrease during the onset of rigor mortis and the first 24 h post-mortem. During this study the ultimate temperature significantly influenced the tenderness of the meat. The mean shear value during the winter was 3.58 kg/1.27 cm F (± 0.35) with an ultimate temperature of 2.08°C (± 0.19), compared to autumn with a mean shear value of 2.38 kg/1.27 cm F (± 0.15) and ultimate temperature of 21.08°C (± 0.31). This clearly indicates that with higher ultimate temperatures the meat tenderness increases.

Table 5

Meat quality parameters between the seasons, different age groups and male and female black wildebeest

	Season				Age			Sex		
	Winter n = 8	Spring n = 10	Autumn n = 10	LSD	Adult n = 25	Young n = 3	LSD	Male n = 14	Female n = 14	LSD
pH_{45}	6.72[a]	6.06[b]	6.63[a]	0.31	6.61	6.59	0.33	6.61[a]	6.59[b]	0.20
$Temperature_{45}$ (°C)	37.65	36.80	37.21	2.48	37.40	36.95	2.84	37.69	37.05	1.62
pH_{24}	5.37[b]	5.54[a]	5.54[a]	0.11	5.48	5.57	0.15	5.53	5.46	0.09
$Temperature_{24}$ (°C)	2.80[c]	7.30[b]	21.05[a]	0.89	10.28[b]	16.30[a]	1.13	9.52[b]	12.33[a]	2.10
Drip loss (%)	2.38[b]	5.45[a]	3.30[b]	1.78	3.85	3.41	2.27	4.06	3.55	1.45
Cooking loss (%)	34.71[b]	39.69[a]	33.44[b]	1.95	36.16	35.03	2.48	36.41	35.66	1.58
Shear force (kg/1.27 cm F)	3.58[a]	3.42[a]	2.38[b]	0.62	3.13	2.77	0.81	3.37[a]	2.82[b]	0.50
L* value	29.00[b]	35.24[a]	33.12[a]	2.97	32.03[b]	38.24[a]	3.78	32.96	32.42	2.41
a* value	13.65[ab]	14.43[a]	12.98[b]	1.43	13.75	13.17	1.83	13.74	13.64	1.16
b* value	8.55	7.88	6.61	1.96	7.52	8.41	2.56	8.07	7.16	1.59
Hue angle (°)	32.78[a]	28.85[ab]	26.34[b]	4.66	28.55	33.41	6.14	29.66	28.49	3.79
Chroma	16.25[ab]	16.55[a]	14.67[b]	1.84	15.80	15.78	2.35	16.09	15.50	1.50

LSD, Least Significant Difference

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

NE, Not Executed

In the present study season also greatly influenced the meat colour. There were significant differences ($P \leq 0.05$) between the seasons for the L*, a*, hue angle and chroma values, where the animals harvested during spring had the darkest meat colour. According to Kim *et al.* (2003), in a study of the effect of season on the colour of Korean native cattle, a* and chroma values are high during autumn and b* and hue angle values low during winter. Although they were not significant, there were tendencies between the ultimate pH and L*; a* and chroma as well as b* and hue angle values were present. These trends are similar to those noted by Kim *et al* (2003). The L* values were darker during the winter and colder months than during spring and autumn, likewise observed by Kim *et al.* (2003).

Proximate chemical composition

The mean proximate chemical composition of the black wildebeest harvested at Maria Moroka is presented in Table 6. The season x sex interactions for the protein and fat percentages are presented in Table 7. There were no correlations or significant differences between the adult and sub-adult black wildebeest, indicating few differences in the proximate composition of the MLD between different age groups. In the present study the moisture content of the animals harvested during autumn was significantly lower ($P \leq 0.05$) than the content in winter and spring. The significant interaction ($P=0.03$) for the protein content between season and sex indicated that the males and females harvested in spring had a lower protein content. This could be ascribed to the fact that the animals had not stored sufficient energy (as fat) to last throughout the winter, causing the body tissues to catabolise protein to survive the period of low food intake. In a study on common eland bulls (*Taurotragus oryx*) Von La Chevallerie, Erasmus, Skinner and Van Zyl (1971) found that the condition of the eland was at its lowest in early spring. The significant season x sex interaction ($P=0.03$) in the fat content indicated that the females harvested during the winter had the highest content of fat. A study by Kroon, Van Rensburg and Hofmeyr (1972) on changes in the seasonal composition of adult male blesbok (*Damaliscus dorcas phillipsi*) revealed that the most important seasonal changes were associated with an increase in fat content from 2.09% during the spring to 7.80% during autumn. In this study the females had a significantly higher fat content than the males. Similar findings of a decrease in total fat content in males due to the rutting season were reported by Stevenson, Seman and Littlejohn (1992) and Hoffman (2000). The black wildebeest meat had a slightly higher mean protein content (23.97%) than farmed venison steak (22.50%), beef (17.60%) and lamb (17.90%), according to a study by Aidoo and Haworth (1995). Although the venison in the latter study had a lower fat content (0.70%) than the mean 0.99% in the present study, the black wildebeest still had an extremely low fat percentage when compared to domestic species such as beef (7.90%) and lamb (9.10%) (Aidoo & Haworth, 1995). No significant differences ($P>0.05$) were found in the ash content between any of the main effects investigated. The above results confirm that game meat species, such as black wildebeest,

Table 6

Mean values of the meat quality parameters between different years, age groups and male and female black wildebeest

	Season				Age			Sex		
	Winter n = 8	Spring n = 10	Autumn n = 10	LSD	Adult n = 25	Young n = 3	LSD	Male n = 14	Female n = 14	LSD
Moisture (%)	75.89[a]	75.26[a]	74.15[b]	1.00	75.17	73.95	1.28	75.13	74.96	0.81
Protein (%)	SI	SI	SI	.	22.90	22.82	1.07	SI	SI	.
Fat (%)	SI	SI	SI	.	1.03	0.95	0.27	SI	SI	.
Ash (%)	1.27	1.27	1.41	0.23	1.32	1.27	0.30	1.26	1.38	2.09

LSD, Least Significant Difference, P=0.05

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

SI, Significant Interaction

Table 7

Season x sex interactions for the protein and fat percentage of the MLD from black wildebeest

	Winter Male n = 5	Winter Female n = 3	Spring Male n = 5	Spring Female n = 5	Autumn Male n = 4	Autumn Female N = 6	LSD	P
Protein (%)	24.31[a]	24.01[a]	19.36[b]	21.09[b]	24.98[a]	24.19[a]	1.17	0.03
Fat (%)	0.98[b]	1.56[a]	0.89[b]	1.02[b]	0.94[b]	0.96[b]	0.29	0.03

LSD, Least Significant Difference

have a lower total fat and higher protein content than domestic meat types, such as beef, mutton and pork.

Conclusion

The results of this study suggest the differences in meat yield, physical characteristics as well as the chemical composition of black wildebeest meat, with a decrease in carcass weight as well as protein and fat content during the winter. The effect of age on the morphological yield, physical properties and chemical composition was restricted to the morphological sizes and lightness of the meat colour, therefore indicating only minor differences due to an age effect. The higher pH and lower fat content of the males due to the rutting season indicated the severe stress experienced by the males during this period. Game meat should be marketed as lean meat. In the present investigation there were significant differences in fat content between seasons; however, these differences did not differ to such an extent that the meat needs to be classified differently.

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CHAPTER 6

THE EFFECT OF AGE AND SEX ON THE QUALITY CHARACTERISTICS OF BLUE WILDEBEEST (*CONNOCHAETES TAURINUS*) MEAT

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Abstract

A total of fifteen blue wildebeest were collected at Sandveld Nature Reserve during 2001 and 2003. The effect of the different years (2001 and 2003), age groups and sex on the physical and proximate chemical composition was investigated. The blue wildebeest had a mean dressing percentage of 51% ± 0.76. There were tendencies ($P>0.05$) towards inverse relations between the ultimate pH and drip loss, cooking loss and meat tenderness for all three main effects investigated. Different ambient temperatures between the years caused significant differences ($P\leq0.05$) in ultimate temperature, with the mean carcass temperature of 2001 (5.58°C ± 0.33) being significantly lower than 2003 (12.40°C ± 0.14). No significant differences ($P>0.05$) between years, ages groups or sexes in the proximate composition of the *M. longissimus dorsi et lumborum* were noted. Like other wild ungulates, blue wildebeest meat has a higher protein (22.99% ± 0.29) and lower fat (1.34% ± 0.12) content compared to beef, which makes it a healthy alternative to traditional red meat.

Keywords: carcass yield, physical parameters, proximate chemical composition, game meat

Introduction

In an attempt to conserve Africa's biological diversity and wildlife estates, concerted attention should be given to sustain the optimum use of the mammal resources. Many landowners are currently attempting to maximize economic returns by utilizing the mammal populations for trophy hunting and meat production, and to exploit tourism opportunities (Hearne, Lamberson & Goodman, 1996). According to Berry (1986), game meat production is the most profitable strategy and is, therefore, playing an increasingly important role in the financial viability of game farms. Indigenous animals are well adapted to the available food and different environmental factors affecting normal growth and development (Cole, 1990). In general, they have lower nutritional requirements and are more resistant to diseases and parasites and exhibit a higher yield of meat than domestic species (Von La Chevallerei, 1971). Limited

research has been done on the factors that influence the nutritional value of the game meat (Hoffman, 2000).

