MEAT QUALITY CHARACTERISTICS OF THE SPRINGBOK (*ANTIDORCAS MARSUPIALIS*)

By

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DECLARATION

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

Signature:______________ Date:______________

SUMMARY

The objective of this investigation was to evaluate the effects of age (adult, sub-adult and lamb), gender (male and female) and production region on the morphological characteristics of springbok (*Antidorcas marsupialis*). In addition, the effects of the latter on the physical, chemical and sensory quality of the *M. longissimus dorsi* (LD) muscle were determined. Where applicable, correlations within the various physical and chemical attributes of the meat were verified in the experiments. The sensory ratings of the meat were correlated with the data on the physical and chemical attributes of the LD muscle, where applicable.

The mean live mass of male and female adult springbok differed significantly ($p < 0.05$) and averaged 31.7 $\pm$ 0.70 and 28.3 $\pm$ 0.60 kg respectively. Gender had no significant effect on the mean live mass of the sub-adult category. The mean dressing percentage of the males (58.83 $\pm$ 0.53%) was noted to be significantly higher than that of the females (55.79 $\pm$ 0.50%). The lambs (58.98 $\pm$ 1.07%) had the highest dressing percentage of all the age categories. An increase in carcass measurements was noted with an increase in animal age. Gender did not have a significant ($p > 0.05$) effect on the carcass measurements.

Inverse correlations were noted between pH_{24} and drip loss ($r = -0.26$, $p < 0.01$) and cooking loss ($r = -0.42$, $p < 0.0001$) of the LD muscle. It was noted that stressed animals had a significantly ($p < 0.05$) higher ultimate pH_{24} (6.30 $\pm$ 0.07), as observed in the meat originating from the Caledon region and this meat consequently had a significantly ($p < 0.05$) lower cooking loss (27.18 $\pm$ 0.62%) and drip loss (1.79 $\pm$ 0.08%). Meat shear force values ranged between 1.67 $\pm$ 0.05 and 2.67 $\pm$ 0.16 kg. 1.27 cm^{-1} diameter. Age-related effects on tenderness were found to be minor in comparison to pH_{24} effects.

The females (3.13 $\pm$ 0.28%) were noted to have a significantly ($p < 0.05$) higher fat content than the males (1.35 $\pm$ 0.08%). The adult (2.45 $\pm$ 0.26%) and sub-adult (2.50 $\pm$ 0.28%) animals had a significantly higher fat content in comparison with the lambs (1.32 $\pm$ 0.11%). The protein content of the springbok meat originating from the four production regions varied between 18.80 $\pm$ 0.35 and 21.16 $\pm$ 0.51%. Gender had no significant effect on the protein content, except for the meat originating from Rustfontein Nature Reserve where the females had a significantly higher protein content. The two major amino acids noted for springbok LD muscle were glutamic and aspartic acid. Phosphorous was the predominant mineral, followed by potassium and calcium. Production region had a significant ($p < 0.05$) effect on both the amino acid and mineral content of the meat.

The saturated fatty acid (SFA) content of the LD muscle contributed 38.40 to 42.69% of the total identified fatty acids. The poly-unsaturated fatty acid (PUFA) content (36.34 - 40.98%) of the meat was very close to this range, meaning that optimal polyunsaturated to saturated (P:S) ratios (0.96 - 1.18) were present. The effects of age and gender on the fatty acid composition were minor in comparison with regional effects.

Warner-Bratzler Shear force (kg. 1.27 cm^{-1} diameter) values were inversely correlated with the following sensory attributes: tenderness ($r = -0.70$, $p < 0.01$), residual tissue ($r = -0.68$, $p < 0.01$) and sustained juiciness ($r = -0.43$, $p < 0.05$). Decreased acceptance of the meat was noted with an increase in ultimate pH (pH_{24}) from 5.4 to 5.8. As the ultimate pH of the meat increased, the rankings for tenderness ($r = -0.46$, $p < 0.05$) and sustained juiciness ($r = -0.54$, $p < 0.05$) decreased significantly.

OPSOMMING

Die doel van hierdie ondersoek was om die invloed van ouderdom, geslag en produksie area op die morfologiese eienskappe van springbok (*Antidorcas marsupialis*) te evalueer. Die effek van laasgenoemde faktore op die fisiese, chemiese en sensoriese kwaliteit van die *M. longissimus dorsi* (LD) is ook ondersoek. Korrelasies in die fisiese en chemiese eienskappe van die vleis is bestudeer. Die resultate van die sintuiglike evaluering van die vleis is gekorreleer met die fisiese en chemiese data van die LD spier, indien van toepassing.

Die gemiddelde gewig van die manlike (31.7 $\pm$ 0.70 kg) en vroulike (28.2 $\pm$ 0.60 kg) diere het betekenisvol ($p < 0.05$) verskil. Geslag het geen betekenisvolle effek op die gemiddelde gewig van die sub-volwasse diere getoon nie. Die gemiddelde uitslag persentasie van die manlike diere (58.83 $\pm$ 0.53%) was betekenisvol ($p < 0.05$) hoër in vergelyking met die vroulike diere (55.79 $\pm$ 0.50%). Met ‘n toename in ouderdom is ‘n toename in karkas metings waargeneem. Geslag het geen effek op die karkas metings getoon nie.

Negatiewe korrelasies is genoteer tussen die finale pH (pH_{24}) en drupverlies ($r = -0.26$, $p < 0.05$) en tussen pH_{24} en kookverlies ($r = -0.42$, $p < 0.0001$) van die LD spier. Gestresde diere van die Caledon area het ‘n betekenisvolle ($p < 0.05$) hoër pH_{24} (6.30 $\pm$ 0.07) getoon en gevolglik ‘n laer ($p < 0.05$) kookverlies (27.18 $\pm$ 0.62%) en drupverlies (1.79 $\pm$ 0.08%). Die skeurkrag waardes van die LD spier het gewissel van 1.67 $\pm$ 0.05 tot 2.67 $\pm$ 0.16 kg. 1.27 cm^{-1} diameter. Die effek van ouderdom op taaiheid was klein in vergelyking met die effek van pH_{24}.

Die vroulike diere (3.13 $\pm$ 0.28%) het ‘n hoër ($p < 0.05$) vetinhoud as die manlike diere (1.35 $\pm$ 0.08%) getoon. Die volwasse (2.45 $\pm$ 0.26%) en sub-volwasse (2.50 $\pm$ 0.28%) diere se vetinhoud was hoër as die van die lammers (1.32 $\pm$ 0.11%). The proteininhoud het gewissel van 18.80 $\pm$ 0.35 tot 21.16 $\pm$ 0.51%. Geslag het geen effek ($p > 0.05$) getoon op die proteieninhoud, behalwe vir die vleis van die Rustfontein Natuur Reservaat. Glutamien en aspartien suur was kwantitatief die belangrikste aminosure. Fosfor was die belangrikste mineraal, gevolg deur kalium en kalsium. Produksie area het ‘n betekenisvolle ($p < 0.05$) effek op die aminosuur en mineraalinhoud getoon.

Die versadigde vetsuur (SFA) inhoud het gewissel van 38.40 tot 42.69% van die totale geïdentifiseerde vetsure. Die poli-onversadigde vetsuur (PUFA) inhoud het gewissel van 36.34 tot 40.98% en daarom is optimale poli-onversadigde tot versadigde (P:S) verhoudings (0.96 - 1.18) genoteer.

Die effek van ouderdom en geslag op die vetsuursamestelling was minimaal in vergelyking met die effek van produksie-area.

Warner-Bratzler skeurkrag (kg. 1.27 cm^{-1} diameter) waardes was negatief gekorreleer met die volgende sensoriese eienskappe: taaiheid ($r = -0.70$, $p < 0.01$), residuweefsel ($r = -0.68$, $p < 0.01$) en volgehoue sappigheid ($r = -0.43$, $p < 0.05$). Daar is ‘n afname in die aanvaarbaarheid van die vleis waargeneem met ‘n toename in pH_{24} van 5.4 tot 5.8. Met ‘n toename in pH_{24}, het die taaiheid ($r = -0.46$, $p < 0.05$) en volgehoue sappigheid ($r = -0.54$, $p < 0.05$) van die vleis afgeneem.

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LIST OF ABBREVIATIONS

pH_0	pH reading at 45 minutes post-mortem
pH_{24}	Ultimate (final) pH reading at 24 hours post-mortem
$Temp_o$	Temperature at 45 minutes post-mortem
$Temp_{24}$	Temperature at 24 hours post-mortem
DFD	Dark, firm and dry
SFA	Saturated Fatty Acids
MUFA	Monounsaturated Fatty Acids
PUFA	Polyunsaturated Fatty Acids
DFA	Desirable Fatty Acids
LD	*M. longissimus dorsi*
W.P	Willem Pretorius Nature Reserve

NOTES

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

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

Kroucamp, M., Hoffman, L.C. & Manley, M. (2003). The fatty acid composition of springbok (*Antidorcas marsupialis*) meat as influenced by age, gender and production region. In: *Southern African Wildlife Management Association Symposium.* Ganzekraal, South Africa.

CHAPTER 1

INTRODUCTION

In Africa in general, the growing population numbers and decrease in protein supply have intensified the search for alternative sources of food protein (Onyango *et al*., 1998). Game meat consumption is an ancient practice in Africa and it is an important alternative to beef in many regions (Onyango *et al*., 1998). The utilisation of bush meat (game meat) is an important economic and social activity in diverse ethnic and habitat areas of Southern and Eastern African countries (Anon, 2000). Game meat production in urbanised areas is also an increasing, regular activity and it constitutes a growing industry in both urban and rural areas (Anon, 2000).

Game meat production in the above-mentioned countries is a valued resource because of the direct benefits it currently provides to communities with decreasing standards of living and increasing populations (Anon, 2000). However, restrictive external and local policies and legislative constraints in these countries have led to limited revenues. This has resulted in the theoretical advantages of game meat production not being realised (Anon, 2000).

Since the early 1960s it has been realised that game production holds several ecological and economic advantages and this has led to a steady increase in wild ungulate numbers on South African ranches (Van der Waal & Dekker, 2000). The game-ranching industry in the Limpopo Province of South Africa, for example, has grown from small beginnings in the 1960s to an industry occupying a large part of the commercial agricultural land. This province had an estimated annual turnover of R221 million in 1997, of which game meat production contributed only R7 million, whereas local hunting and foreign hunting contributed R82 and R48 million, respectively (Van der Waal & Dekker, 2000). In terms of the size of exempted game ranches, a growth of 5.6% was observed between 1993 and 2000. This does not include Provincial and National Parks, which comprise 12.5% of agricultural land in South Africa (Eloff, 2002). This provides an indication that the game industry of South Africa has grown extensively since the early 1960s.

It is envisaged that the South African venison industry has great local and international production potential (Buys *et al*., 1996). As early as 1987, the total mass of venison production was 1 215 136 kg, 69.9% of which was springbok meat. During that year, 553 t of venison was exported, and springbok represented 95.6% of this total (Buys *et al*., 1996).

Springbok, eland, blesbok, impala and kudu have been noted to be the most common game species ranched in South Africa (Conroy & Gaigher, 1982). Springbok (*Antidorcas* *marsupialis*) has been reported to be the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999).

Venison exports from South Africa to European countries in the early nineties were approximately as follows:

- 1990: 300 t (bone-in meat);
- 1993: 120 t;
- 1994: 50 t (lower export due to drought); and
- 1995: 100 t (increased demand for deboned venison) (Jansen van Rensburg, 1997).

Systems for the utilisation of game range from the cropping of unmanaged wild populations to the utilisation of farming systems, similar to the conventional herding of domesticated breeds (Fairall *et al*., 1990). There are four forms of utilising game, namely trophy hunting, non-trophy recreational hunting, live animal sales and venison production (Berry, 1986). Experiences from South Africa and game ranches in Eastern and Southern African countries (Botswana, Mozambique, Zimbabwe, Zambia, Malawi, Tanzania and Kenya) have led to the recognition that game farming can only be a feasible land use option if all the methods of game utilisation forms are utilised fully, rather than just focusing on venison production (Anon, 2000). This phenomenon can be observed if one takes into consideration the relatively small proportion that venison contributes to the turnover of the game industry in South Africa (Van der Waal & Dekker, 2000).

During the past 30 years, the game industry in South Africa has generally showed development, as can be seen from the gross profit it contributes annually (Table 1). It has been reported (Eloff, 2002) that the annual gross profit of the South African game industry amounted to R843 million in the year 2000 (Table 1). Game meat sales contributed only R20 million (2.4%) to this amount. Therefore game meat production in South Africa is relatively underdeveloped in comparison with the other utilisation forms in the game industry. However, according to Hoffman (2003), game meat exports from South Africa to the European Union is increasing rapidly.