Von La Chevallerie (1971) states that the carcass weight gives a good indication of the meat production potential of an animal. The blue wildebeest, also known as the brindled gnu, is one of the largest bushveld mammal species in South Africa. The males have a shoulder height of 1.30 m to 1.50 m and weigh between 210 kg and 260 kg, while the females are 1.22 m to 1.35 m high and weigh between 170 kg and 200 kg (Furstenburg, 2002). Blue wildebeest are widely distributed throughout South Africa, which makes it possible to meet production demands, especially with an annual population increase of 28% to 33% (Furstenburg, 2002). During droughts blue wildebeest are predisposed towards migration, because of responses to water availability and forage quality and quantity (Brooks, 1982). This increases their survival rates. The low mortality rates during unfavourable environmental conditions, distribution, as well as their size make blue wildebeest an excellent source of game meat for production purposes.

According to Stevenson, Seman and Littlejohn (1992), the factors that are thought to influence the nutritional value of meat, such as age and sex, have not yet been studied extensively in game meat. None of these factors have been studied for most of southern Africa's ungulates. This study will therefore determine the carcass yield and physical and chemical composition, as well as investigate possible differences between different age groups, and male and female blue wildebeest harvested at Sandveld Nature Reserve, South Africa.

Materials and Methods

Animals

This study included a total of fifteen blue wildebeest (*Connochaetus taurinus*) collected at Sandveld Nature Reserve, in the Free State province, South Africa. Sandveld Nature Reserve encompasses the northwest area of the large peninsula created by the Bloemhof Dam in the north-western Free State (*Reader's Digest*, 1983). This 14 700 ha reserve is characterised by a grassy ground layer and a distinct upper layer of woody plants (Low & Rebelo, 1998). Due to the culling procedures the 15 animals consisted of six wildebeest collected in 2001 and nine collected in 2003. Table 1 illustrates the lay-out of age and sex according to the different years when the animals were harvested. The age was estimated on the basis of tooth eruption and wear, as well as horn size and length. Only the non-trophy males were culled; the larger or trophy bulls are sold as part of hunting packages and licenses at auctions to local or overseas hunters. Adult refers to a reproductive animal, while sub-adults refer to young animals and calves that have not been weaned.

Table 1

The distribution of the age groups and sex according to the year when the blue wildebeest were sampled at Sandveld Nature Reserve

	Year						
	2001			2003			
	Adult	Sub-adult	Calf	Adult	Sub-adult	Calf	Total
Male	0	3	0	0	1	1	5
Female	1	2	0	4	3	0	10
Total	1	5	0	4	4	1	15

Harvesting

The culling at Sandveld Nature Reserve was done during the day. Two hunting vehicles drove to opposite ends of the herd of blue wildebeest, creating an angle to trap the wildebeest. The huntsmen aimed for the head or upper neck, as this method causes the least damage to and wastage of the carcass (Von La Chevallerie & Van Zyl, 1971), using either a .270 calibre or .243 calibre rifle fitted with telescopic sights and using high-velocity bullets.

The cropped animals were exsanguinated, approximately 2 min after shooting, by cutting the throat and then loaded onto the back of the culling vehicle. After the targeted number of animals had been harvested, they were taken to the reserve's skinning shed. Live mass was recorded on the hot carcasses after being bled, approximately 60 min post-mortem. The animals were then eviscerated, skinned and cleaned, and the head, gut and other edible and non-edible parts of the body were subsequently removed. These included the kidneys, liver, lungs, internal fat as well as the leg from the hoof to the knee. The dressed carcass was moved into the cooling facility approximately 18 h post-mortem. The cold carcasses were weighed, 24 h post-mortem, and the dressing percentage calculated.

Morphological measurements

Due to various extraneous reasons and the nature of experimental fieldwork, it was not possible to weigh every animal, and weight data are consequently limited to the animals harvested in 2003. The morphological measurements to obtain the length, width and depth of the carcass as well as carcass circumferences were also taken on the cold eviscerated carcasses. The carcass length was measured from the base of the neck to the base of the tail at the juncture of the pelvis. The depth of the carcass was measured from the spine to the sternum, just posterior to the forelegs, while the width of the carcass was measured between the widest points of the rib cage just posterior to the forelegs. The circumferences included the maximum chest circumference and the leg (buttock) circumference. The length of the leg was measured from the base of the leg to the end. The chest circumference was measured around the chest also posterior to the forelegs and the leg circumference at the top of the leg at the juncture with the abdomen, posterior to the thigh. The carcass length, width and depth

were taken with a steel slide yardstick, while the circumferences were taken with a standard tape measure.

Physical measurements

Forty-five minutes post-mortem the initial muscle pH (pH_{45}) and temperature were taken and after 24 h the ultimate pH (pH_{24}) and temperature were measured. These measurements were taken on the *M. longissimus dorsi et lumborum* (MLD) between the 4th and 5th lumbar vertebrae counting from the caudal end. The pH was measured with a penetrating glass electrode on a hand-held Crison pH/mV-506 meter. The pH meter consisted of an automatic temperature compensator to ensure the adjustment of the pH for temperature. The pH meter was calibrated after every four readings with pH 4.01 and pH 7.02 buffers and cleaned with distilled water after every reading.

For the physical and chemical analyses, both the MLD were removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra, and trimmed of all visible subcutaneous fat. For the determination of the drip loss, 1.0 cm thick meat samples weighing ca. 30 g, cut perpendicular to the longitudinal axis of the muscle on the caudal side of the MLD, were weighed. The samples were placed in netting and suspended in an inflated plastic bag. After a storage period of 24 h at 4°C, the samples were blotted with absorbent paper, weighed again and the drip loss was calculated as weight loss expressed as a percentage of the original mass of the sample (Honikel, 1998). For the cooking loss determination, freshly cut MLD samples (1.0 cm thick) were weighed and placed in thin-walled plastic bags in a water-bath at 80°C. After 1 h the samples were removed from the water-bath, cooled in cold water, blotted dry and weighed. Cooking loss was calculated as the difference in sample weight before and after cooking, expressed as a percentage of the initial sample weight (Honikel, 1998).

Three cylindrical cores were cut from each cooked sample (after determining cooking loss) using a 1.27 mm diameter bore. Samples were randomly removed from the centre of each MLD. Maximum Warner Bratzler shear force values required to shear a cylindrical core of cooked muscle, perpendicular to the longitudinal orientation of the muscle fibres at a crosshead speed of 299 mm/min, were recorded for each sample and the mean was calculated for each muscle. A larger value indicates greater shear force and therefore tougher meat (Honikel, 1998).

The remaining lean meat samples were homogenised, placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further analyses could be carried out.

Proximate chemical analysis

Proximate analysis was conducted on the MLD samples. After removing the subcutaneous fat and superficial connective tissue, the frozen muscle samples were cut into smaller portions, minced three times through a 2 mm sieve to ensure homogeneity and analysed chemically. Total percentage moisture, protein and ash were determined according to standard AOAC methods (AOAC, 1997). The moisture content was analysed by drying a 2.5 g sample at 100°C for a period of 24 h. The protein (N x 6.25) content was determined by the block digestion method (AOAC, 1997), while ashing was done at 500°C for a period of 5 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee, Trevino & Chaiyawat, 1996).

Statistical analysis

A three-factor factorial experiment was performed in a completely randomised design with unequal number of random replications. The factors were two years (2001 and 2003), three age groups (adult, sub-adult and calf) and two sexes (male and female). 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, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998). Correlations were made using the Pearson product moment correlation coeffisient.

Results and Discussion

In the present investigation there were no interactions between the main effects and factors studied; therefore, only the significant differences, where $P \leq 0.05$, and, where applicable, tendencies ($P > 0.05$) towards differences of the main effects will be discussed.

Morphological attributes

Due to the nature of the culling procedures there is an uneven distribution between the main effects, especially the sex groups. The skew distribution between the male and female blue wildebeest was due to the fact that none of the larger or trophy bulls were harvested; this extraneous factor affected the morphological measurements and yield. Table 2 illustrates the mean mass and morphological sizes of the blue wildebeest harvested during 2003 at Sandveld Nature Reserve. The significant differences between the male and female blue wildebeest live and carcass mass can be ascribed to the fact that the sample size consisted of non-trophy males and can also be due to the uneven distribution of age groups as a result of the culling techniques. The sample size included one male calf and one male sub-adult compared to three sub-adult females and four adult females. It is known that males - particularly mature, adult males - are heavier and larger than the females (Skinner & Smithers, 1990). The differences in the dressing percentage between the male and female

blue wildebeest are also due to the sample bias and the fact that the males generally take longer than the females to attain asymptotic values as a result of sexual dimorphism (Attwell, 1982). Body mass gain in females during the first year is greater than in males, but in subsequent years the increase in the mass of males exceeds that of the females. In a comparative study between male and female blue wildebeest Attwell (1982) found the mean blue wildebeest mass to be 174.1 kg. The mean live mass of the blue wildebeest in this study was 157.6 kg (± 14.88); although this is lower than that reported by Attwell (1982), it must be borne in mind that none of the larger bulls were harvested at Sandveld Nature Reserve, and the sample size in the present study included nine sub-adult animals and a calf.

Table 2

The mean weights and morphological sizes of the blue wildebeest harvested during 2003 at Sandveld Nature Reserve

	Age				Sex		
	Adult n = 4	Sub-adult n = 4	Calf n = 1	LSD	Male n = 2	Female n = 7	LSD
Live mass (kg)	209.48[a]	130.68[a]	114.10[b]	28.56	127.28[b]	174.31[a]	22.90
Carcass mass (kg)	109.55[a]	66.75[b]	58.00[b]	19.21	62.95[b]	91.04[a]	15.40
Dressing (%)	52.28	51.16	50.83	6.04	49.60	52.19	4.84
Length (cm)	117.53[a]	112.18[ab]	98.10[b]	15.60	108.30	114.33	12.51
Width (cm)	35.55	34.63	31.30	9.93	33.40	35.03	7.96
Depth (cm)	58.25[a]	47.10[b]	50.90[ab]	9.56	48.95	53.49	7.66
Chest circumference (cm)	157.68[a]	125.45[b]	122.10[b]	19.61	124.00[b]	143.80[a]	15.73
Leg circumference (cm)	83.43	75.88	74.90	39.73	75.65	80.11	31.85
Leg length (cm)	69.15[a]	60.05[b]	63.20[ab]	7.31	62.65	64.96	5.86

LSD, Least Significant Difference, P=0.05

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

Attwell (1982) calculated theoretically that the chest girth of a calf gives a reliable indication of the body mass, according to the following relationship, $M = 1.90\ CG - 118.76$ (r = 0.9998; $P \leq 0.001$), where M = mass in kg, and CG = Chest girth in cm. In the present study, using the same theoretical formula given by Attwell (1982), the calculated live mass of the calf would be 113.20 kg. As seen above, the actual live mass of the calf was 114.10 kg, indicating a 99.20% accurate prediction. According to Attwell (1982), the calculation is less accurate for older animals. This is because the physical activity of the animal is at its highest during the first year of life, after which it tapers off rapidly, particularly in females. Keeping this in mind, it can be presumed that the male adult blue wildebeest will have a larger dressing percentage than that of the females, if the sample size included male adults. In the present study the mean dressing percentage of 51.60% (± 0.76) was lower than the 54.80% reported by Atwell (1982) of blue wildebeest harvested during 1973 and 1974 at Hluhluwe Game Reserve, Kwazulu Natal, South Africa. The higher dressing percentage of Attwell (1982) might well be due to different dressing techniques during slaughtering. The optimal age to harvest blue

wildebeest, according to the logarithmic increase in animal size, would be approximately one year.

Physical characteristics

Table 3 illustrates the means for the three main effects investigated for the physical characteristics studied. There were no significant differences ($P>0.05$) between the three main effects investigated for the initial pH and temperature. In the present study the calf had a significantly lower ($P\leq0.05$) pH_{24} compared to the adults and sub-adults. The relationship between pH and temperature is well known, and these two parameters are closely related and dependent upon the other. The lower pH_{24} of the calf can, therefore, either be ascribed to the higher carcass temperature taken 24 h post-mortem or due to a sampling effect. The significant differences ($P\leq0.05$) in the ultimate temperatures between 2001 and 2003 are due to different ambient temperatures, causing different chilling rates. The significant differences ($P\leq0.05$) in $temperatures_{24}$ between 2001 and 2003 consequently caused significant differences ($P\leq0.05$) between the age groups and male and female black wildebeest, as well as a significantly higher ($P\leq0.05$) percentage of cooking loss and tendency ($P>0.05$) toward a higher percentage drip loss during 2003. This indicated that in the present study there was a tendency towards an inverse relation between pH_{24} and the drip loss ($r = -0.65$; $P = 0.06$) and cooking loss ($r = -0.58$; $P = 0.08$), and a slight correlation ($P>0.05$) between the temperature and drip loss ($r = 0.54$; $P = 0.08$) and cooking loss ($r = 0.60$; $P = 0.07$) for all the three main effects investigated. A large number of authors, such as Onyango, Izumimoto and Kutima (1998), have made similar observations; in example, an increase in the pH_{24} causes a decrease in the water-holding capacity (WHC) and an increase in $temperature_{24}$ causes an decrease in the WHC of the meat. Therefore, a decrease in pH_{24} and an increase in $temperature_{24}$ caused more fluid to be exudated. Although not significant, the meat tenderness also tended ($P>0.05$) to be inversely related to the pH_{24} ($r = -0.49$; $P = 0.09$), and related to the $temperature_{24}$ ($r = 0.51$; $P = 0.09$) for all three main effects investigated. Shear force or meat tenderness is greatly influenced by the ultimate pH as well as the decline in carcass temperature during the onset of rigor mortis and for the first 24 h post-mortem. According to Dransfield, Jones and MacFie (1981), temperature has the greatest influence on the rate of tenderising, especially the variation in the rate of temperature decline (in the range of 0°C to 20°C). In the present investigation there were, however, no significant differences ($P>0.05$) between the three main effects for the maximum shear force.

Proximate chemical composition

The proximate composition of the MLD muscle, obtained from the meat samples of 2001 and 2003, the different age groups and male and female blue wildebeest are given in Table 4.

Table 3
Mean physical characteristic investigated, for 2001 and 2003, male and female and different age groups of blue wildebeest

	Year			Age				Sex		
	2001 n = 6	2003 n = 9	LSD	Adult n = 5	Sub-adult n = 9	Calf n = 1	LSD	Male n = 5	Female n = 10	LSD
pH_{45}	6.32	6.59	0.61	6.62	6.41	6.52	1.07	6.25	6.60	0.63
$Temperature_{45}$ (°C)	34.68	36.13	2.07	36.12	35.29	35.10	3.67	34.72	35.97	2.15
pH_{24}	5.42	5.40	0.07	5.41^{a}	5.41^{a}	5.28^{b}	0.13	5.43	5.39	0.08
$Temperature_{24}$ (°C)	5.58^{b}	12.40^{a}	0.62	11.18^{b}	8.43^{c}	13.30^{a}	1.16	8.38^{b}	10.32^{a}	0.68
Drip loss (%)	3.55	4.10	1.76	3.68	3.92	4.51	8.22	4.39	3.63	1.83
Cooking loss (%)	33.43^{b}	39.42^{a}	4.63	37.37	36.57	39.35	3.12	36.32	37.37	4.81
Shear force (kg/1.27cm F)	3.65	4.77	1.19	4.66	4.20	3.68	2.10	3.77	4.60	1.23

LSD, Least Significant Difference, P=0.05

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

Table 4
Mean proximate composition of the MLD from the blue wildebeest harvested during 2001 and 2003 according to their age and sex

	Year			Age				Sex		
	2001 n = 6	2003 n = 9	LSD	Adult n = 5	Sub-adult n = 9	Calf	LSD	Male n = 5	Female n = 10	LSD
Moisture (%)	74.69	76.56	1.32	75.89	76.17	74.77	1.55	75.55	75.99	1.24
Protein (%)	23.91	22.38	1.45	23.43	22.73	23.18	3.18	23.31	22.83	1.86
Fat (%)	1.69	1.10	0.73	1.47	1.26	1.44	1.30	1.26	1.38	0.76
Ash (%)	1.27	1.27	1.41	0.23	1.32	1.27	0.30	1.26	1.38	2.09

LSD, Least Significant Difference, P=0.05

Knowledge of the chemical composition of game is of great importance, not only to determine the energy flow in eco-systems but also in calculating its contribution in comparison to meat derived from domestic species (Kroon, Van Rensburg & Hofmeyr, 1972). The results on the proximate composition of blue wildebeest MLD showed no significant differences between any of the main effects studied. The moisture content tended ($P>0.05$) to be higher for the females, sub-adults and animals harvested in 2003. Dawood and Alkanhal (1995) found a correlation between low moisture content and higher fat content in a study on najdi-camels. In the present study the lower moisture content of 74.69% (± 0.25) in 2001, compared to the higher moisture content of 76.56% (± 0.22) in 2003, tended ($P>0.05$) to have a similar relationship with the higher fat content of 2001 being 1.69% (± 0.25) and the lower fat content of 1.10% (± 0.23) in 2003. The same pattern was found between the different age groups, since the calf had the lower moisture content of 74.77% and the higher fat content of 1.44%, compared to the sub–adult, which had 76.17% (± 0.38) moisture and 1.26% (± 0.15) fat. The fat content did not differ significantly between the sexes, although the females tended ($P>0.05$) to have a slightly higher percentage of fat. The same results were obtained by Hoffman (2000) in a study on impala (*Aepyceros melampus*), where the females had a significantly higher fat content than the males. The low fat content, combined with the high protein content in the present investigation, is confirmed in other studies on wild ungulates, such as that of Onyango *et al.* (1998) in their comparative study on selected game meats. These findings, in particular that of a lower fat content, can be beneficial in the marketing of blue wildebeest meat, especially as a healthier alternative to other red meats.

Conclusion

The present results indicate that the dressing percentage of the blue wildebeest might be dependent on the combination of age and animal sex, due to the increase of animal size and progressive development of the sexual dimorphism, but the sample size in the present investigation was biased; therefore, not enough data were available to quantify this observation. The differences in the physical characteristics of the MLD between the main effects were only significant for the temperature taken 24 h post-mortem. Higher temperatures subsequently caused higher percentages of cooking loss. The differences in the proximate chemical composition between the years, age groups and sex were slight and the mean values can therefore be used as a baseline reference for different age groups and male and female blue wildebeest meat. Similar to meat derived from other wild ungulates, the blue wildebeest has a high protein content and low intramuscular fat content.