Biltong hunting delivers the highest gross profit of the various utilisation forms, followed by live game sales and trophy hunting (Table 1). As early as 1991, venison contributed 68% to the South African game industry's income and biltong hunting contributed 63% to this amount (Van Rooyen, 1996). In addition, local hunting, live game sales, foreign hunting and venison production in the Limpopo Province of South Africa contribute 42.3, 29.0, 25.0 and 3.7% respectively to the total turnover in this area (Van der Waal & Dekker, 2000).

Table 1. Gross profits of the different utilisation forms of the South African game industry in the year 2000 (Eloff, 2002).

Utilisation activity	Gross profit in South African Rand	% Contribution
Biltong hunting	450 000 000	53.4
Trophy hunting	153 000 000	18.1
Live game sales	180 000 000	21.4
Ecotourism	40 000 000	4.7
Game meat sales	20 000 000	2.4
TOTAL	**843 000 000**	**100**

The prices of game (e.g. springbok) at live auctions are decreasing (Eloff, 2002) and it is evident that other utilisation forms, such as game meat sales, should be expanded to reach their maximum potential. Game meat production also has the potential to be the primary utilisation form for many ranches that do not possess the management or capital expertise required for the other utilisation forms (Anon, 2000).

Today consumers are showing a growing interest in the characteristics of meat and the system by which it is produced (Volpelli *et al*., 2003). Meat is required to be safe in terms of its composition, preferably with no artificial additives added to the animals' (domesticated) diet or to the product (Volpelli *et al*., 2003). According to Issanchou (1996), the safety of meat products is very important to the consumer. The consumer is willing to pay more for meat that is free of microorganisms, antibiotics and hormones (Issanchou, 1996). South African game meat is still untamed and is seen as organic and exotic. It therefore has the ability to distinguish itself from the domesticated game species from Australia, New Zealand and Europe (Hoffman & Bigalke, 1999). In addition, it has been reported that the consumer is showing interest in alternatives to conventional meat products (Rule *et al*., 2002). All of the above-mentioned factors leave a niche in the market for underdeveloped meat sources, such as game meat.

Meat consumption is associated with the ingestion of fat and consumers are becoming more conscious of their dietary intake of high fat animal foods containing saturated fats and cholesterol, which elevate serum cholesterol levels *in vitro* (Flynn *et al*., 1985; Berry, 1992). In 1996 there was consumer resistance to the red meat market in the United Kingdom, probably because the consumers had become more aware of the quality attributes of the meat they consume (Viljoen, 1999). This phenomenon led to an 11% decrease in red meat consumption in that year in comparison with 1995 (Viljoen, 1999).

Mad cow disease (*bovine spongiform encephalopathy*) is a chronic degenerative disease that attacks the central nervous system of cattle. This disease is spread by means of animal recycling, when ground animal parts and bone meal are used in commercial feeds (Anon, 2001). This phenomenon has led to a decline in beef and beef-related product consumption, leaving a gap in the market for alternative red meat sources.

In comparison with domestic ruminant meat, venison provides lower amounts of intramuscular fatty acids, with a higher composition of polyunsaturated fatty acids (PUFA) and lower amounts of mono-unsaturated (MUFA) and saturated fatty acids (SFA) (Fisher *et al*., 1998). Game meat is healthier because of its leanness in comparison to domesticated meat sources that are fed on cereal products (Viljoen, 1999) and is recognised as a meat source that is low in fat, energy and cholesterol (Drew, 1992). Venison is therefore viewed as a natural, lean and 'real' meat, which is attractive to the health-conscious consumer (Fisher, 1991).

Most information on game populations is based solely on biological studies and little scientific research has been done on the potential of game meat (Fairall *et al*., 1990). Game meat is commonly consumed in Europe, but little research exists on meat quality-related parameters (Taylor *et al*., 2002). In addition, there is also little information on the nutritional composition of venison and venison products, although the demand for these products is growing internationally. As early as 1991, McCance & Widdowson's: The Composition of Foods (Anon, 1991) had only one entry for venison in comparison with 30 for lamb and 27 for beef (Aidoo & Haworth, 1995).

Modern consumers want to be informed about the total nutritional composition of the food they consume (Horbañczuk *et al*., 1998). It is known that factors such as age, gender, muscle type, carcass weight and degree of fatness influence the nutrient content of meat (Sales, 1995). Fundamental information is therefore required by the game industry (producers and processors) to determine whether its meat products will meet the needs of the markets and consumers (Buys *et al*., 1996).

The effect of age, gender and species on the quality of meat is well estabilished, but there is little data on game meat quality (Onyango *et al*., 1998). It is therefore important that these effects on game meat quality are researched extensively in terms of the physical, chemical and sensory attributes.

In South Africa, research on springbok includes work done by Veary (1991) on the effect of slaughter methodology and ambient temperature on the pH and temperature of springbok meat. Jansen van Rensburg (1997) studied some aspects of the physical, chemical and sensory quality characteristics of springbok meat and also investigated the effect of ageing methods and periods on the sensory characteristics of springbok meat. Viljoen (1999) researched the fatty acid profile of springbok in comparison with that of beef, but did not give any indication of the effect that age, gender or region may have on the fatty acid profile of springbok meat. Different cuts of only one springbok were used in this investigation. Van Zyl & Ferreira (2003) researched the chemical composition and body component distribution of springbok, blesbok and impala. This study was conducted on the whole carcass (including bone) (Van Zyl & Ferreira, 2003). It is clear from the above, that verly little information is available on the meat quality attributes of springbok, which is the major harvested and exported game species in South Africa.

AIMS

The aims of this study were to investigate the effects of age, gender and production region on the meat quality characteristics of the *M. longissimus dorsi* (LD) muscle of springbok (*Antidorcas marsupialis*) in terms of the following:

- Chemical composition: moisture; protein; lipid; ash; minerals; fatty acid and amino acid profiles.
- Physical attributes: Warner Bratzler shear values; pH-profiles; colour (CIEL*, CIEa*, CIEb*, hue and chroma); cooking and drip loss.
- Sensory quality characteristics: game aroma, juiciness, tenderness, residual tissue (connective tissue) and overall game flavour.

The morphological parameters evaluated included live mass, carcass mass, dressing percentage and circumferences of the carcass.

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CHAPTER 2

LITERATURE REVIEW

1.1 Taxonomy and description of springbok (*Antidorcas marsupialis*)

Three subspecies of springbok were originally distinguished, namely *Antidorcas marsupialis marsupialis* from the south-western region of the Cape Province, *Antidorcas marsupialis hofmeyri* from southern Namibia and Botswana, and *Antidorcas marsupialis angolensis* from northern Namibia and Angola (Furstenburg, 2002). Through electrophoretic and cariological testing it was found that there are no genetic differences between these subspecies and therefore springbok has only one species, with no subspecies (Furstenburg, 2002). However, two types of springbok can be distinguished morphologically, namely the black and white springbok. The black springbok has a larger build and produces heavier lambs. The white springbok has two variations: an albino form, with grey-black horns, and the non-albino springbok, with white-brown horns (Furstenburg, 2002).

The live mass of mature springbok has been noted to vary geographically (Robinson, 1979), from 31.1 to 47.6 kg (± 41.0) in males and from 26.5 to 43.5 kg (± 37.1) in the female gender (Skinner & Smithers, 1990). According to Fairall *et al*. (1990), who evaluated the productivity of springbok under a practical farming system in the Karoo, springbok reach their maximum growth rate before the age of one year. At this stage, the males and females reach 88% and 92% of their respective mean mature body mass of 31.5 and 27.1 kg respectively (Fairall *et al*., 1990). Variation in the live mass of springbok may occur, because it is known that locality, mediated by the quality and quantity of the vegetation and thus the available nutrients in the habitat, influences the live weight of antelope (Von la Chevallerie, 1970; Furstenburg, 2002).

Up to the age of 28 weeks, the sex of a springbok does not effect the carcass mass (Von la Chevallerie & van Zyl, 1971a). Springbok exhibit a rapid increase in total body mass up to an age of 28 weeks, after which the growth rate slackens to the age of 52 weeks (Von la Chevallerie & van Zyl, 1971a). In most game species, males have a higher live mass than females and subsequently will have a higher carcass yield (Smithers, 1983). With regard to meat production, weight differences between the sexes of wild ungulates become apparent only when adult animals are cropped (Von la Chevallerie, 1970; Hoffman, 2003).

1.2 Yield

The dressing percentage of wild ungulates has been reported to vary from 56 to 66% of their live weight (Hoffman & Bigalke, 1999). Van Zyl *et al*. (1969) and Van Zyl & Ferreira (2003) noted that there are several factors that influence the dressing percentage of an animal, for example position of shot, stomach fill and insufficient exsanguination. The dressing percentage of all age groups of springbok is high and carcasses of 10 kg upwards are suitable for marketing (Fairall *et al*., 1990). Fairall *et al*. (1990) noted that young (3 - 6 months) springbok have a dressing percentage of 56.1% and 53.3% for males and females respectively. For older animals, the dressing percentage increases to 58.8% and 55.0% respectively. This indicates that older animals of both genders and the male gender in general tend to have a higher dressing percentage.

1.3 Nutrition

The springbok is a ruminant, like all other antelope species. Intermediate type or mixed-dicotyledonous feeders has been noted to comprise 35% of all ruminant species (Hofmann, 1989). The following species form part of this feeding category: red deer (*Cervus alephus*), domestic goat (*Capra hircus*), impala (*Aepyceros melampus*), eland, Grant's gazelle (*G. granti*) and the springbok. These species are forage selectors that prefer a mixed diet, avoiding high-fibre diets (Hofmann, 1989). When plants become highly lignified during drought, the springbok digestive system is inadequate and the animals are forced to migrate (Skinner & Louw, 1996).

If the feeding habits of springbok are considered, the percentage contribution of various plant species to the springbok's diet is as follows: 38.0% chamaephytes, 31.6% perennial herbs, 19.0% shrubs or trees, 7.6% annual herbs, 2.5% grass and 1.3% succulents (Bigalke, 1972). The diet of springbok consists mainly of grasses, shrubs and herbs (Furstenburg, 2002). Grasses consumed by the springbok are mainly *Themeda triandra, Cynodon dactylon, Panicum, Eragrostis, Brachiaria, Pennisetum, Sporobulus, Digitaria, Enneapogon* and *Stipagrostis*. The shrubs and herbs consumed include *Monechma, Rhigosum, Psoralea, Grewia, Pentzia incana, Chrysoeoma tenuifolia, Rhus ciliata, Acacia, Boscia albitrunca, Zygophyllum, Ziziphus mucronata, Colophospermum mopane* and *Solanum* (Furstenburg, 2002).

The springbok maintains a constant body mass during the drier seasons. The metabolic rates of springbok are lower than the rates for a 45 kg mammal, with 55% of the predicted rate during the dry season and a higher rate of 82% during the cold, dry season (Nagy & Knight, 1994). The above-mentioned facts therefore suggest that springbok are adapted to arid habitats that usually have unpredictable food resources (Nagy & Knight, 1994).

Rutting males have metabolic rates averaging at 155% of the predicted rate and therefore have a tendency to lose weight during the rutting period. This is mainly attributed to reduced foraging time during this period (Nagy & Knight, 1994). The same phenomenon has been noted in farmed red deer stags, which had a 25 - 30% lower carcass weight when slaughtered post-rut in comparison with deer slaughtered pre-rut (Stevenson *et al*., 1992).

1.4 Social behaviour and reproduction

The following social groups can be distinguished in springbok populations: territorial males; nursery herds (female springbok and young); harem herds (nursery herd accompanied by one adult male); bachelor herds (males of ten months and older) and mixed herds (Bigalke & Van Hensbergen, 1993).

Springbok are seasonal breeders, mating occurs throughout the year and is dependent on the physiological status of the ewes, which is mediated by the nutritional value of their diet (Furstenburg, 2002). Although the breeding season of springbok is unrestricted, it is influenced by climatic changes (Skinner & Louw, 1996). The duration and timing of the male rut of springbok have been noted to be random, with no relation to any specific factor (Skinner & Van Zyl, 1970; Skinner *et al*., 1996). The duration of the male rut of springbok varies from five to 23 days (Skinner *et al*., 1996).