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CHAPTER 7

THE YIELD AND CHEMICAL PROPERTIES OF MALE AND FEMALE MOUNTAIN REEDBUCK (*REDUNCA FULVORUFULA*) MEAT

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Abstract

This investigation was undertaken to determine the differences in yield and proximate chemical composition between male and female mountain reedbuck. The mean live weights of ten male and nineteen female mountain reedbuck did not differ statistically; they were 28.58 kg ± 5.69 and 30.58 kg ± 4.88 respectively, while the mean cold carcass mass was 16.36 kg (± 0.48) for both sexes. Although, the dressing percentage did not differ significantly, it was higher for the male (56.03% ± 1.43) than for the female (54.96% ± 1.16) mountain reedbuck. The morphological measurements indicated no significant differences ($P>0.05$) between the size of male and female mountain reedbuck. For the proximate chemical analysis of the *M. longissimus dorsi et lumborum* muscle, the effect of animal sex was only significant for the protein content, where the females (24.51% ± 0.20) displayed a higher percentage of protein compared to the males (23.68% ± 0.22). Glutamic acid (11.35 g/100 g ± 0.45) was the most abundant amino acid, followed by aspartic acid (2.94 g/100 g ± 0.33), glycine (0.86 g/100 g ± 0.18) and serine (0.66 g/100 g ± 0.26). The mineral content of mountain reedbuck indicated the meat derived from this species to be high in phosphorus (206.47 mg/100 g ± 11.32), high in iron (4.19 mg/100 g ± 0.51), a source of zinc (1.80 mg/100 g ± 0.09) and low in sodium (4.19 mg/100 g ± 0.74). Neither the amino acid nor the mineral content differed significantly between the two sexes.

Keywords: game meat, yield, proximate chemical composition, amino acids, minerals

Introduction

An annual increase in the human population worldwide and the consequent increase in food demand is leading to a decrease in the per capita food supply and resources available. Concern for the survival of the rich diversity of South Africa is tempered by a lack of knowledge about the optimum sustained use of our mammal resources. The utilisation of South African game species has the potential of utilisation of wildlife by providing an economic enticement to conserve it. This involves regulated seasonal harvesting of the animals to sustain and maintain optimal animal populations, thereby not only matching the

carrying capacity of the vegetation available, but also ensuring the restoration of the vegetation, where necessary. Unlike domestic species, native game animals do not destroy the vulnerable grass cover in the marginal areas and they are also better adapted to utilising the limited water and food supplies efficiently (Cole, 1990). But limited data have been reported on the yield and chemical composition of the different African ungulates. This emphasizes the definite need for more information and standard regulations guiding both environmentalists and game farmers on how to exploit the production possibilities of the South African wild ungulates, not only to generate comparisons between the meat production of indigenous ungulates with those of domestic animals, but also to create a market of its own.

The mountain reedbuck (*Redunca fulvorufula*) is a medium-sized antelope, with the adult males standing about 0.76 m at the shoulder and weighing between 24 kg and 36 kg, while the females have a shoulder height of 0.70 m and weigh between 18 kg and 34 kg (Furstenburg, 1999). They are grazers that specialize in selecting young green shoots, when available. They are most active during the early mornings, late afternoons and at night, while they rest in the cover of bushes in the late mornings and early afternoons (Skinner & Smithers, 1990). Mating can take place throughout the year, peaking in autumn (April/May) (Skinner & Smithers, 1990). A single lamb is usually born in early summer (October to January) (Hes & Mills, 1997), after a gestation period of eight months (236 to 251 days), with a mass of approximately 3 kg, although some are born at other times of the year. The growth curve, low mortality rates and lifespan of mountain reedbuck make it an excellent species suitable for sustainable harvesting. The object of this investigation is thus to present carcass data, as well as the physical and chemical characteristics on the meat of mountain reedbuck kept under free-range conditions in their natural habitat at Tussen die Riviere Nature Reserve, South Africa.

Materials and Methods

Animals

A total of 29 mountain reedbuck were harvested at Tussen die Riviere Nature Reserve during 2002. The sample size comprised 19 adult females and ten non-trophy males (the larger or trophy rams were sold as part of hunting packages and to local or international hunters; therefore none of the larger rams were culled). Seven of the females included in the sample size were pregnant and two were lactating. Tussen die Riviere Nature Reserve near Bethulie, in the Free State Province, South Africa, is a 21 000 ha game farm where the Caledon and Orange Rivers converge to create a flood plain surrounded by high rocky ridges with occasional plateaus and lower-lying grassy plains (Low & Rebelo, 1998).

Harvesting

The culling at Tussen die Riviere Nature Reserve was conducted at night. The animals were culled according to the method described by Lewis, Pinchin and Kestin (1997), which consists of driving slowly with four-wheel drive vehicles, immobilizing the animals with spotlights and then shooting them. Shooting of the animals was done using a .270 calibre rifle fitted with a telescopic sight and using high-velocity bullets. The huntsman aimed for the head or upper neck, as this method causes the least damage to and wastage of the carcass (Von La Chevallerie & Van Zyl, 1971). The animals were exsanguinated with sharp knives immediately after death and then hung onto the hunting vehicle. The hunting vehicles had been especially adapted for culling, with frames constructed on both sides with hooks to suspend smaller antelope species such as mountain reedbuck by their Achilles tendon.

After the targeted number of animals had been harvested, they were taken to the reserve's skinning shed. Live mass was recorded on the hot carcasses after being bled, approximately 60 min post-mortem. The animals were then eviscerated, skinned and cleaned, followed by the subsequent removal of the head, gut and other edible and non-edible parts of the body. This included the kidneys, liver, lungs, internal fat as well as the leg from the hoof to the knee. The skinned carcasses at Tussen die Riviere were moved into a cooling room (set at 4°C), approximately 18 h post-mortem.

Morphological measurements

The morphological measurements to obtain the length, width and depth of the carcass as well as carcass circumferences were also taken on the cold eviscerated carcasses. The carcass length was measured from the base of the neck to the base of the tail at the juncture of the pelvis. The depth of the carcass was measured from the spine to the sternum, just posterior to the forelegs, while the width of the carcass was measured between the widest points of the rib cage just posterior to the forelegs. The circumferences included the maximum chest circumference and the leg (buttock) circumference. The length of the leg was measured from the base of the leg to the end. The chest circumference was measured around the chest also posterior to the forelegs and the leg circumference at the top of the leg at the juncture with the abdomen, posterior to the thigh. The carcass length, width and depth were taken with a steel slide yardstick, while the circumferences were taken with a standard tape measure.

For the chemical analyses both the *M. longissimus dorsi et lumborum* (MLD) were removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra, 24 h post-mortem. The lean meat samples were placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further analyses could be carried out.

Proximate chemical analysis

Proximate chemical analysis was conducted on the MLD samples. After removing the subcutaneous fat and superficial connective tissue, the frozen muscle samples were cut into smaller portions, minced three times through a 2 mm sieve to ensure homogeneity and analysed chemically. Total percentage moisture, protein and ash were determined according to standard AOAC methods (AOAC, 1997). The moisture content was analysed by drying a 2.5 g sample at 100°C for a period of 24 h. The protein (N x 6.25) content was determined by the block digestion method (AOAC, 1997), while ashing was done at 500°C for a period of 5 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee, Trevino & Chaiyawat, 1996).

Total collagen analysis

Hydroxyproline is quantitatively determined as a measure of the collagen in meat and was determined according to the method of Kolar (1990). A 4 g meat sample was hydrolysed in 3.5 M H_2SO_4 at 100°C for 12 to 14 h, filtered and diluted. Hydroxyproline was oxidised with choloramine-T and the colour reagent, 4-dimethylaminobenzaldehyde added. After calibration the absorbance was measured spectrometrically at 560 nm.

Amino acids analysis

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 hydrolysed 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 1.5 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 1.5 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 (minimum of 3 h). 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 5000 ppm EDTA. The data were analysed using Breeze software (Waters, USA).

Mineral analysis

The mineral composition of the meat was determined after ashing the defatted meat samples. The defatted meat samples (1- 3 g) were air dried and ground to pass through a 0.5 to 1.0 mm sieve. Thereafter, the samples were ashed overnight in a muffle furnace at 550°C. A 6 M hydrocloric acid (HCl) solution was prepared by diluting 500 cm^3 of a 36% (m/m) HCl solution to 1 dm^3. After ashing, 5 cm^3 of a 6 M HCl was added to dissolve the cooled sample. Thereafter, the samples were dried on a waterbath. After cooling, a 5 cm^3 6 M nitric acid (HNO_3) solution was added to the samples. The 6 M HNO_3 solution was prepared by diluting 429 cm^3 of a 65% (m/m) solution to 1 dm^3. After adding the latter solution, the samples were heated on a waterbath and removed after boiling point was reached. The solution was subsequently filtered through filter paper into a 100 cm^3 volumetric flask and diluted to volume with deionized water (Giron, 1973). Element concentrations were then measured on an ICP-Thermo Jarrel Ash, IRIS (AP).

Statistical analysis

A one-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factor was two sexes (male and female). 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, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998).

Results and Discussion

Morphological attributes

The culling method employed at Tussen die Riviere was efficient, with fifteen animals being shot through the head, whilst the remaining four were shot through the upper section of the neck. All the animals dropped immediately. Table 1 illustrates the live and carcass mass and general morphological data obtained from the mountain reedbuck carcasses.

No significant differences ($P>0.05$) in live mass and carcass mass or dressing percentage were found between the males and females, although there was a tendency for the females to weigh more than the males. This tendency could be ascribed to the fact that the sample size consisted of the younger, smaller, non-trophy males and a few of the females were pregnant and therefore the mass of the fetus was included in the live mass. The dressing percentage of mountain reedbuck (55.32%) was slightly lower than the 56.68% of kudu (*Tragelaphus s. strepsiceros*) noted by Huntley (1971), but higher than the 52.90% for blesbok (*Damaliscus dorcas phillipsi*) (Huntley, 1971). Compared to domestic species, wild ungulates are able to

Table 1

Live and carcass mass and dressing yields, as well as the morphological results of male and female mountain reedbuck

	Sex		
	Male n = 10	Female n = 19	LSD
Live mass (kg)	28.58	30.58	4.45
Carcass mass (kg)	16.23	16.43	2.06
Dressing (%)	56.03	54.96	3.98
Length (cm)	73.59	73.53	5.07
Width (cm)	19.82	21.93	2.20
Depth (cm)	26.64	27.36	1.79
Chest circumference (cm)	72.38	75.22	4.89
Leg circumference (cm)	46.61	46.87	3.13
Leg length (cm)	52.19	53.33	2.21

LSD, Least Significant Difference, P=0.05

achieve similar or higher dressing percentages without carrying the same proportion of body fat (Von La Chevallerie, 1971). Huntley (1971) found the carcass composition of wild ungulates (in particular blesbok and kudu) to yield high-quality lean retail cuts due to the fact that the meat from wild ungulates has barely any subcutaneous fat that needs to be trimmed.

Proximate chemical composition

The mean proximate chemical composition and collagen content of the MLD of male and female mountain reedbuck are presented in Table 2.

Table 2

Mean proximate composition and collagen content of the MLD of male and female mountain reedbuck

	Sex		
	Male n = 10	Female N = 19	LSD
Moisture (%)	72.76	72.59	1.02
Protein (%)	23.68[b]	24.51[a]	0.66
Fat (%)	2.94	2.43	0.79
Ash (%)	1.23	1.22	0.14
Total Collagen (%)	0.56	0.36	0.22

LSD, Least Significant Difference, P=0.05

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

The sex of the animals had no influence on the moisture content of the MLD. However, the females had a significantly higher ($P \leq 0.05$) percentage of protein, whereas the males tended to have a slightly higher proportion ($P > 0.05$) of total fat. The higher protein content of the females could most probably be attributed to their lower moisture, fat and ash content. The

tendency towards a higher fat content ($P>0.05$) of the males in the present study differed from the finding of Hoffman (2000), who noted a significantly higher fat content in female impala.

Collagen content

Although the males tended ($P>0.05$) to have a higher mean collagen content, there were no significant differences between the male and female connective tissue content of the MLD. The physical properties of collagen both in native and heat-denaturated state, play an important role in determining the texture of the meat, since it influences the meat tenderness (Bailey & Sims, 1977), and therefore it was interesting to note no significant differences between the sexes in the present investigation for the collagen content, and therefore possibly no significant differences in tenderness.

Amino acid content

According to Casey (1993), the nutrient value of meat in the human diet lies in its ability to satisfy the daily requirement for amino acids, in particular the essential amino acids. Table 3 illustrates the amino acid composition in g/100 g meat as well as g/100 g of protein of the MLD muscle for male and female mountain reedbuck.

Table 3

Amino acid composition in g/100g meat sample and g/100g protein of the male and female mountain reedbuck

	Sex			Sex		
	Male n = 9	Female n = 7	LSD	Male n = 9	Female n = 7	LSD
	g/100g meat sample			g/100g protein		
Alanine	2.72	2.66	0.44	9.24	8.83	1.41
Arginine	1.50	1.54	0.17	5.07	5.10	0.40
Aspartic acid	2.91	2.97	0.36	9.86	9.87	1.02
Cystine	0.24	0.23	0.04	0.81	0.76	0.13
Glutamic acid	3.62	3.72	0.49	12.25	12.36	1.31
Glycine	2.07	2.07	0.19	7.00	6.88	0.42
Histidine	0.78	0.75	0.13	2.65	2.48	0.41
Isoleucine	1.28	1.27	0.16	4.36	4.22	0.68
Leucine	2.51	2.49	0.44	8.57	8.26	1.50
Lysine	3.00	4.31	1.58	9.92	14.34	5.08
Methionine	0.84	0.84	0.09	2.86	2.79	0.26
Phenylalanine	0.91	0.97	0.17	3.05	3.20	0.43
Proline	1.41	1.49	0.19	4.80	4.94	0.53
Serine	1.96	1.98	0.29	6.63	6.55	0.78
Threonine	1.84	1.88	0.26	6.23	6.25	0.73
Tyrosine	0.82	0.86	0.09	2.79	2.84	0.18
Valine	1.41	1.57	0.44	4.67	5.21	1.41

LSD, Least Significant Difference, $P=0.05$

Aspartic acid = aspartic acid + aspartine; and glutamic acid = glutamic acid + glutamine

In the present study there were no significant differences in the amino acid content from the meat samples from male and female mountain reedbuck. In a study on impala (*Aepyceros melampus*) Kritzinger (2002) also found no significant differences in the amino acid composition between male and female animals. In the present investigation glutamic acid was the most abundant amino acid, followed by aspartic acid, glycine and serine. According to Rice (1978), the amino acid content of meat is quite constant, regardless of the species, sex or the muscle from which the meat is obtained.

Mineral content

The mean mineral content for male and female mountain reedbuck is presented in Table 4. There were no significant differences for any of the minerals analysed in the MLD between the two sexes. However, the males tended ($P>0.05$) to have higher concentrations of phosphorus, potassium, sodium, and iron.

Table 4

Mean mineral content for the male and female mountain reedbuck

	Sex		
	Male n = 9	Female n = 7	LSD
Phosphorus	207.77	204.80	49.10
Potassium	204.60	164.00	52.70
Calcium	8.04	10.79	5.27
Magnesium	25.25	25.17	7.43
Sodium	16.93	13.91	4.72
Iron	4.61	3.64	2.63
Copper	0.15	0.16	0.08
Zinc	1.75	1.86	0.41

LSD, Least Significant Difference, $P=0.05$

Sanders (1998) stated that iron and zinc are found in highly biologically available forms in red meat. The mean iron content of mountain reedbuck is higher than that in meat from domestic sources and contributes 28% to 42% of the recommended daily allowance. The high content of iron is an extremely advantageous attribute, since the function of iron results from its ability to participate in oxidation and reduction reactions, thereby forming an integral part of the human diet (Mahan & Escott-Stump, 2000). The mean sodium content of mountain reedbuck meat (16 mg/100 g ± 0.74) was lower than that of other game species, such as the 43 mg/100 g in ostrich noted by Sales and Hayes (1996), and also lower than that of domestic species, such as beef (65 mg/100 g), lamb (75 mg/100 g) and pork (64 mg/100 g) (Warris, 2000). A too high sodium intake can cause hypertension, which can lead to cardiovascular diseases and, apart from causing higher blood pressure, a high sodium intake is also associated with stomach cancer, especially with an inadequate intake of potassium (Weisburger, 2000). The higher phosphorus and iron content and lower sodium content, thus, make mountain

reedbuck meat, as far as nutrients are concerned, a healthier alternative to meat derived from domestic species.

The mineral values and the composition are important to both animal and human nutritionists. Animal nutritionist identify possible deficiencies in mineral content to ensure normal growth and development of the animals, while dieticians use the values for compiling nutrient tables and associated tables such as the recommended daily allowances for different nutrients.

Conclusion

The dressing percentages of mountain reedbuck were similar to those of domestic species and other wild ungulates. Apart from the females, which had a significantly higher content of protein, only minor differences in the proximate composition, mineral, and amino acid contents were found between male and female mountain reedbuck, indicating that the composition of the meat does not depend on or change considerably between sexes.

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CHAPTER 8

PHYSICAL CHARACTERISTICS, FATTY ACID AND CHOLESTEROL CONTENT, AND SENSORY ATTRIBUTES OF MOUNTAIN REEDBUCK (*REDUNCA FULVORUFULA*) MEAT AS INFLUENCED BY SEX AND AGE

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Abstract

The influence of animal sex on the physical, chemical and sensory attributes of the *M. longissimus dorsi et lumborum* (MLD) muscle of mountain reedbuck was examined. A total of 29 mountain reedbuck were used to determine the composition of the physical characteristics and a 16-animal sub-sample was used to determine the fatty acid and cholesterol content as well as the sensory characteristics of the meat. Sex had only minor influences, with no significant differences ($P>0.05$) between the physical characteristics investigated, although the males tended to have a higher percentage drip loss and lower percentage cooking loss. No significant differences between the sexes for the saturated fatty acid (SFA), mono-unsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA) and total fatty acid (TUFA) content were noted. Only arachidonic acid (C20:4n-6) and eicosapentaenoic acid (C20:5n-3) were significantly higher ($P\leq0.05$), in mg/100 g of meat, in the females, namely 0.81 (± 0.05) and 0.34 (± 0.03) compared to the 0.34 (± 0.02) and 0.25 (± 0.02) of the males, respectively. The mean polyunsaturated:saturated fatty acid ratio for mountain reedbuck was 1.15 and the mean n-6:n-3 PUFA ratio was 2.08. Descriptive sensory analysis was conducted with sex and age (adult vs sub-adult) as main effects. No significant differences ($P>0.05$) between the male and female mountain reedbuck for the aroma, flavour, initial juiciness and residue attributes were noted. The adult animals (7.01) had significantly more residue than the sub-adults (7.47). A sex x age interaction, at a 95% confidence level, indicated the samples from female sub-adult animals to be more juicy (6.66) and more tender (7.16) than the female adults (6.07; 6.37).