Springbok males start mating after 30 months of age (Furstenburg, 2002). Females can conceive before the age of 12 months and reach maximum fecundity by 24 months (Fairall *et al*., 1990). Most lambs are born in the peak of the rainfall season of the particular environment that springbok inhabit (Furstenburg, 2002). The annual, natural production increase of springbok is 28 to 42%, with an average of 33%, depending on rainfall and field conditions in their habitat. A 1000 ha optimal habitat with a rainfall that varies from 300 - 400 mm can carry 450 springbok (Furstenburg, 2002).

1.5 Cropping

It is necessary to employ efficient cropping methodology during the cropping of game species. A suitable cropping procedure must induce the least ante-mortem stress, bullet damage (wastage of meat unfit for human consumption) and wounding. The procedure employed should also be practically applicable and economically viable.

1.5.1 Factors contributing to meat losses during cropping

Three factors contributing to losses caused by the shooting of game are meat wastage (bullet damage), shot animals not being recovered and meat quality decline because of ante-mortem stress (Von la Chevallerie & Van Zyl, 1971b). The position of the shot may lead to wounding and meat wastage. A shoulder shot, for example, may result in a meat loss of ± 20%, which can be reduced to 3% by neck shots and become totally negligible with head shots (Von la Chevallerie & Van Zyl, 1971b). Head shots are the most desirable on welfare grounds (Lewis *et al*., 1997). Neck shots often result in paralysis not rendering the animal immediately insensible and heart shots lead to higher wounding percentages (Lewis *et al*., 1997).

Silinced rifles has been noted to reduce disturbances in the herds during shooting thereby increasing the percentage of animals being shot (Lewis *et al*., 1997). Males generally respond more actively to disturbances than females and show an increase in response when in breeding herds, leading to a higher percentage of animals being wounded (Lewis *et al.*, 1997).

1.5.2 Cropping procedures

Culling of wild ungulates is an important component of wildlife management as a result of the fact that game species become compressed in smaller areas (Lewis *et al*., 1997). In South Africa the commercial cropping of game species consists of the following: shooting from a helicopter or hide (day-time shooting) or night-time shooting (Hoffman, 2000; Hoffman & Ferreira, 2000). Different cropping techniques are used by croppers, but springbok are mainly cropped with shotguns from helicopters or at night using a vehicle, spotlights and high velocity small-calibre rifles (Skinner & Louw, 1996).

1.5.2.1 Night cropping

Nighttime cropping is the method of cropping often most used and is the best method for the harvesting of game (Veary, 1991; Lewis *et al*., 1997; Hoffman, 2000; Hoffman & Ferreira, 2000). The cropping operation takes place after dark with the aid of spotlights. Spotlights immobilise the animals and they are shot from a distance of between 70 to 100 m, usually in the head or neck (Onyango *et al*., 1998). This method of cropping induces less damage to and wastage of the carcass and results in less stress on the survivors (Hoffman, 2000). On welfare grounds, night shooting is a satisfactory method for the cropping of wild ungulates (Lewis *et al*., 1997).

According to Kritzinger (2002), who compared day and night-time cropping of impala (*Aepyceros melampus*), night-cropped impala had a slower rate of pH decline than those cropped in the day. Night-cropped impala had significantly lower shear force values (kg. 1.27 cm^{-1} diameter) and drip loss (%) in comparison to the animals cropped in the day. Factors such as the visibility of the croppers and noise are eliminated by night cropping and animals are more restful, resulting in a lower incidence of wounding (Kritzinger, 2002).

1.5.2.2 Day-time and helicopter cropping

Day-time harvesting involves the herding of animals towards shooting lines, Scrambler motorcycles, pick-up vehicles and horsemen are often used in these procedures (Hoffman, 2000). Day-time cropping therefore imposes the highest ante-mortem stress on animals, resulting in higher mean ultimate pH (pH_u) values in comparison with night-time or helicopter harvesting (Veary, 1991). Helicopter harvesting consists of animals shot from an altitude of 6 m using 12-bore shotguns (Hoffman, 2000). The latter method results in similar pH_u values as obtained during night shooting (Veary, 1991), but it requires extreme skill and is an expensive cropping method (Kritzinger, 2002).

1.5.2.3 Commercial cropping

Hoffman (2003) provides a detailed discussion of the commercial harvesting of springbok as presently practiced and has indicated that the methods employed result in meat that is acceptable for export to European Union (EU) countries. He also discusses the methods employed for meat inspection and to ensure complete traceability to the farm of origin. These factors are especially important if game meat is to satisfy the demands of modern consumers with regard to meat safety.

1.6 General comparison between the productivity of springbok and sheep

If the productivity of springbok and sheep is compared, Merino sheep are 46% more efficient when converting food energy into net profit due to the additional production of apparel wool and having a stable, lucrative market (Skinner *et al*., 1986). However, springbok are 19% more efficient when the conversion of food energy into saleable meat is considered (Skinner *et al*., 1986).

Springbok exhibit less over-exploitation of vegetation and have a favourable carcass composition (Davies & Skinner, 1986). Springbok, in addition, require lower management costs and provide trophy hunting potential and aesthetic appeal (Skinner *et al*., 1986). However, the disadvantages for management practices include that rotational grazing is almost impossible and harvesting procedures are more difficult (Skinner *et al*., 1986).

Lambs (18 - 22 weeks) have a dressing percentage of 46.01%, which is very low in comparison to springbok of the same age, and this may be attributed to the fleece and skin yield of sheep (Van Zyl *et al*., 1969). According to Skinner *et al*. (1986), springbok and sheep have a mean dressing percentage of 56 and 48% respectively.

1.7 Chemical composition

1.7.1 Moisture

Water is mainly present in the spaces between the thin (actin/tropomyosin) and thick (myosin) filaments of the muscle (Lawrie, 1985) and is the largest component of muscle by weight. It is well known that the tenderness, texture and juiciness of meat depends on the amount of water and the extent to which it is bound by the muscle components (Paul & Palmer, 1972). It can be seen in Table 2 that the moisture content of the different game species varies between 74.7 and 75.7%, with springbok meat having an average moisture content of 74.7% (Skinner & Louw, 1996). An inverse correlation exists between moisture and the intramuscular fat (IMF) content of meat (Sales, 1995; Rowe *et al*., 1999), and venison species therefore will have a higher moisture content than other domesticated species.

Table 2 Moisture and fat composition of springbok in comparison with other game species (Skinner & Louw, 1996).

	Springbok	**Eland**	**Impala**	**Blesbok**
Moisture (%)	74.7	74.8	75.7	75.5
Buttock fat (%)	1.7	2.4	1.4	1.7

1.7.2 Protein and amino acid composition

Meat is an important source of protein with a high biological value and is rich in essential amino acids (Higgs, 2000). Essential amino acids must be supplied by the diet and include the following: isoleucine, leucine, lysine, methionine, cystine, phenylalanine, threonine, tryptophan, valine, arginine and histidine (Lawrie, 1985). The non-essential amino acids are alanine, aspartic acid, glutamic acid, glycine, proline, serine and tyrosine. Amino acid profiles do not vary much between different species (Sales, 1995). The amino acid content of meat may be altered during processing, although destruction is minimal when processing conditions are not severe or prolonged (Lawrie, 1985).

1.7.3 Fat and fatty acid composition

Venison has a very low fat content and therefore will have a higher protein, sodium and moisture content than other red meat because the latter are mainly contained within the lean portion of the meat (Aidoo & Haworth, 1995). The mean fat content of springbok has been reported to never exceed 4% (Von la Chevallerie & Van Zyl, 1971a; Skinner & Louw, 1996). According to Ledger *et al*. (1967), the female gender of ungulate species generally has a slightly higher IMF content than males and, with an increase in animal age, the carcass fat content tends to increase (Lawrie, 1985; Volpelli *et al*., 2003). Springbok meat has been noted to have a lower total lipid content in comparison to beef (four-folded) (Viljoen, 1999). Table 2 shows that the buttock fat percentage of the different game species varies between 1.4 and 2.4%, with springbok having an average IMF content of 1.7%.

In comparison to beef, springbok has a lower level of saturated fatty acids, especially myristic acid (C14:0) and palmitic acid (C16:0) (Viljoen, 1999), which have serum-cholesterol-highering attributes *in vitro*. Springbok meat has a high concentration of arachidonic acid, which is a highly polyunsaturated fatty acid (PUFA) with serum-cholesterol-lowering attributes. Highly polyunsaturated fatty acids that are not found in beef have been noted in springbok meat (C20:5, C22:4 and C22:6) (Viljoen, 1999). The fatty acid composition (mg. 100 g^{-1}) of springbok meat and its effect on serum-cholesterol levels are presented in Table 3. There is a higher level of fatty acids (6514.26 mg. 100 g^{-1}) with serum-cholesterol-lowering and neutral attributes in the different cuts of springbok (Table 3). However, different cuts of only one springbok were analysed (Viljoen, 1999), which is not representative, and no indication of IMF content or age category are given.

Table 3 Composition of fatty acids (mg. 100 g^{-1}) in springbok meat and their effect on serum-cholesterol (Viljoen, 1999).

Cuts	**Fatty acids with serum-cholesterol highering attributes (mg. 100 g^{-1})**	**Fatty acids with serum-cholesterol lowering and neutral attributes (mg. 100 g^{-1})**	**Fatty acids with unknown effect on serum-cholesterol (mg. 100 g^{-1})**
Shoulder	398.54	1244.36	40.01
Brisket and flank	577.76	1565.58	44.78
Neck	450.07	1312.35	32.88
Loin	427.42	1292.48	35.58
Buttock	343.02	1099.49	22.09
Total	**2196.81**	**6514.26**	**175.34**

Some of the factors influencing the fatty acid profile of meat are the type of feed consumed and the level of carcass fatness (Wood & Enser, 1997). There is an increasing trend in the absolute fatty acid and total lipid content of older animals (Volpelli *et al*., 2003). According to Volpelli *et al*. (2003), older deer show an increase in mono-unsaturated fatty acids (MUFA), with younger deer having a higher content of both n-3 and n-6 polyunsaturated fatty acids (PUFA), although similar n-6:n-3 ratios were observed between the two age categories. The n-6:n-3 ratio in Western diets averages at 10, which is well above the preferred ratio of 5 (Sañudo *et al*., 2000). According to Girolami *et al*. (2003), the ideal n-6:n-3 ratio is 1 and the recommended maximum is 4. In general, grazing ruminants produce muscle with a desirable n-6:n-3 PUFA ratio (Wood & Enser, 1997). The ratio of PUFA's to saturated fatty acids (SFA) (P:S) of products is very important to the health conscious consumer. A low saturated to polyunsaturated ratio or high oleic acid content is important to reduce the risk of cardiovascular diseases (Harrington, 1994). A high PUFA content in meat increases the risk of oxidation and therefore influences the shelf life of meat (Tshabalala *et al*., 2003).

1.7.4 Mineral composition

Meat is an important source of essential minerals that are required by the human diet (Zarkadas *et al*., 1987). Potassium (K) is quantitatively the most abundant mineral in several meat types, followed by phosphorus (P) (Lawrie, 1985). Red meat, in addition, is an important contributor of iron (Fe), with 50 to 60% of the iron in the haem form (Higgs, 2000).

The heam form of iron is more effectively absorbed than the non-heam form, which is found in plant foods (Higgs, 2000). Meat is also considered to be an important source of zinc (Zn) and magnesium (Mg) as a result of their high bioavailability (Lin *et al*., 1989).

The mineral composition of meat may be influenced by physiological, genetic and environmental factors (Zarkadas *et al*., 1987). Other factors, such as the concentration of minerals in the diet, hormones, age, gender, geographical region (Doyle, 1980) and retail cut (Doornenbal & Murray, 1981; Lin *et al*., 1989) are also known to influence the mineral composition of meat.

1.8 Physical characteristics

1.8.1 pH

When the muscle enters rigor, the hydrogen ion (H^+) production decreases with a decrease in the anaerobic glycolysis rate and myosin ATPase activity as the muscle is cooled (Bruce *et al*., 2001). This leads to a deviation in pH decline from a linear function (Bruce *et al*., 2001) and is best described by an exponential decay curve. According to Bendall & Davey (1957), the pH decline rate of the muscle is further slowed by the buffering effect of ammonia that is formed from adenosine monophosphate (AMP) deamination. The muscle temperature has an effect on the muscle buffers and causes an increase in pH (0.1 pH unit) for every 10°C decrease in temperature (Bendall & Wismer-Pederen, 1962).