Keywords: game meat, physical characteristics, fatty acid, sensory attributes, pH

Introduction

The meat industry is one of the world's oldest and most important industries (Swatland, 1984). However, in recent years there has been a rapid change in consumer trends. Consumers have become increasingly demanding and are very health conscious in their choice of food products, in particular with respect to meat with a lower fat content (Zotte, 2002). The increased demand for organic food has also created a market for meat that is free of antibiotics and added hormones, and that can be guaranteed free of mad cow disease. The concept of meat quality is, therefore, continuously changing to satisfy the demand for healthier meat with accompanying sensory attributes.

The association of meat consumption with increased risk of cardiovascular diseases, cancer as well as arteriosclerosis, has also intensified the search for healthier alternative sources of red meat. Present nutritional guidelines state that total fat intake in the diet should decrease, while the intake of polyunsaturated fatty acids should increase (Wood & Enser, 1997). Therefore, attention is now devoted to alternative meat sources, i.e. meat that is equally nutritious and flavourful to the consumer (Sink, 1979).

South African game species, such as the mountain reedbuck, live in a natural, pure and healthy environment. The meat from game species is high in protein and has a low fat content, making it a healthier substitute for meat from domestic animals (Hoffman, 2000). Attempts must, therefore, be made to study the nutritional profile of these species. This study was therefore undertaken to determine the physical properties, the fatty acid and cholesterol content, as well as the sensory characteristics of male and female mountain reedbuck meat. Knowledge of the impact of these variables will provide an insight into and a fuller understanding of the wholesomeness of game meat.

Materials and Methods

Animals

A total of 29 mountain reedbuck were culled at Tussen die Riviere Nature Reserve during 2002. The sample size consisted of 19 adult females and ten non-trophy males. Five of the females included in the sample size were pregnant and two were lactating. Tussen die Riviere Nature Reserve near Bethulie, in the Free State province, South Africa, is a 21 000 ha game farm, where the Caledon and Orange Rivers converge to create a flood plain surrounded by high rocky ridges with occasional plateaus and lower-lying grassy plains (Low & Rebelo, 1998).

Harvesting

The culling at Tussen die Riviere Nature Reserve was conducted at night. The animals were culled according to the method described by Lewis, Pinchin and Kestin (1997), which consists

of driving slowly with four-wheel drive vehicles, immobilizing the animals with spotlights and then shooting them. Shooting of the animals was done using a .270 calibre rifle fitted with a telescopic sight and using high-velocity bullets. The huntsman aimed for the head or upper neck, as this method causes the least damage to and wastage of the carcass (Von La Chevallerie & van Zyl, 1971). The animals were exsanguinated with sharp knives immediately after death and then hung onto the hunting vehicle. The hunting vehicles had been especially adapted for culling, with frames constructed on both sides of the utility vehicle and adapted with hooks to suspend smaller antelope species such as mountain reedbuck by their Achilles tendon. After the targeted number of animals had been harvested, they were taken to the reserve's skinning shed.

Physical measurements

Forty-five minutes post-mortem the initial muscle pH (pH_{45}) and temperature were taken and after 24 h the ultimate pH (pH_{24}) and temperature were measured. These measurements were taken on the *M. longissimus dorsi et lumborum* (MLD) between the 4th and 5th lumbar vertebrae counting from the caudal end. The pH was measured with a penetrating glass electrode on a hand-held Crison pH/mV-506 meter. The pH meter consisted of an automatic temperature compensator to ensure the adjustment of the pH for temperature. The pH meter was calibrated after every four readings with pH 4.01 and pH 7.02 buffers and cleaned with distilled water after every reading.

For the physical and chemical analyses, both the MLD were removed from between the 12th and 13th rib to between the 4th and 5th lumber vertebra, and trimmed of all visible subcutaneous fat. For the determination of the drip loss, 1.0 cm thick meat samples weighing ca. 30 g, cut perpendicular to the longitudinal axis of the muscle on the caudal side of the MLD, were weighed. The samples were placed in netting and suspended in an inflated plastic bag. After a storage period of 24 h at 4°C, the samples were blotted with absorbent paper, weighed again and the drip loss was calculated as weight loss expressed as a percentage of the original mass of the sample (Honikel, 1998). For the cooking loss determination, freshly cut MLD samples (1.0 cm thick) were weighed and placed in thin-walled plastic bags in a water-bath at 80°C. After 1 h the samples were removed from the water-bath, cooled in cold water, blotted dry and weighed. Cooking loss was calculated as the difference in sample weight before and after cooking, expressed as a percentage of the initial sample weight (Honikel, 1998).

Three cylindrical cores were cut from each cooked sample (after determining cooking loss) using a 1.27 mm diameter bore. Samples were randomly removed from the centre of each MLD. Maximum Warner Bratzler shear force values required to shear a cylindrical core of cooked muscle, perpendicular to the longitudinal orientation of the muscle fibres at a

crosshead speed of 299 mm/min, were recorded for each sample and the mean was calculated for each muscle. A larger value indicates greater shear force and therefore tougher meat (Honikel, 1998).

The MLD was used for the determination of fresh meat colour. Three readings were taken per sample after blooming for 20 min. Colour was evaluated according to the method described by Honikel (1998) using a Colorgard System 2000 colorimeter (Pacific Scientific, Silver Spring, MD, USA) to determine L*, a* and b* values, with L* indicating lightness, a* the red-green range and b* the blue-yellow range. These values were also used to calculate the chroma value and hue angle according to the following equations, chroma = $\sqrt{(a^{*2}+b^{*2})}$, and the hue angle (°) = $\tan^{-1}(b^*/a^*)$.

The remaining lean meat samples were homogenised, placed in polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further analyses could be carried out.

Fatty acid analysis

The fatty acid content was determined using the same method described by Tichelaar, Smuts, Van Stuihvenber, Faber and Benade (1998). After thawing the meat a 2 g sample was extracted with choroform/methanol (CM 2:1; v/v) according to a modified method of Folch, Lees and Sloane-Stanley (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 tude 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 standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Cholesterol analysis

From the same lipid extraction used for the fatty acid determination, a sub-sample was used for cholesterol determination. After drying the sub-sample under nitrogen Stigmasterol (3-B-

hydroxy-24-ethyl-5.22-cholestadiene; Sigma Chemical Co., St Louis, MO, USA) was added as internal standard and 6% Ethanolic KOH used to saphonifise the extraction for 2 h at 70°C in a heating block. After cooling, distilled water and hexane were added and the resultant extraction was analysed by GLC (Varian Model 3700, equipped with flame ionization detection). A 1.2 m glass column of 2 mm internal diameter packed with 3% SP2401 on 100/120 mesh Supelcoport (Supelco Inc., Bllefonte, PA, USA) was used. Gas flow rates were: hydrogen, 20 ml/min; air, 200 ml/min and nitrogen (carrier gas), 25 ml/min. Temperatures were: injector temperature 280°C; column temperature 255°C and detector temperature 290°C.

Sensory analysis

The vacuum-packed meat samples taken from the left side of the MLD were defrosted at a temperature of 4°C to 6°C for a period of 24 h prior to cooking on their pre-assigned sensory analysis dates. The meat samples were roasted in cooking bags placed on a wire-rack covered in foil on an open roasting pan to an internal temperature of 72°C. The temperature changes were monitored using thermocouples connected to hand-held digital recorders until the ultimate temperature of 72°C was reached. The samples were cooked at 160°C in two Defy 835 electric ovens connected to a computerised temperature control system (Viljoen, Muller, De Swardt, Sadie & Vosloo, 2001). Immediately after cooking, the samples were cut into 1 cm x 1 cm cubes, wrapped in aluminium foil, placed in preheated glass ramekins marked with random three-digit codes and placed in a preheated oven at 100°C (until evaluated 10 min later) and were served to the panel.

Descriptive sensory analysis was performed on the mountain reedbuck meat. The panellists were selected and trained in accordance with the guidelines for the sensory evaluation of meat of the American Meat Science Association (AMSA, 1978) and the generic descriptive analysis technique (Lawless & Heymann, 1998). A trained, and test-re-tested, six-member panel evaluated the mountain reedbuck samples for the following sensory attributes: game aroma and flavour, juiciness and tenderness. An 8-point structured scale was used to evaluate the latter sensory attributes. Table 1 depicts the definitions of the attributes used in the sensory analyses.

The panellists were seated in individual booths in a temperature-controlled and light-controlled (artificial daylight) room (AMSA, 1978). Distilled water, apples and crackers were given to the panellists between samples to cleanse their palates.

Table 1

Definitions of the attributes used in the sensory analyses of the MLD muscle of mountain reedbuck

Characteristic	Description	Score
Game aroma intensity	Take a few short sniffs as soon as you remove the foil	8 Extremely intense 1 Extremely bland
Overall game flavour	This is a combination of taste and swallowing	8 Extremely intense 1 Extremely bland
Initial impression of juiciness	The amount of fluid exuded on the cut surface when pressed between your thumb and forefinger	8 Extremely juicy 1 Extremely dry
Sustained juiciness	The impression that you form after the first two to three chews between the molar teeth	8 Extremely juicy 1 Extremely dry
First bite	The impression of tenderness after the first two to three chews between the molar teeth	8 Extremely tender 1 Extremely tough
Residue	The amount of residue left in the mouth after the first fifteen to twenty chews, using the molar teeth	8 None 1 Abundant

Statistical analysis

A one-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The one factor was two sexes (male and female). 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, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998). Correlations were made using the Pearson product moment correlation coeffisient.

Results and Discussion

Physical characteristics

The culling method employed at Tussen die Riviere was efficient with fifteen animals being shot through the head and the remaining four through the upper neck. All the animals dropped immediately and none of the animals showed any visible signs of ante-mortem stress. Consequently, none of the meat was discarded due to bullet damage. The mean physical meat quality parameters measured on the mountain reedbuck are shown in Table 2.

In the present study there were no significant differences ($P>0.05$) between male and female mountain reedbuck for any of the meat quality characteristics reported in Table 2. Hoffman and Ferreria (2000) found the pH of the *M. longissimus thoracis* of night-cropped Grey Duiker (*Sylvicapra grimmia)* males to be higher than that of the females. This phenomenon was ascribed to the excitable stage of the males because of the rutting season. The slightly

higher mean initial pH values of the males during the present study can possibly be attributed to the excitable stage of the male mountain reedbuck during the culling season. Sex had no influence on the drip loss and cooking loss. More drip is formed when the water-holding capacity (WHC) is poor. The rate and extent of muscle acidification and rate of temperature decline during rigor mortis can also affect the WHC (Warris, 2000) as a high ultimate pH results in high WHC. The latter was not the case in the present investigation. There were no significant differences (P>0.05) in shear force between the male and female mountain reedbuck in the present study, therefore sex has no significant effect on tenderness.

Table 2

Mean physical attributes of the MLD of male and female mountain reedbuck

	Sex		
	Male n = 10	Female n = 19	LSD
pH_{45}	6.84	6.53	0.46
$Temperature_{45}$ (°C)	32.69	33.17	2.57
pH_{24}	5.64	5.64	0.12
$Temperature_{24}$ (°C)	9.09	10.04	2.24
Drip loss (%)	4.51	4.41	2.93
Cooking loss (%)	29.79	30.95	4.16
Shear force (kg/1.27cmF)	3.00	2.95	0.66
L* value	31.13	33.35	2.61
a* value	11.89	10.54	1.47
b* value	8.16	8.92	1.10
Hue angle (°)	36.50	39.14	4.83
Chroma	14.52	13.96	1.21

LSD, Least Significant Difference, *P*=0.05

There were no significant differences between the CIELab values, hue angle or chroma values between the male and female mountain reedbuck. The males tended to have slightly higher a* and chroma values than the females, which in turn, tended to have higher L* and b* values and wider hue angles. Similar findings were present in a study on Hanwoo beef (Kim *et al.,* 2003): the males had higher a* and chroma values, compared to the higher b* and hue angle values of the females. Game meat is normally perceived to be darker than meat from domestic species. Mountain reedbuck meat having a mean L* value of 32.58 ± 0.60, was not as dark as would normally be expected from wild ungulates, impala being 25.44 (Hoffman, 2000) and ostrich 27.34 (Hoffman & Fisher, 2001). Furthermore, the mountain reedbuck was only slightly darker than beef, which has a mean L* value of 35.73 (Kim *et al.*, 2003).

Fatty acid content

According to Enser *et al.* (1998), it is useful to present the fatty acid composition in mg per 100 g muscle, especially when calculating its nutritional value. Alternatively, the fatty acid composition can be expressed as a percentage of the total identified fatty acids present. Although the percentage of fatty acids can be misleading, it still gives a fair indication of the distribution between the different fatty acids. The mass (mg) of the fatty acids per 100 g MLD muscle is presented in Table 3 and the percentage contribution of each fatty acid to the total fatty acid content is illustrated in Table 4.

According to Table 3, there were no significant differences ($P>0.05$) between the sexes for the total fatty acids, saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), as well as desirable fatty acids (DFA) studied. Only the polyunsaturated long chained arachidonic acid (C20:4n-6) and eicosaentaenoic acid (C20:5n-3) was found in significantly higher ($P\leq0.05$) quantities in the MLD of the females. In a study by Nürnberg, Wegner and Ender (1998) the relative concentrations of linoleic acid (C18:2n-6) and PUFA were lower in females, whilst the saturated fatty acid percentages were lower in the males. These differences are also seen in beef (Malau-Aduli *et al.,* 1998), lambs (Nürnberg *et al.*, 1998) and pigs (Cameron & Enser, 1991), and are caused by the negative relationship between concentrations of fat and PUFA in the carcass (Nürnberg *et al.*, 1998). It is known that at lower levels of total fat the contribution made by phospholipids are proportionally greater than that of the triacylglycerols (Marmer, Maxwell & Williams, 1984).

In turn, Table 4 illustrates that the females had significantly higher ($P\leq0.05$) percentage values for the mono-unsaturated nervonic acid (C24:1n-9) and polyunsaturated dihomo-γ-linolenic acid (C20:3n-9) and eicosapentaenoic acid (20:5n-3), while the males had significantly higher percentage values for linoleic acid (C18:2) and α-linolenic acid (C18:3n-3). These significant differences ($P\leq0.05$) caused minor differences in the total mono-unsaturated and polyunsaturated fatty acids, for which the females also displayed higher percentages.

The main fatty acids contributing to the total SFA were palmitic acid (C16:0) and stearic acid (C18:0). The proportion of saturated fatty acids has been considered a major risk factor for coronary heart disease (Santos-Silva, Bessa & Santos-Silva, 2002). However, stearic acid (C18:0), the dominant saturated fatty acid in the present study, is listed as a desirable fatty acid (DFA), with health promoting advantages by lowering blood cholesterol.

Table 3

Fatty acid composition and cholesterol content of the MLD of male and female mountain reedbuck in mg/100 g meat muscle

	Sex		
	Male n = 9	Female n = 7	LSD
Total fatty acids	7.46	8.13	1.20
Saturated			
C16:0	1.19	1.19	0.23
C18:0	1.59	1.80	0.41
C20:0	0.02	0.03	0.01
C22:0	0.02	0.02	0.01
C24:0	0.03	0.03	0.01
Mono-unsaturated			
C16:1n-7	0.01	0.00	0.02
C18:1n-9	1.26	1.54	0.44
C20:1n-9	0.01	0.01	0.00
C24:1n-9	0.02	0.02	
Polyunsaturated			
C18:2n-6	1.53	1.36	0.33
C18:3n-6	0.01	0.02	0.00
C18:3n-3	0.34	0.22	0.09
C20:2n-6	0.01	0.02	0.01
C20:3n-9	0.09	0.12	0.02
C20:4n-6	0.58^{b}	0.81^{a}	0.13
C20:5n-3	0.25^{b}	0.34^{a}	0.08
C22:4n-6	0.02	0.03	0.01
C22:5n-3	0.40	0.44	0.11
C22:6n-3	0.07	0.06	0.03
SFA	2.85	3.07	0.45
MUFA	1.29	1.58	0.44
PUFA	3.31	3.49	0.61
TUFA	4.60	5.02	0.88
DFA	6.19	6.86	1.19
P:S	1.16	1.16	0.20
n-6	2.15	2.23	0.41
n-3	1.07	1.14	0.25
n-6:n-3	2.07	1.98	0.39
Cholesterol	51.08	52.05	7.90

LSD, Least Significant Difference, P=0.05

^{a,b} Means, in rows, within groups, with different superscript letters are significantly different, $P \leq 0.05$

Abbreviations: SFA, Saturated Fatty Acids; MUFA, Mono-unsaturated Fatty Acids; PUFA, Polyunsaturated Fatty Acids; TUFA, Total Unsaturated Fatty Acids, DFA, Desirable Fatty Acids (C18:0 + TUFA); P:S, Polyunsaturated:Saturated fatty acid ratio; n-6 consists of 18:2, 18:3, 20:2, 20:4, 22:4; n-3 consists of 18:3, 20:5, 22:5.