Ante-mortem stress imposed on animals leads to a low glycogen content in the muscle, resulting in a higher ultimate pH (pH_u), a quality defect that is known to reduce meat shelf life (Wiklund *et al*., 1995; Viljoen *et al*., 2002). Dark, firm and dry (DFD) meat is classified as having a pH_u above 6.2, whereas intermediate DFD meat has a pH_u that ranges from 5.8 to 6.2 (Wiklund *et al*., 1995). Generally, the male gender of game species tends to have a higher pH_u than the females due to their more active response to disturbances, especially when cropping occurs during the rutting season (Lewis *et al*., 1997; Hoffman, 2000). According to Hoffman (2000), who researched the meat quality attributes of night-cropped impala (*Aepyceros melampus*), the males had a higher pH_u of 5.82, in comparison with the females (pH = 5.70), due to their more excitable state after the rutting season. A wounded animal in that investigation had the highest mean pH_u and showed the fastest rate of pH decline. This observation was supported by the pH decline constants of the exponential decay curve (a = 6.084; b = 2.292; c = -0.786).

The isoelectric point of muscle protein is approximately at pH 5.5, at which point the muscle protein exhibits its lowest water-binding capacity (WBC) and solubility, accounting for higher water loss through evaporation and drip loss (Swatland, 1984). High temperature conditions and low pH in postmortem muscles leads to protein denaturation and consequently a decrease in the WBC of meat (Offer & Knight, 1988; Honikel, 1998). The fluid consequently accumulates between the fibre bundles of the meat and, when the meat is cut the fluid drains under gravity from the surface, forming drip (Honikel, 1998).

Meat proteins denature at temperatures that vary from 37 to 75ºC during heating (Honikel, 1998). Structural changes that occur include cell membrane destruction, shrinkage (transverse and longitudinal) of muscle fibres, connective tissue shrinkage and aggregation of sarcoplasmic proteins (Honikel, 1998). The cooking loss of meat increases extensively with an increase in temperature from 75 to 80°C, probably as a result of protein denaturation (Bowers *et al*., 1987; Aaslyng *et al*., 2003). Meat that is classified as DFD tends to have lower cooking losses (Katsaras & Peetz, 1990).

1.8.2 Tenderness

The consumer considers tenderness to be the most important factor determining meat quality (Koohmaraie *et al*., 2003). A high quality meat product will therefore be defined by the consumer as one that is consistent in tenderness. Tenderness inconsistency is a result of the variability in the tenderisation process and the amount of ageing time that is allowed (Koohmaraie *et al*., 2003). In addition, meat tenderness is affected by the pH_u (Devine *et al*., 1993), the state of muscle contraction (Smith *et al*., 1971), postmortem temperature (Pierson & Fox, 1976) and the enzymatic proteolysis of myofibrillar proteins (Yu & Lee, 1986).

Meat tenderness may also vary between animals, between muscles within the same animal and within different parts of the same muscle (Tornberg *et al*., 1985). In general, an increase in animal age is association with a decrease in meat tenderness (Lawrie, 1985).

Myofibrillar toughness is affected by two processes, namely the development of rigor mortis and enzymatic tenderisation (Hertzman *et al*., 1993). The extent of postmortem glycolysis has an effect on the tenderness of beef, pork and lamb, with a decrease in tenderness as the pH_u increases from 5.5 to 6.0 (Lawrie, 1985; Watanabe *et al*., 1996). However, at ultimate pH (pH_u) values above 6, tenderness increases again. The rate and extent of glycolysis have an effect on the pH and temperature of the muscle and therefore may influence the rate and extent of proteolytic enzyme activity and thus the postmortem tenderisation process (Koohmaraie *et al*., 1986). There is an increase in tenderness as the pH_u rises from 6 to 7 due to greater calpain activity, which is maximal at a neutral pH (Yu & Lee, 1986). Increasing tenderness at a pH_u below 6.0 is attributed to acidic protease activity (Yu & Lee, 1986). It has been suggested (Yu & Lee, 1986) that proteolytic activity decrease at pH 5.8 to 6.3.

The solubility and content of collagen connective tissue in the meat are also known to affect meat tenderness (Bruwer *et al*., 1987; Devine *et al*., 1993). Intramuscular connective tissue is regarded as a background level of toughness and is determined solely by the degree of covalent cross-linkages between tropocollagen units, which increase with animal age (Swatland, 1984). Collagen solubility therefore declines significantly with an increase in animal age, with the M. *longisimus dorsi* muscle being no exception (Devine *et al*., 1993). The higher the insoluble collagen content, the tougher the meat (Tshabalala *et al*., 2003).

1.8.3 Colour

Meat colour is the basis of product acceptability and critical appraisal by the consumer (Stevenson *et al*., 1989), since colour affects the visual appeal of meat (Hopkins & Fogarty, 1998). Red meat colour is one of the most important criteria used by consumers to select meat and is used as an indication of freshness (Jeremiah *et al*., 1972). Consumers prefer meat with a normal colour and meat which is too dark or too pale is discriminated against (Issanchou, 1996; Viljoen *et al*., 2002). CIE L*, a* and b* (CIELAB) values are appropriate measures of colour (Stevenson *et al*., 1989). The hue-angle and the a* and b* chroma are psychometric correlates of perceived hue and chroma (Setser, 1984). L* indicates lightness and the a* and b* values are chromaticity coordinates. The general type of colour, such as red, for example, is called the hue and the intensity of the colour is determined by the chroma (Swatland, 1984). High a* and b* values result in higher saturation (S) and leads to brighter colour with greater colour purity (Onyango *et al*., 1998).

The lightness (paleness) of meat is directly influenced by the pH_U and the total haemoprotein content of the muscle, as these pigments determine the intensity of the perceived colour (Hector *et al*., 1992). In South Africa, venison has a dark, unattractive red colour (Hoffman, 2000) that is similar to beef that is classified as dark, firm and dry (DFD) meat (Viljoen *et al*., 2002). The L*, a* and b* values that are characteristic of the dark red colour of venison are L* < 40, high a* values and low b* values (Volpelli *et al.*, 2003).

Myoglobin is a soluble protein that is formed from a single polypeptide chain that is twisted around an oxygen-carrying heme group. The transformation of myoglobin to oxymyoglobin is seen after cutting the anaerobic centre of meat (Swatland, 1984). After prolonged atmosphere exposure, the iron atom of myoglobin are converted to the ferric form, forming brown metmyoglobin. The latter occurs rapidly under the meat surface (Swatland, 1984). The derivatives of myoglobin absorb or reflect different amounts of light at different wavelengths (colours) (Swatland, 1984). Myoglobin has also been reported to increase with increasing age of the animal (Onyango *et al*., 1998). In addition, an inverse correlation ($p < 0.01$) was noted between the lightness and the myoglobin content of meat (Onyango *et al*., 1998).

An elaboration of myoglobin occurs during systematic exercise (Lawrie, 1998). The dark colour of game meat therefore may also be attributed to elevated levels of myoglobin in the muscle and this may be a result of systematic exercise in comparison to traditionally farmed animals (Hoffman, 2000; Vestergaard *et al*., 2000). Hoffman (2000) noted that a wounded impala (*Aepyceros melampus*) showed faster pH decline and had a high pH_u and consequently also had the darkest meat. This was supported by the following CIELab values: L* = 25.44; a* = 9.13; b* = 4.88. Ante-mortem stress imposed on the animal will therefore contribute to glycogen depletion, leading to high pH_u values (Wiklund *et al*., 1995) and therefore darker meat colour (Hoffman, 2000).

1.9 Sensory attributes

The components of the palatability of meat include tenderness, juiciness and flavour. The combination of these attributes determines the overall eating satisfaction (Koohmaraie *et al*., 2003). Of these attributes, tenderness is considered by consumers to be the most important factor influencing meat quality (Strydom *et al*., 2000; Aaslyng *et al*., 2003; Koohmaraie *et al*., 2003).

1.9.1 Juiciness

The tender texture of meat does not only indicate ease of penetration during mastication, but also embraces the juiciness level of the meat (Tornberg *et al*., 1985). An absence of juiciness limits the overall palatability of the meat, regardless of all the other organoleptic characteristics. Meat juiciness is a combination of moisture chewed out of the meat as well as saliva production during mastication (Aaslyng *et al*., 2003). Meat juiciness therefore has two organoleptic components, namely initial and sustained juiciness. Initial juiciness is the impression of juiciness after the first few chews and sustained juiciness is influenced by the infiltration of fat (Lawrie, 1985). According to Skinner & Louw (1996) the mean fat content of springbok carcasses never exceeds 4% and therefore springbok has the potential to be marketed as a health product. However, some fat is necessary in meat to impart juiciness and flavour (Melton, 1990; Tshabalala *et al*., 2003). In beef it has been assessed that juiciness and cooking loss are negatively correlated (Toscas *et al*., 1999). A high cooking loss therefore leads to less optimal eating quality (Aaslyng *et al*., 2003). High temperature conditions and low pH in postmortem muscles leads to protein denaturation, decreasing the water-binding capacity (WBC) of meat (Offer & Knight, 1988; Honikel, 1998), which may lead to a decrease in the perceived juiciness of the meat.

1.9.2 Tenderness

Meat tenderness is regarded by the consumer as one of the most important components of meat quality (Koohmaraie *et al*., 2003). The tenderness and acceptability of meat are therefore closely related (Toscas *et al*., 1999). This relationship is confirmed by the positive correlation that exists between cut price and the relative tenderness of the meat (Savell & Shackelford, 1992). Tender texture of meat indicates the ease of penetration through the meat during mastication (Tornberg *et al*., 1985). In general, an increase in meat tenderness means that juices are released more rapidly by chewing and less connective tissue residue remains after mastication (Tshabalala *et al*., 2003).

Both sensory and instrumental methods are used for the evaluation of meat tenderness. According to Tornberg (1996), sensory evaluation of meat texture is the ultimate test. Sensory panels are used widely for meat evaluation (Toscas *et al*., 1999), although this method of evaluation is very labour- and time-consuming (Tornberg *et al*., 1985). The Warner-Bratzler (WB) shear device has long been recognised as the mechanical method of tenderness evaluation that is quantitatively used the most (Moller, 1980-1981). The latter instrument determines the maximum peak force that is required to shear a sample of meat with a certain cross-sectional area at a right angle to the fibre direction (Moller, 1980-1981). This method of tenderness evaluation correlates the best with sensory panel scores for meat tenderness evaluation (Tornberg, 1996).

1.9.3 Flavour and aroma

Meat flavour is determined by a combination of aroma, taste and overall mouthfeel during mastication (Jansen van Rensburg, 1997). The flavour intensity of meat is positively correlated with its fat content (Tshabalala *et al*., 2003). Meat flavour is influenced by the composition of the animal's diet, which is known to alter the fatty acid composition of the meat (Tshabalala *et al*., 2003). The fat composition of ruminant meat therefore contributes to its sensory properties by affecting the degree of fat saturation (Webb *et al*., 1994). Both volatile fatty acids and long-chain fatty acids, for example, contribute to the flavour of lamb (Webb *et al*., 1994). According to Swanson & Penfield (1991), the high level of polyunsaturated fatty acids in venison contributes to the gamey flavour that many consumers find unacceptable. A higher proportion of unsaturated fatty acids in mutton could be negatively correlated with meat flavour intensity (Webb *et al*., 1994).

Fat traps and carries aroma compounds that improve taste (Enser, 1995). Aroma compounds of meat are more soluble in fat and are retained for longer in the matrix (De Roos, 1997). Therefore, when the meat is more lean, the aroma compounds become volatile faster and are released together with water vapour (aroma perception) (Tshabalala *et al*., 2003). The aroma compounds will thus be retained for longer in the more fatty tissue and will then be perceived as flavour during mastication.

1.10 Conclusion and objective

The South African game industry has shown extensive growth during the past years, as can be seen from the literature. Venison production is a growing utilisation form of the game industry and exports to the European Union are increasing rapidly. Many aspects of the meat quality of wild ungulates are poorly documented and it is therefore imperative that species-specific research becomes a priority. The extent to which age, gender and production region may influence the meat quality of springbok with regard to its chemical, physical and sensory quality needs to be quantified. This data is of invaluable importance to the game industry, since it may affect the consistency of the meat quality of wild ungulates. The objective of this study was therefore to determine the meat quality of springbok and to quantify the effect of the above-mentioned factors on the overall meat quality of springbok.