Table 4

Percentage contribution (molar %) of the individual fatty acids to the total fatty acid content from the MLD of the male and female mountain reedbuck

	Sex		
	Male n = 9	Female n = 7	LSD
SFA	38.47	37.59	3.62
C16:0	16.12	14.88	3.36
C18:0	21.47	21.80	3.05
C20:0	0.33	0.34	0.07
C22:0	0.22	0.23	0.07
C24:0	0.41	0.43	0.14
MUFA	17.27	19.03	4.13
C16:1n-7	0.18	0.00	0.30
C18:1n-9	16.75	18.71	4.20
C20:1n-9	0.12	0.14	2.15
C24:1n-9	0.18^{b}	0.27^{a}	0.11
PUFA	44.15	43.23	4.26
C18:2	20.45^{a}	16.88^{b}	3.08
C18:3n-6	0.13	0.16	0.05
C18:3n-3	4.57^{a}	3.61^{b}	0.73
C20:2n-6	0.20	0.21	0.07
C20:3n-9	1.15^{b}	1.42^{a}	0.20
C20:4n-6	7.72^{b}	10.13^{a}	1.57
C20:5n-3	3.28	4.26	0.99
C22:4n-6	0.28	0.33	0.08
C22:5n-3	5.38	5.45	0.88
C22:6n-3	0.98	0.78	0.32

LSD, Least Significant Difference, P=0.05

^{a,b} Means, in rows, within groups, with different superscript letters are significantly different, $P \leq 0.05$

In the present study the mean total SFA percentage for mountain reedbuck (38.11% ± 0.10) contributing to the total fatty acids was lower than the SFA found by Onyango, Izumimoto and Kutima (1998) in their comparative study between beef and selected game meats, where kongoni (74%) had the highest percentage of saturated fatty acids compared to those of beef (50%), oryx (40%) and zebra (<40%). A lower percentage (17.24% ± 0.13) of total MUFA was found for the males, with a comparable figure of 19.12% ± 0.17 for the females.

When judging the fatty acid content of food, dieticians increasingly focus on the polyunsaturated to saturated fatty acid ratio (P:S), as well as the n-6:n-3 PUFA ratio. The mountain reedbuck has less than 3% total fat. The P:S ratio of 1.16 of the MLD of mountain reedbuck is beneficially higher than the ratio of 0.45 recommended by the British Department of Health (1994). Furthermore, the P:S ratio for mountain reedbuck (1.16 ± 0.05) is also higher than the 0.11, 0.15 and 0.58 reported for beef, mutton and pork, respectively (Warris, 2000).

The mean n-6:n-3 PUFA ratio of mountain reedbuck (2.08) is in line with the recommendation of 4.0 or below set by the British Department of Health (1994). The fatty acid composition of mountain reedbuck meat, therefore, indicates that this species' meat is suitable as a healthier alternative for the traditional red meat derived from domestic species.

Many authors have found regional differences in the fatty acid composition due to different food availability, diets and feeding regimes, such as Santos-Silva *et al.* (2002). Although the latter variables were not taken into account in the present investigation, the fatty acid content can serve as a reference standard for future mountain reedbuck investigations.

Cholesterol content

The females displayed a slightly higher ($P>0.05$) cholesterol content than the males, while the mean cholesterol content of mountain reedbuck was 51.56 mg/100g ± 1.82. Dietary cholesterol is strictly linked to foods of animal origin, since cholesterol is an essential constituent of animal cells (Chizzolini *et al.*, 1999). Meat, particularly red meat, is commonly identified as a major source of dietary cholesterol. However, mountain reedbuck has a lower, more favourable cholesterol content than other species such as ostrich. Red neck and blue neck ostriches were found to have cholesterol contents of 65.63 mg/100 g and 63.04 mg/100 g respectively (Horbanczuk *et al.,* 1998).

Sensory attributes

In the present investigation there were significant interactions ($P\leq0.05$) between the two main effects, namely sex and age, for two of the sensory attributes, namely sustained juiciness and first bite. The results obtained from the sensory analysis of the MLD mountain reedbuck samples are presented in Tables 5 and 6. Table 5 illustrate individual variables, sex and age, while Table 6 illustrates the interactions between the two main variables.

The sex of the mountain reedbuck did not influence the aroma, flavour, initial juiciness and residue of the MLD. What is interesting to note is that the panel used the upper limits of the scale to describe the meat. Also noteworthy is the high value given to the residue, indicating that the panel did not perceive most of this species to be very tough.

Table 5

Sensory evaluation of the MLD muscle of mountain reedbuck to measure the difference in eating quality between males and females and different age groups

	Sex			Age		
	Male n = 9	Female n = 7	LSD	Adult n = 14	Sub-adult n = 2	LSD
Aroma	5.81	5.89	0.29	5.87	5.76	0.39
Flavour	5.83	5.74	0.25	5.82	5.64	0.33
Initial juiciness	6.53	6.39	0.27	6.45	6.52	0.36
Residue	7.07	7.10	0.25	7.01^{b}	7.47^{a}	0.33

LSD, Least Significant Difference, P=0.05

^{a,b} Means, in rows, within groups, with different superscript letters are significantly different, $P \leq 0.05$.

As far as the age (adult and sub-adult animals) of the animal is concerned, the panel did not find any age effect for the aroma, flavour and initial juiciness of the meat. However, they did indicate that the adults had significantly more ($P \leq 0.05$) residue left in the mouth after the first fifteen to twenty chews. As such, it is difficult to explain why the sub-adults had less residue than the adults. One can only assume that this might either be due to the collagen content, as collagen becomes less soluble with an increase in animal age, causing the meat to be tougher and to have more residue or the fact that there were only two sub-adults, resulting in a sample bias.

Table 6

Interactions between the two main effects investigated during the sensory evaluation of the MLD muscle of mountain reedbuck

	Male Adult n = 8	Male Sub-adult n = 1	Female Adult n = 6	Female Sub-adult n = 1	LSD
Sustained juiciness	6.34^{ab}	6.36^{ab}	6.07^{b}	6.66^{a}	0.55
First bite	6.51^{ab}	7.18^{a}	6.37^{b}	7.16^{a}	0.73

LSD, Least Significant Difference, P=0.05

^{a,b} Means, in rows, within groups, with different superscript letters are significantly different, $P \leq 0.05$.

According to Table 6, there were significant interactions ($P \leq 0.05$) for the sensory attributes sustained juiciness and first bite (tenderness), where the female sub-adults had significantly higher ratings than the female adults. Differences in sustained juiciness and tenderness can normally be explained by the ultimate pH of the meat, the moisture and fat content as well as the total and soluble collagen content. None of these variables differed significantly ($P \leq 0.05$) in the present study and its higher ratings can, therefore, not be attributed to the latter factors. The higher ratings of the female sub-adults can only be attributed to a sample effect as an extraneous variable of the skew sample size. There was a positive correlation between

sustained juiciness and first bite (r = 0.686; $P \leq 0.002$), indicating a significant association between the sustained juiciness of the meat and its tenderness.

Conclusion

In the present study there were no significant differences in the physical parameters analysed. The fatty acid composition of the meat samples had only minor differences between the sexes, with no significant differences between the SFA, MUFA, and PUFA. Meat from this species was also found to contain low cholesterol levels when compared to domestic species such as beef, mutton and pork. Sex and age interactions in the sensory evaluation of mountain reedbuck meat proved female sub-adult mountain reedbuck to be more juicy and tender. Sex and age had no effect on any of the sensory attributes except for residue, where the adults were found to have more residue than the sub-adults.

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CHAPTER 9

CONCLUSION

This study was undertaken because comprehensive data describing the physical properties and nutrient content of different South African wild ungulates and game meats from different regions, slaughter ages and sexes are lacking.

Black wildebeest, blue wildebeest and mountain reedbuck, three of the indigenous mammal species in South Africa, had comparable dressing percentages, not only when compared to other wild ungulates but also domestic species, and can definitely be utilised for meat production purposes. This statement can be made after a thorough investigation of the properties that have an influence on the physical, chemical and sensory parameters associated with the meat qualities studied.

The physical qualities indicated that different harvesting regions, animal age as well as sex influenced the meat qualities of the latter species. The physical properties of black wildebeest, blue wildebeest and mountain reedbuck meat are influenced by the same variables and show the same effects and tendencies on the latter parameters as meat from domestic species does. The low content of collagen, especially if referred to the high protein content, makes the game meat less tough and renders these meats more digestible, which should lead to a greater appreciation by consumers. Colour, another important parameter, was found to be more comparable with beef than that of impala and ostrich, which is a definite advantage as darker meat colour is associated with a higher risk of spoilage, off-flavour and odours.

The chemical analysis illustrated that the meat from these three species, just like other wild ungulates, has higher protein content and lower fat percentages. The black wildebeest, as well as mountain reedbuck females, had higher percentages of protein than the males. The minerals and amino acids showed no significant differences between any of the effects, indicating only minor changes in the composition between the variables studied.

Seasonal changes in the meat composition were also evident in the study on the black wildebeest. During the colder seasons the animals are subject to severe winter nutritional depression because the dry grass has low feeding value and edible bush and shrubs are scarce. The rutting season, in addition to the food scarcity, caused lower fat content, as well as protein content for the males. These factors should all be taken into account during year-round cropping.

Domestic animals are well rested and watered before slaughter, while game animals are cropped either during the night or day. The effect of these cropping methods on the resulting meat quality may cause an inconsistency in meat quality. The cooling method and time used should promote the desired characteristics necessary to improve the end product. Standardisation of the culling procedures and cooling methods and duration are therefore essential to ensure consistency of meat quality, even if it is carried out at different reserves by different people. Considering the large number of game farms in South Africa, slaughtering, cooling and meat safety regulations should be implemented as soon as possible, thus enabling the production of game meat - not only for the local market, but also to exploit possible export opportunities and international markets. It is also evident that the game meat industry needs to build a positive image regarding the many health factors and qualities of game meat in order to market it successfully.

The worldwide tendency towards natural food products, and that fact that the animals in the present study were kept under free-range conditions without supplementary feeding, can create lucrative opportunities for the marketing of the so-called 'organic meat'.

It can be deduced from these results that meat from black wildebeest, blue wildebeest and mountain reedbuck meat fulfils today's nutritional principles, its composition and easy digestibility making it an ideal food.