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CHAPTER 3

MORPHOLOGICAL AND CARCASS YIELD CHARACTERISTICS OF SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) AS INFLUENCED BY AGE, GENDER AND PRODUCTION REGION

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ABSTRACT

The effects of age (adult, sub-adult, lamb), gender and production region on the and morphological and carcass yield characteristics of springbok (n = 149) were evaluated in this study. Springbok were sampled from three nature reserves (Gariep, Rustfontein and Willem Pretorius) and from a farm in the Caledon district of South Africa. A significant ($p < 0.05$) gender and age interaction was observed for live mass (kg). The live mass of the adult males (31.74 ± 0.70 kg) was significantly ($p < 0.05$) higher than that of the adult females (28.33 ± 0.60 kg). No significant differences were observed between the live mass of the two genders in the sub-adult category. The dressing percentage of the males (58.83 ± 0.53%), irrespective of age, was significantly ($p < 0.05$) higher in comparison with the females (55.79 ± 0.50%). Dressing percentages of the different age categories of springbok varied between 55.9 and 59.0%. Morphological measurements (cm) of the carcasses included the length, width, depth, leg length, buttock and chest circumference. The effects of age on the carcass measurements were noted to be significant increases in these measurements with increasing age. Gender, however, had no significant effect on the carcass measurements taken.

Keywords: body weight; length; dressing percentage; gender; age

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INTRODUCTION

The importance of springbok to the game industry and to game meat production is emphasised by the fact that springbok, eland, blesbok, impala and kudu are the most common game species ranched in South Africa (Conroy & Gaigher, 1982). However, springbok is the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999), probably as a result of their numeric abundance and distribution (Fairall *et al*., 1990).

The live mass of male and female adult springbok has been noted to average at 36.57 and 29.91 kg, respectively (Von la Chevallerie & Van Zyl, 1971). The carcass mass (kg) of male and female adults were noted to averaged at 20.58 and 16.95 kg respectively (Von la Chevallerie & Van Zyl, 1971). Fairall *et al*. (1990), however, reported that the mean live mass of male and female adult springbok on a farm in the Karoo averaged at 31.5 and 27.1 kg respectively. The carcass mass of the male and female adults was noted to average at 18.3 and 14.9 kg respectively (Fairall *et al*., 1990). It is therefore evident that the live mass of springbok originating from different localities may vary. Variation in the live weight of wild ungulates may occur because of the effect of the different localities on the quality and quantity of the vegetation and hence the available nutrients (Von la Chevallerie, 1970; Furstenburg, 2002).

Both sexes of springbok exhibit a rapid increase in total body mass up to an age of 28 weeks, followed by a slower weight gain up to 52 weeks (Von la Chevallerie & Van Zyl, 1971). The dressing percentage of springbok (up to age 28 weeks) varies between 54.5 and 58.5% (Von la Chevallerie & Van Zyl, 1971). Fairall *et al*. (1990), however, noted that young (3-6 months) male and female springbok have a dressing percentage of 56.1% and 53.3% respectively. For older animals, the dressing percentage increased to 58.8% and 55.0% respectively. According to Hoffman & Bigalke (1999) the carcass yield of wild ungulates varies between 56 and 66% of their live weight. It has been reported (Van Zyl *et al*., 1969) that sheep lambs (18 - 22 weeks) have a dressing percentage of 46.01%, which is very low in comparison with springbok of the same age. In addition, the dressing percentage of beef (*Bos indicus*) have been noted to average at 51.0 ± 1.5%, which is lower than that of the various game species evaluated (Onyango *et al*., 1998).

The carcass length and buttock circumference of springbok have been noted to have similar growth curves that increase rapidly to about 28 weeks and then decline (Von la Chevallerie & Van Zyl, 1971). However, data on the morphological characteristics and carcass yield of springbok are limited.

The purpose of this study therefore was to evaluate morphological characteristics and to quantify the effect that age, gender and production region may have.

MATERIALS AND METHODS

Animals and sampling

Springbok (n=149) were sampled from three nature reserves (Gariep, Rustfontein and Willem Pretorius) in the Free State region and from a farm in the Caledon district of South Africa.

The Free State Province's largest nature reserve is a combination of the 36 487 ha Gariep Nature Reserve on the Orange River and an 11 237 ha game sanctuary on its northern shore. The Gariep Nature Reserve accommodates a large population of springbok, black wildebeest and red hartebeest. The Rustfontein Nature Reserve is a 1000 ha reserve that accommodates springbok, black wildebeest and blesbok, amongst other species (Hocking *et al*, 1983). The Willem Pretorius Nature Reserve (WP) is an 10 520 ha game reserve that accommodates springbok, black wildebeest, blesbok, red hartebeest, eland, zebra, impala and white rhino (Bulpin, 1992).

Springbok originating from the three nature reserves were randomly harvested at night by a professional culling team using spotlights (1 million candela) and small calibre rifles, similar to the method described by Lewis *et al*. (1997). The springbok originating from Caledon were also harvested at night using a similar procedure as described above, except that all the shooters were inexperienced, which resulted in a higher incidence of missed shots and wounded animals (n = 7). All the springbok in this herd were cropped. Animals were sighted directly or by the reflection of the light from their retinas. The shots were either head or high neck shots, resulting in immediate insensibility.

The ages of the springbok were calculated using the length and size of the horns as parameters (Rautenbach, 1971). The springbok were divided into three age categories, namely adult (2 to 5 years), sub-adult (1 to 2 years) and lamb (0 to 1 year).

After harvesting, the animals were exsanguinated within 2 to 5 min. by cutting the throat with a sharp, sterile knife. Each carcass was then individually tagged with an identification number and hung from the Achilles tendons to promote bleeding. After the targeted number of antelope had been harvested, the carcasses were taken to a nearby abattoir for processing. This included skinning, evisceration and cleaning of carcasses according to South African practices (Hoffman, 2000). During commercial cropping procedures, the carcasses are transported to the processing plant with the skin on (Hoffman, 2003). The springbok cropped at Caledon were transported in this manner. The carcasses were cooled to 4°C approximately five to eight hours after cropping (depending on the time the animals were shot).

Physical measurements

Live mass (kg) was taken immediately after exsanguination. Cold carcass mass (kg) was recorded 24 hr postmortem. The dressing percentage of the springbok was expressed as the proportion of the chilled dressed carcass to the live mass. The physical measurements (cm) of the carcasses included length, width, depth, chest circumference, buttock circumference and leg length. The length, width and depth of the carcass were measured after slaughter, using a steel slide-rule. The other measurements were taken using a standard tape measure.

The carcass length was measured from the base of the neck to the base of the tail at the juncture with the pelvis. Width was measured between the widest points of the rib cage posterior to the forelegs. The depth of the carcass was measured from the spine to the sternum. The chest circumference was measured around the chest posterior to the forelegs and the buttock circumference was taken at the top of the leg at the juncture with the abdomen. Data on the sample distribution of the springbok with regard to age, gender and production region for the live mass, carcass mass and dressing percentage determinations are presented in Table 1. Data for the springbok with regard to the physical measurements (cm) are presented in Table 2.

Table 1 Data of sample distribution of springbok (n=149) according to age, gender and production region for the live mass, carcass mass and dressing percentage determinations.

	Gariep		**Willem Pretorius**		**Rustfontein**		**Caledon**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Adult	15	5	5	1	13	24	.	.
Sub-adult	10	8	3	5	1	6	7	27
Lamb	5	1	4	1	1	2	2	3
Total	**30**	**14**	**12**	**7**	**15**	**32**	**9**	**30**

Table 2 Data of sample distribution of springbok (n=127) according to age, gender and production region for the physical measurements (cm) of the carcasses.

	Gariep		Willem Pretorius		Rustfontein		
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Total**
Adult	21	6	5	1	13	24	70
Sub-adult	12	12	3	5	1	6	39
Lamb	7	3	4	1	1	2	18
Total	**30**	**14**	**12**	**7**	**15**	**32**	**127**

Statistical analyses

A three-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were the four regions (Gariep, Willem Pretorius, Rustfontein and Caledon), three age groups (adult, sub-adult and lamb) and two genders (male and female). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to analysis of variance (ANOVA) using SAS version 8.2 statistical software (SAS, 1999). The Shapiro-Wilk test was performed for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference was calculated at the 5% confidence level to compare treatment means (Ott, 1998).

RESULTS AND DISCUSSION

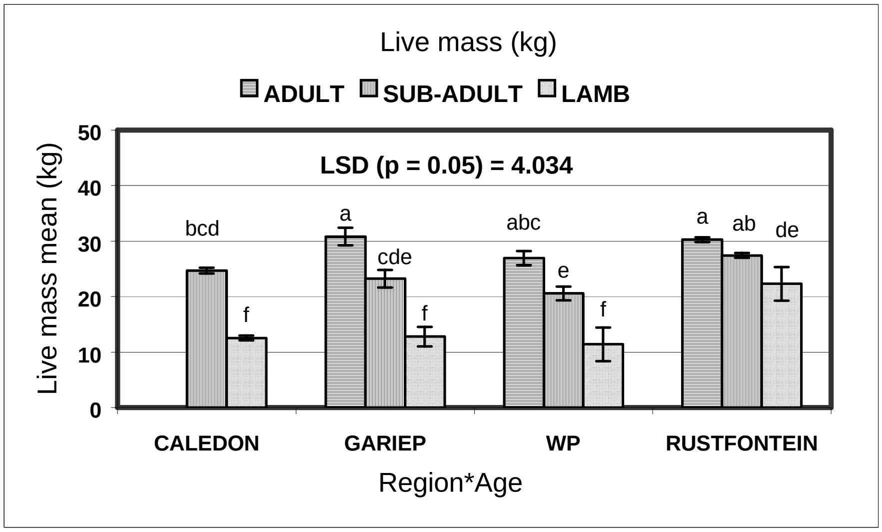
The analysis of variance (ANOVA) of the live mass (kg) and carcass mass (kg) of springbok sampled from different production regions and divided into age and gender categories is presented in Table 3. Significant interactions between the main effects were observed for the live and carcass mass (kg) variables. A significant production region and age interaction (Table 3) was observed for the mean live mass ($p = 0.0068$) and carcass mass ($p = 0.0075$) variables. These interactions are depicted in Figures 1 and 2, respectively.

Table 3 Analysis of variance (ANOVA) of the live mass (kg) and carcass mass (kg), with age, gender and production region as main effects, as well as the interactions between the main effects.

		Live mass (kg)			Carcass mass (kg)	
Main effects	**df**	**MS**	**p**	**df**	**MS**	**p**
Production region	3	482.781	< 0.0001	3	93.169	< 0.0001
Age	2	1436.490	< 0.0001	2	640.340	< 0.0001
Production region * Age	5	51.580	0.0068	5	26.679	0.0075
Gender	1	45.538	0.0868	1	73.303	0.0023
Production region *Gender	3	59.121	0.0110	3	32.520	0.0006
Gender*Age	2	59.802	0.0225	2	16.704	0.0944
R*G*A	5	16.395	0.3787	5	6.538	0.6488
Error	127	15.286	.	144	4.819	.

df - Degrees of freedom
MS - Mean square
p - Probability value of F-ratio test
*Interaction between main effects
R*G*A - Interaction between production region, gender and age categories

The springbok (n = 39) originating from the Caledon region consisted of only sub-adults and lambs (Table 1). The live mass (kg) of these sub-adults (24.68 ± 0.51 kg) and lambs (12.54 ± 0.43 kg) differed significantly ($p < 0.05$) (Figure 1), as expected. The live mass of the adults, sub-adults and lambs originating from Gariep differed significantly ($p < 0.05$) and averaged at 30.82 ± 1.13, 23.23 ± 1.58 and 12.80 ± 1.76 kg respectively. The same trend was observed for springbok originating from Willem Pretorius. The adults, sub-adults and lambs differed significantly ($p < 0.05$) in their live mass which averaged at 26.92 ± 0.66, 20.56 ± 1.26 and 11.40 ± 3.03 kg respectively. The adults (30.26 ± 0.58 kg) and sub-adults (27.40 ± 0.43 kg) originating from Rustfontein (n = 47) did not differ significantly ($p < 0.05$) in their live weight, although both differed significantly from the lamb (22.30 ± 0.65 kg) category. The springbok randomly sampled from Rustfontein Nature Reserve consisted mainly of adult animals. This indicates that there were skew ratios between the different age categories of the randomly cropped springbok, which may have influenced the data.

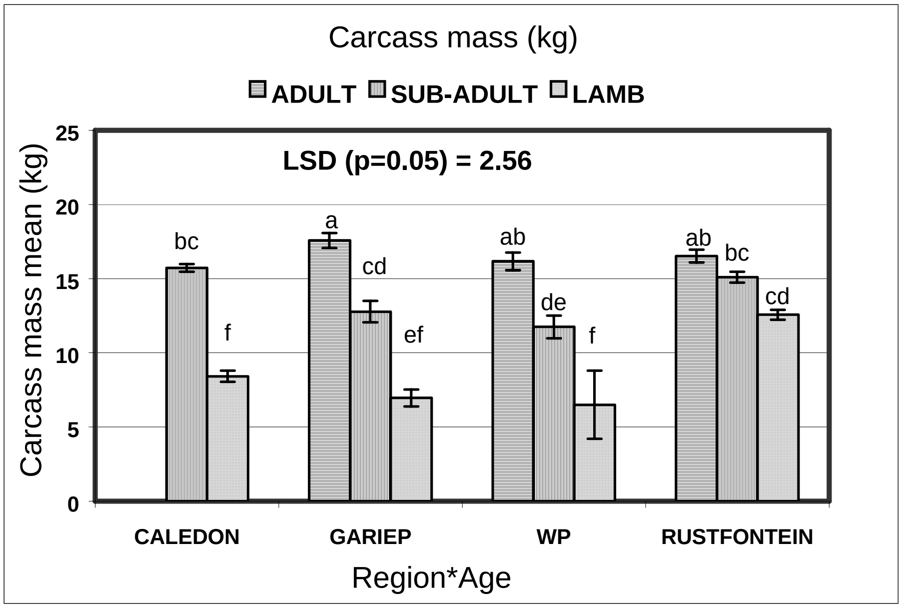


[a,b,c] Columns with different letters are significantly different within trait ($p < 0.05$).

Figure 1 Live mass (kg) means for the production region and age (Region*Age) interaction ($p = 0.0068$).

The carcass mass variable also showed a significant ($p = 0.01$) production region and age interaction (Table 3, Fig 2). Sub-adult (15.72 ± 0.26 kg) and lamb (8.42 ± 0.38 kg) springbok originating from Caledon differed significantly ($p < 0.05$) in their mean carcass mass (Figure 2). The Gariep region also showed significant differences between the carcass mass of the adult, sub-adult and lamb categories and averaged at 17.57 ± 0.50, 12.78 ± 0.72 and 6.96 ± 0.57 kg respectively. The same trend was observed for springbok cropped in the Willem Pretorius Nature Reserve. The carcass mass of the adults (16.17 ± 0.60 kg), sub-adults (11.75 ± 0.77 kg) and lambs (6.50 ± 1.79 kg) from this region differed significantly ($p < 0.05$). The Rustfontein region was noted to be the only production region that did not show a significant difference between the carcass mass of the adults (16.53 ± 0.43 kg) and the sub-adults (15.10 ± 0.36 kg), although both differed significantly ($p < 0.05$) from the lamb category (12.57 ± 0.33 kg) (Figure 2). A similar trend was also observed for the mean live mass (kg) values.

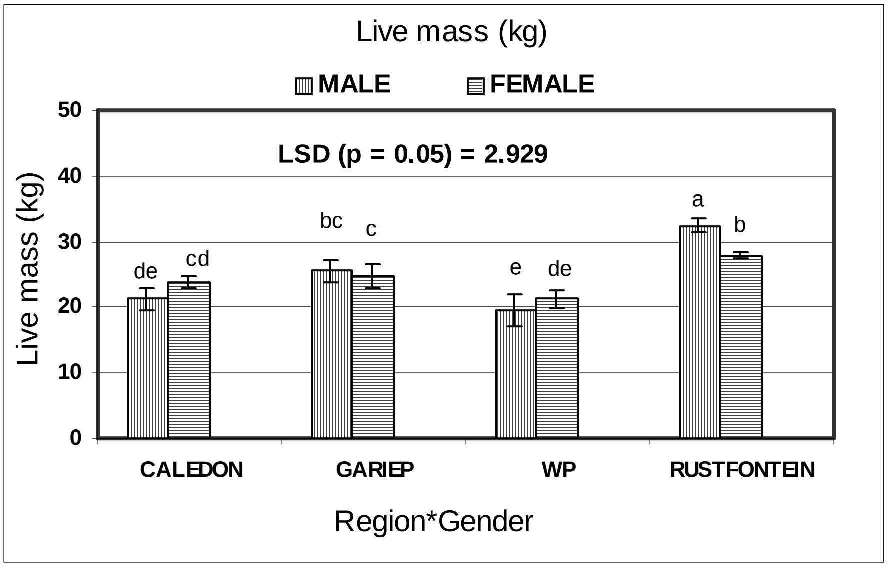
A significant production region and gender interaction (Table 3) was observed for the mean live mass ($p = 0.01$) and carcass mass ($p = 0.0006$) variables. These interactions are depicted in Figures 3 and 4, respectively.



[a,b,c] Columns with different letters are significantly different within trait ($p < 0.05$).

Figure 2 Carcass mass (kg) means for the production region and age (Region*Age) interaction ($p < 0.01$).

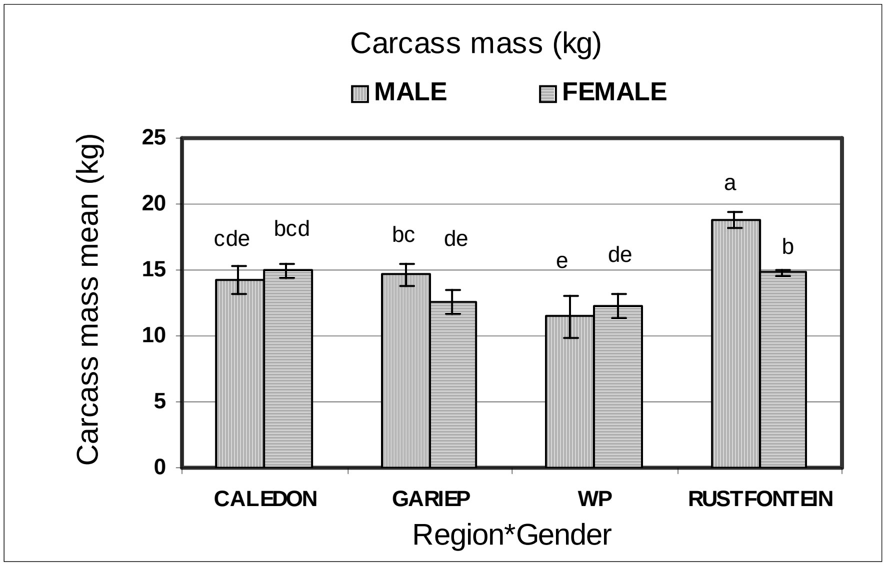
There was no significant ($p > 0.05$) gender effect (Figure 3) on the live weight of springbok originating from Caledon and this could be attributed to the fact that this sample group consisted of only sub-adults and lambs. When the effect of gender, irrespective of age category, was evaluated, the males (25.51 ± 1.61 kg) from Gariep had a higher mean live mass than the females (24.70 ± 1.96 kg), although not significant. The springbok from the Rustfontein region were mainly adults and significant differences were consequently observed between the mean live mass of the two genders. The live mass of male and female springbok from this production region averaged at 32.46 ± 1.15 kg and 27.85 ± 0.40 kg respectively (Figure 3). Gender does not significantly influence the live weight of young springbok up to an age of 28 weeks (Von la Chevallerie & Van Zyl, 1971). In most species, the males are heavier than the females and will therefore also have higher carcass yields (Smithers, 1983). As far as meat production is concerned, live mass differences between the sexes of wild ungulates become apparent in the adult category (Von la Chevallerie, 1970; Hoffman, 2003).



[a,b,c] Columns with different letters are significantly different within trait ($p < 0.05$).

Figure 3 Live mass (kg) means of the production region and gender (Region*Gender) interaction ($p = 0.01$).

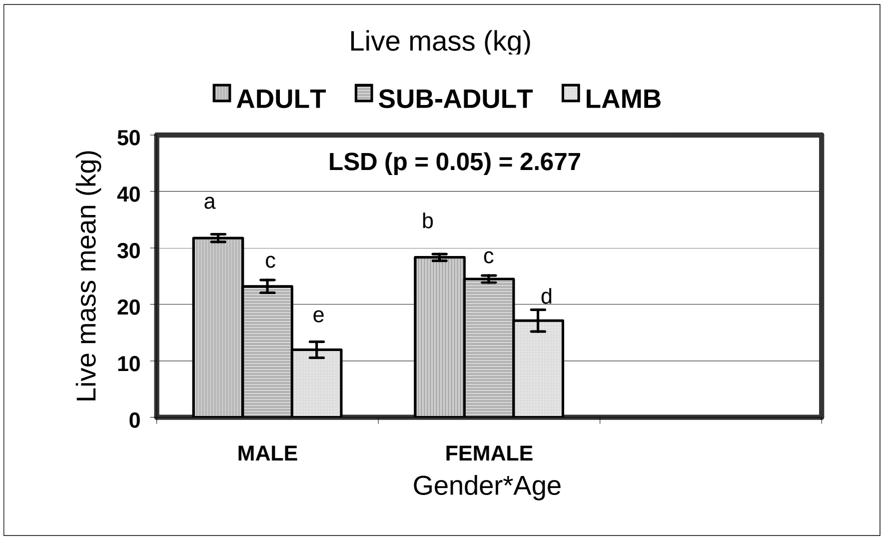
The carcass mass of the males and females originating from Caledon averaged at 14.97 ± 0.51 and 14.19 ± 1.08 kg respectively, but did not differ significantly (Figure 4). The effect of gender, irrespective of age category, was evaluated and skew gender and age combinations may have influenced the data. The carcass mass of springbok originating from Gariep were influenced significantly ($p < 0.05$) by gender, with the males (14.64 ± 0.79 kg) having a higher mean carcass mass than the females (12.62 ± 0.90 kg). However, this trend was not observed for Willem Pretorius, where it was noted that the males (11.46 ± 1.57 kg) did not have a significantly ($p < 0.05$) higher mean carcass mass than the females (12.28 ± 0.92 kg). The same trend observed in the Gariep region was noted for the Rustfontein region, where the males had a significantly ($p < 0.05$) higher mean carcass mass (18.73 ± 0.62 kg) than the females (14.82 ± 0.26 kg), irrespective of age category. It is important to note that variation in the live mass and the carcass mass of the springbok may occur because locality could influence the live weight of antelope by determining the quality and quantity of the vegetation and hence the available nutrients (Von la Chevallerie, 1970). In addition, possible skew ratios between gender and age may have influenced the data.



[a,b,c] Columns with different letters are significantly different within trait ($p < 0.05$).

Figure 4 Carcass mass (kg) means for the production region and gender (Region*Gender) interaction ($p = 0.0006$).

A significant ($p = 0.02$) gender and age interaction (Table 3, Figure 5) was observed for the live mass variable. In the adult category, the males and females differed significantly ($p < 0.05$) in their live weight, which averaged at 31.74 $\pm$ 0.70 and 28.33 $\pm$ 0.60 kg respectively. The live mass of springbok has been noted to vary geographically (Robinson, 1979) from 31.1 to 47.6 kg (x = 41.0) in males and from 26.5 to 43.5 kg (x = 37.1) in the females (Skinner & Smithers, 1990). The live mass of the adult springbok in this investigation lay well within these parameters. The mean live mass of the males and females in the sub-adult category averaged at 23.19 $\pm$ 1.13 and 24.49 $\pm$ 0.62 kg respectively and did not differ significantly ($p < 0.05$). This is in agreement with the fact that live mass differences between genders become apparent only in adult animals. In the lamb category, the females (17.14 $\pm$ 1.93 kg) had a significantly ($p < 0.05$) higher live mass than the males (12.95 $\pm$ 1.42 kg), although in this age category the males and females were represented by small numbers (Table 1) and skew gender and age ratios in this age category.



[a,b,c] Columns with different letters are significantly different within trait ($p < 0.05$).

Figure 5 Live mass (kg) means for the gender and age (Gender*Age) interaction ($p < 0.05$).

The means of the dressing percentages (± standard error) of springbok (n = 149) expressed as a proportion of the chilled dressed carcass to the live weight, are presented in Table 4. The percentage of skin expressed as a proportion of the live mass of springbok originating from Caledon varied from 6.13 ± 0.21 to 6.60 ± 0.15%. Dressing percentages of springbok originating from the four production regions varied between 54.68 and 58.98%. Fairall *et al*. (1990) noted that young (3 - 6 months) springbok have a dressing percentage of 56.1% and 53.3% for males and females respectively. For older animals, the dressing percentage increases to 58.8% and 55.0% respectively. It is therefore evident that the male and adult categories have a tendency towards a higher dressing percentage. In this study the male (58.83 ± 0.53%) springbok, irrespective of age category, had a significantly ($p < 0.05$) higher dressing percentage in comparison with the females (55.79 ± 0.50%) (Table 4). According to Van Zyl & Ferreira (2003), the dressing percentage (expressed as a % of body weight) of springbok varies from 56.2 to 57.6% and does not differ significantly ($p > 0.05$) between the sexes. The dressing percentage of the different age categories of springbok varied between 55.91 and 58.97%. The lambs (58.98 ± 1.07%) had the highest mean dressing percentage and this differed significantly from the adult category, which is contradictory to previous findings (Fairall *et al*., 1990).

However, only 21 springbok were included in the lamb category and this data may therefore not have been as representative as the other age categories.

Table 4 Means (± standard error) of dressing percentage of springbok (n = 149), with age, gender and production region as main effects.

Characteristic		**Dressing %**
Region :	**Rustfontein (n = 47)**	$54.684^{b} \pm 0.53$
	Gariep (n = 44)	$58.630^{a} \pm 0.80$
	Willem Pretorius (n = 19)	$57.848^{a} \pm 0.93$
	Caledon (n = 39)	$58.063^{a} \pm 0.80$
Gender:	**Male (n = 66)**	$58.832^{a} \pm 0.53$
	Female (n = 83)	$55.790^{b} \pm 0.50$
Age:	**Adult (n = 62)**	$55.915^{b} \pm 0.53$
	Sub-adult (n = 66)	$57.701^{ab} \pm 1.49$
	Lamb (n = 21)	$58.976^{a} \pm 1.07$

^{a,b,c} Values in same column (within main effects) with different letters are significantly different ($p < 0.05$).

According to Kritzinger (2002), variation in the dressing percentage of game species may occur on the basis of whether the blood and gut fill are included or excluded in the definition of live weights. There are also several other factors that have to be considered that may influence the dressing percentage of an animal, for example the position of the shot, stomach fill and sufficient exsanguination (Van Zyl *et al*., 1969; Von la Chevallerie, 1970; Van Zyl & Ferreira, 2003).

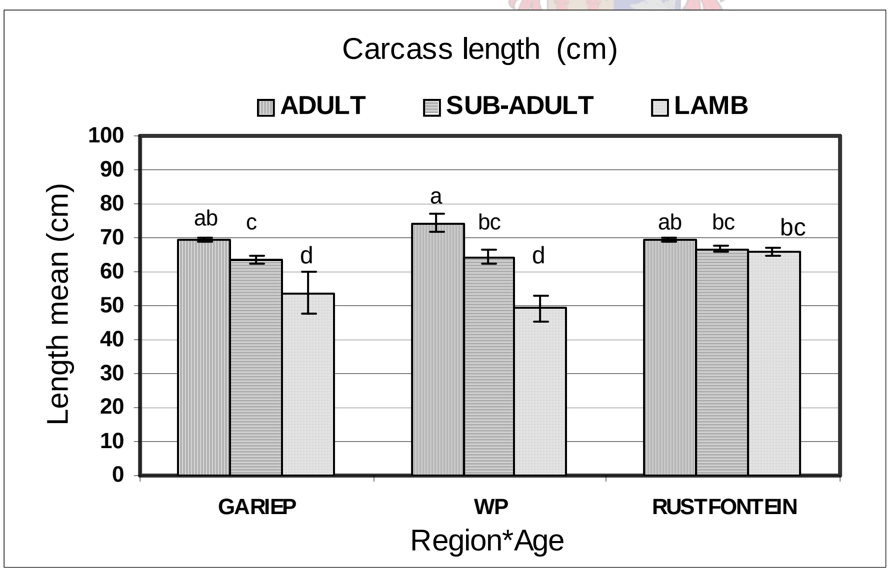
The mean (± standard error) values of the width and depth and the chest and buttock circumferences of springbok are presented in Table 5. The carcass length ($p = 0.0002$) and leg length ($p < 0.05$) parameters showed significant interactions between the production region and age categories and therefore the means of these measurements are not presented in Table 5. These interactions are depicted in Figures 6 and 7 respectively. Regional differences were observed for width, depth and for buttock circumference. This result may have been mediated by the random cropping procedures, resulting in skew ratios between different age categories representing each production region. The effect of gender on these measurements (Table 5) was found to be not significant ($p > 0.05$). As expected, age had a significant ($p < 0.05$) effect on the above-mentioned measurements. The mean respective width measurements for the adult, sub-adult and lamb categories averaged at 22.14 ± 0.25, 20.46 ± 0.40 and 16.75 ± 0.99 cm respectively. The same trend was observed for the carcass depth and chest and buttock circumferences.

Table 5 Means (± standard error) of width, depth and buttock and chest circumferences of springbok (n = 127).

Characteristic		Width (cm)	Depth (cm)	Chest circumference (cm)	Buttock circumference (cm)
Region :	**Rustfontein (n = 47)**	22.35 [a] ± 0.31	25.27 [a] ± 0.29	72.36 ± 1.30	46.02 [a] ± 0.50
	Gariep (n = 61)	19.84 [b] ± 0.40	23.68 [b] ± 0.38	69.55 ± 1.10	44.87 [ab] ± 0.74
	W.P (n = 19)	20.28 [b] ± 0.90	23.83 [b] ± 0.83	70.17 ± 2.23	43.07 [b] ± 1.41
Gender:	**Male (n = 67)**	20.75 ± 0.42	24.15 ± 0.40	69.73 ± 1.26	44.54 ± 0.87
	Female (n = 60)	20.99 ± 0.37	24.44 ± 0.30	70.29 ± 1.25	44.68 ± 0.74
Age:	**Adult (n = 70)**	22.14 [a] ± 0.25	25.73 [a] ± 0.20	74.92 [a] ± 0.59	47.89 [a] ± 0.47
	Sub-adult (n = 39)	20.46 [b] ± 0.40	23.75 [b] ± 0.37	68.80 [b] ± 1.08	43.71 [b] ± 0.76
	Lamb (n = 18)	16.75 [c] ± 0.99	19.86 [c] ± 0.62	58.56 [c] ± 2.59	37.29 [c] ± 1.55

[a,b,c] Values in same column (within) with different letters are significantly different ($p < 0.05$).

Significant ($p < 0.05$) differences between the carcass length of the different age categories were observed for springbok originating from both Gariep and Willem Pretorius. The adults, sub-adults and lambs originating from Gariep nature reserve had a mean carcass length of 69.53 ± 0.94, 63.42 ± 1.27 and 53.72 ± 6.00 cm respectively (Figure 6). Adults, sub-adults and lambs originating from Willem Pretorius nature reserve had a mean carcass length of 74.28 ± 2.53, 64.36 ± 1.93 and 49.12 ± 3.80 cm respectively.

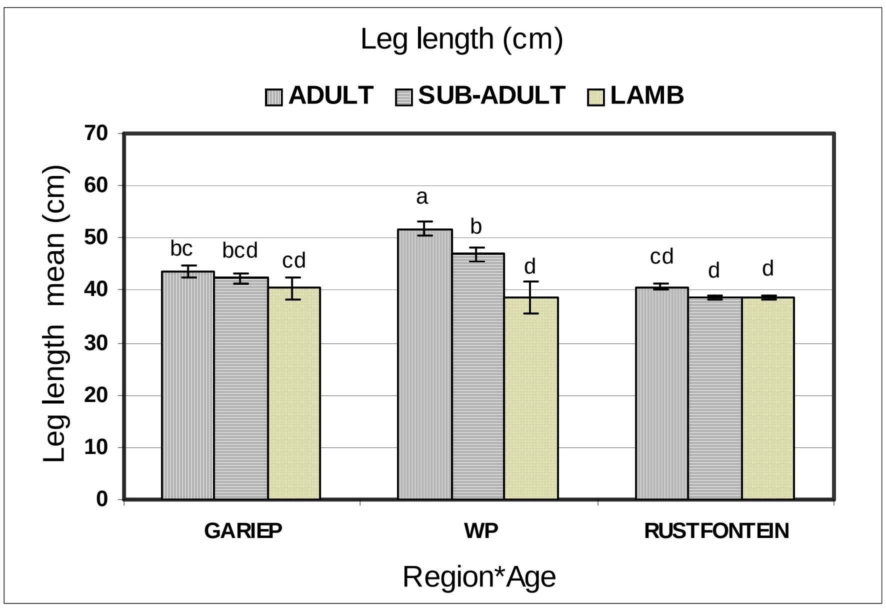


[a,b,c] Columns with different letters are significantly different ($p < 0.05$).

Figure 6 Carcass length (cm) means for the production region and age (Region*Age) interaction ($p = 0.0002$).

The carcass length of springbok rams has been noted to increase from 55.6 cm (55.4 cm for ewes) at 28 weeks to 64.9 cm (63.1 cm for females) in the adult category (Von la Chevallerie & Van Zyl, 1971).

The leg length of the adults (43.62 ± 1.08 cm), sub-adults (42.28 ± 1.01 cm) and lambs (40.48 ± 2.14 cm) from the Gariep region did not differ significantly (Figure 7). The different age categories of springbok originating from Willem Pretorius nature reserve, however, differed significantly ($p < 0.05$), with the adults, sub-adults and lambs having a mean leg length of 51.76 ± 1.41 cm, 46.93 ± 1.35 cm and 38.7 ± 3.14 cm respectively. No significant differences were observed between the age categories in the Rustfontein region. As mentioned before, this is possibly as a result of skew ratios between the age categories of the randomly cropped springbok.



[a,b,c] Columns with different letters are significantly different within trait ($p < 0.05$).

Figure 7 Leg length (cm) means for the production region and age (Region*Age) interaction ($p < 0.05$).

CONCLUSION

The results of this study emphasise that the live weight, carcass weight and dressing percentage (expressed as a percentage of live weight) of springbok are similar to previous estimations of these physical parameters. The main effect brought about by animal age was an increase in the live and carcass weights. Differences in the live mass of springbok was apparent in the adult category. Regional differences with regard to the extent to which age and gender influence these parameters may possibly be a result of variations in vegetation and hence the diet of the springbok, as well as skew ratios of the different age and gender categories brought about by the random cropping procedures. The males were noted to have a significantly higher dressing percentage than the females. The dressing percentage of the lamb category was significantly higher than that of the adult category, which is contradictory to the findings of previous research. The lamb category, however, was represented by a small sample group and this may have influenced the results. The effects brought about by animal age were an increase in the carcass measurements. Gender had no significant effect of these measurements.

ACKNOWLEDGEMENTS

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CHAPTER 4

THE PHYSICAL ATTRIBUTES OF SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) MEAT AS INFLUENCED BY AGE, GENDER AND PRODUCTION REGION

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ABSTRACT

Springbok is the most extensively cropped game species in South Africa. The effects of age (adult, sub-adult, lamb), gender and production region on the physical attributes (pH_{24}, cooking loss and drip loss, Warner Bratzler Shear and colour) were determined in an experiment using samples of the *M. longissimus dorsi* (LD) muscles of 166 springbok. Stressed animals had a significantly ($p < 0.05$) higher ultimate pH_{24} (6.3 ± 0.07), as observed in the meat originating from the Caledon region. These animals were fenced in on a 6 ha paddock and cropped continuously during a four hour period. This meat had significantly ($p < 0.05$) lower cooking loss (27.2 ± 0.62%) and drip loss (1.8 ± 0.08%) values in comparison with meat originating from the other regions. The pH_{24} of the meat originating from the four production regions varied from 5.4 to 6.3. Inverse correlations were noted between pH_{24} and drip loss ($p = -0.26$, $p < 0.01$) and cooking loss ($r = -0.42$, $p < 0.0001$). Shear force values (kg/1.27 cm diameter) correlated positively ($r = 0.25$, $p < 0.01$) with the pH_{24} of the meat. Meat shear force values ranged between 1.67 ± 0.05 and 2.67 ± 0.16 kg/ 1.27 cm diameter. Age-related effects on tenderness were small in comparison with pH_{24} effects. Non-linear regression of a subsample ($n = 26$) of springbok showed that the rate of pH-decline of the LD muscle was very fast and varied between -0.77 ± 0.12 and -0.97 ± 0.11 units per hour. CIELab colorimetric values were typical of venison ($L^* < 40$, high a^* and low b^* values). It was noted that pH_{24} showed a negative ($r = -0.51$, $p < 0.0001$) and positive ($r = 0.33$, $p < 0.0001$) correlation with the hue-angle and the chroma value of colour respectively. Springbok originating from Caledon had a significantly ($p < 0.05$) higher a^* value, indicating redder meat and thus colour saturation.

Keywords: game meat; pH; water holding capacity; drip loss; cooking loss; colour; shear force

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INTRODUCTION

Springbok (*Antidorcas marsupialis*) is the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999) and therefore has great venison production potential.

It is known that the ante-mortem physical condition of the animal and the physical conditions imposed on the carcass postmortem (O'Halloran *et al*., 1997) influence the meat quality. The extent of postmortem glycolysis has an effect on the tenderness of beef, pork and lamb, with a decrease in tenderness as the pH increases from 5.5 to 6.0 (Lawrie, 1985; Watanabe *et al*., 1996). However, at ultimate pH (pH_u) values above 6, tenderness increases again. With an increase in pH_u up to 6.2, shear force values in beef increase partially as a result of decreased sarcomere length in this pH region (Purchas, 1990). It has been reported (Marsh *et al*., 1980-1981) that slow glycolysis improves beef tenderness, provided that cold shortening does not occur. O'Halloran *et al*. (1997), on the other hand, reported that fast glycolysing *M. longissimus dorsi* beef muscle was significantly more tender than slow glycolysing muscle.

Myofibrillar toughness is affected by two processes, namely development of rigor mortis and the enzymatic tenderisation process (Hertzman *et al*., 1993). The tenderness of meat is strongly influenced by the pH and temperature of the muscle postmortem (Marsh *et al*., 1980-1981; Yu & Lee, 1986), which affect the enzymatic tenderisation process. High temperature conditions and low pH in postmortem muscles lead to protein denaturation and therefore a decrease in the water-binding capacity (WBC) of meat (Offer & Knight, 1988). Factors such as postmortem temperature and pH therefore have a direct effect on the physical parameters of meat, such as tenderness and WBC capacity of the meat.

The lightness (paleness) of meat is directly related to the pH_U of the muscle (Hector *et al*., 1992). Dark, firm and dry (DFD) meat is classified as having a pH_u above 6.2, whereas intermediate DFD meat has a pH_u that ranges from 5.8 to 6.2 (Wiklund *et al*., 1995). The pH_U of meat, however, is dependent on various ante-mortem stress factors imposed on the animal, and these contribute to ante-mortem glycogen depletion and will affect the ultimate pH and meat quality (Wiklund *et al*., 1995; Pollard *et al*., 2002; Viljoen *et al*., 2002).

The purpose of this study was to determine the physical attributes of the *M. longissimus dorsi* (LD) muscle of springbok (*Antidorcas marsupialis*) and to investigate the effects that age, gender and production region may have on the meat quality. Where applicable, correlations between the various physical attributes of the meat were verified.

MATERIALS AND METHODS

Animals and sampling

Springbok (n=166) were sampled from three nature reserves (Gariep, Rustfontein and Willem Pretorius) in the Free State Province and from a farm in the Caledon district of South Africa. At Gariep, Rustfontein, Willem Pretorius and Caledon, 61, 47, 19 and 39 springbok were harvested respectively. At Gariep nature reserve the 61 springbok consisted of 21 females and 40 males. The Rustfontein and Willem Pretorius sample groups consisted of 32 females, 15 males and 7 females and 12 males, respectively. A complete herd (n = 39) of springbok, 30 females and 9 males, was harvested at Caledon. This springbok herd was fenced in on a 6 ha paddock and the entire herd was cropped over a four hour period at night.

The Free State Province's largest Nature Reserve is a combination of the 36 487 ha Gariep Nature Reserve on the Orange River and an 11 237 ha game sanctuary on its northern shore. The Gariep Nature Reserve accommodates a large population of springbok, black wildebeest and red hartebeest. The Rustfontein Dam Nature Reserve is a 1000 ha Reserve that accommodates springbok, black wildebeest and blesbok, amongst others (Hocking *et al.*, 1983). The Willem Pretorius Nature Reserve (WP) is an 10 520 ha game reserve (Bulpin, 1992) that accommodates springbok, black wildebeest, blesbok, red hartebeest, eland, zebra, impala and white rhino.

Springbok originating from the three Nature Reserves were randomly harvested at night, by a professional culling team using spotlights (1 million candela) and small calibre rifles, similar to the method described by Lewis *et al*. (1997). The springbok originating from Caledon were also harvested at night using a similar procedure as described above, except that all the shooters were inexperienced, which resulted in a higher incidence of missed shots and wounded animals (n = 7). Animals were sighted directly or by the reflection of the light from their retinas. The shots were either head or high neck shots, resulting in immediate insensibility.

The ages of the springbok were estimated using the length and size of the horns as parameters (Rautenbach, 1971). The springbok were divided into three age categories, namely adult (2 to 5 years), sub-adult (1 to 2 years) and lamb (0 to 1 year). The adult, sub-adult and lamb categories consisted of 70, 73 and 23 animals, respectively.

After harvesting, the animals were exsanguinated within 2 to 5 min. by cutting the throat with a sharp, sterile knife. Each carcass was then individually tagged with an identification number and hung from the Achilles tendons to promote bleeding. After the targeted number of antelope had been harvested, the carcasses were taken to a nearby abattoir for processing. This included the skinning, evisceration and cleaning of carcasses according to South African practices (Hoffman, 2000a). During commercial cropping procedures, the carcasses are transported to the processing plant with the skin on (Hoffman, 2003) and the springbok cropped at Caledon were transported in this manner. The carcasses were cooled to 4°C approximately five to eight hours after cropping (depending on the time the animals were shot).

The LD muscle was dissected 24 hr postmortem to assess the physical attributes (pH_{24}, cooking loss, drip loss, Warner-Bratzler Shear and colour) of the meat. The samples from the right and left hand side of the carcass were removed between the 12th and 13th rib and anterior to the last lumbar vertebra. All visible connective tissue and subcutaneous fat were removed from the samples. Samples were vacuum packed and subsequently frozen at -20ºC until further analyses were done.

Physical analyses

A subsample (n=26) of the 166 springbok was analysed in terms of the rate of pH and temperature decline in the *M. longissimus dorsi* (LD) muscle. The distribution of these springbok in terms of age, gender and production region is presented in Table 1. The pH measurements of the LD muscle were taken between the 12 and 13th rib at 0.75, 2, 4, 6, 8, 12, 16, 20 and 24 hr post-mortem by means of a calibrated (standard buffers pH 4.0 and 7.0) Crison 506 portable pH-meter, as described by Hoffman (2000b). The pH of all the remaining animals were measured 0.75 and 24 hr postmortem.

Cooking loss of the LD muscle was determined by placing approximately 50 to 70 g meat (± 15 mm diameter) in a sealed plastic bag in a water bath (preset at 80°C) for 1 hr (Honikel, 1998). Meat samples were cut perpendicular to the longitudinal axis on the caudal side of the LD muscle. The samples were then cooled to 25°C under running water. The weight of the dried cooked samples was recorded and the cooking loss was calculated.

Drip loss was determined by placing a meat sample (± 15 mm diameter) of a similar weight of the LD muscle in netting, suspended in an inflated bag in a cold room at 4°C for a 24 hr period, after which the weight was recorded. Drip loss and cooking loss were expressed as a percentage of the initial weight of the meat sample (Honikel, 1998).

Table 1 Distribution of springbok (n = 26) according to age, gender and production region for the pH and temperature decline evaluation of the LD muscle.

	Gariep		Rustfontein		
	Male	**Female**	**Male**	**Female**	**Total**
Adult	2	3	8	4	17
Sub-adult	2	2	0	5	9
Total	4	5	8	9	**26**

Three to four 1.27 cm diameter (cylindrical core) meat samples of the muscle were randomly removed from the cooked samples. The samples were cut perpendicular to the longitudinal axis of the LD muscle. Maximum shear force values (kg. 1.27 cm^{-1} diameter) to shear a cylindrical core of cooked meat (at a crosshead speed of 3.80 mm. s^{-1}) were recorded for each sample and a mean was calculated for each individual animal using a Warner-Bratzler Shear attachment fitted to an electrical scale (Honikel, 1998).

The colour of the LD muscle was recorded 24 hr post-mortem using a Color-guide 45°/0° colorimeter (Cat no: 6805; BYK-Gardner, USA). Samples were allowed to bloom for a 20 min. period, after which the colour was measured in triplicate for each sample at randomly selected positions. Colour was expressed by the coordinates L*, a* and b* of the CIELab colorimetric space (Commission International de l'Eclairage, 1976). The L*, a* and b* values are an indication of the lightness, red-green and blue-yellow range of colour respectively. The hue-angle and the a* and b* chroma are psychometric correlates of perceived hue and chroma (Setser, 1984) and were determined as follows (Commission International de l'Eclairage, 1976):

$$\text{Chroma } (C^*) = [(a^*)^2 + (b^*)^2]^{1/2}$$

$$\text{Hue angle } (h_{ab}) = \tan^{-1}\{b^*/a^*\}$$

Statistical analyses

A three-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were the four regions (Gariep, Willem Pretorius, Rustfontein and Caledon), three age groups (adult, sub-adult and lamb) and two genders (male and female). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to analysis of variance (ANOVA) using SAS version 8.2 statistical software (SAS, 1999). Th Shapiro-Wilk test was performed for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference was calculated at the 5% confidence level to compare treatment means (Ott, 1998). Pearson correlation coefficients were determined using the linear regression procedure (Proc CORR) of SAS (1999).

Exponential decay models were fitted to the pH and temperature decline data using the non-linear regression procedure (Proc NLIN) of SAS (1999). The function of this model was (Wiklund *et al*., 1995):

$$y = a + b\,e^{-ct}$$

where:

y = pH at time t; a = ultimate pH; e = base of natural logarithm and b,c are the function parameters describing the shape of the curve.

The pH readings were standardised at 4°C because the rate of muscle temperature decline differed for the different production regions. The formula used for the standardisation was as follows (Bruce *et al*., 2001):

$$pH_{\text{adjusted at t}} = \text{measured } pH_t + \{ (T_t - T_{adjusted}) * 0.01\}$$

where:

pH_t is the actual pH at the measured time (t); T_t is the muscle temperature at the measured time (t) and $T_{adjusted}$ is the muscle temperature (4°C) to which the data has been adjusted.

The a, b and c constants of the unadjusted and adjusted model of the pH decline data , as well as the temperature decline data, were then analysed by analysis of variance (ANOVA) using SAS version 8.2 (SAS, 1999). The Shapiro-Wilk test was performed for non-normality (Shapiro & Wilk, 1965). The a, b, and c values of the unadjusted model of the pH decline data were linearly correlated with the physical attributes of the meat. Pearson correlation coefficients were determined using the linear regression procedure (Proc CORR) of SAS (1999).

RESULTS AND DISCUSSION

The means (± standard errors) of the physical attributes of the springbok LD muscle are presented in Table 2. The ultimate mean pH_{24} values of the springbok originating from the four production regions ranged between 5.4 and 6.3. In the Caledon region, a full herd of springbok were fenced in on a paddock (6 ha) and the herd became increasingly stressed as cropping progressed. This observation was also reflected in the high mean pH_{24} of 6.30 ± 0.07 (Table 2) recorded. However, the cropping team in this case was relatively inexperienced, resulting in higher ante-mortem stress in the herd. Ante-mortem stress is usually lower if an experienced cropping team is used. Physical activity and stressful situations and procedures lead to glycogen depletion, which influences the ultimate pH (pH_u) values and hence the meat quality (Wiklund *et al*., 1995; Devine *et al*., 1993; Viljoen *et al.*, 2002). Intermediate dark, firm and dry (DFD) meat is normally defined as meat with a pH_u that ranges between $5.8 \leq pH_u \leq 6.2$ and DFD with a $pH_u \geq 6.2$ (Wiklund *et al*., 1995). The majority of the springbok originating from the Caledon region therefore had DFD meat. A low glycogen content in muscle ante-mortem results in higher pH_u values in the meat, a quality defect that is known to reduce the meat shelf life (Wiklund *et al*., 1995).

It was noted that the females had a significantly ($p > 0.05$) higher mean pH_{24} (5.75 ± 0.05) than the males (5.63 ± 0.04) (Table 2). The male gender of game species generally tends to have a higher pH_u than the females due to their more active response to disturbances, especially when cropping occurs during the rutting season (Lewis *et al*., 1997; Hoffman, 2000b). The duration and timing of the male rut in springbok occurs randomly and cannot be related to any specific factor (Skinner & Van Zyl, 1970; Skinner *et al*., 1996). The above-mentioned result may have been influenced by the fact that the sample group of springbok originating from Caledon (pH_{24} = 6.30 ± 0.07) consisted of 30 females and 9 males of which the majority was classified as DFD meat.

The isoelectric point of muscle protein is approximately at pH 5.5. At this point, the muscle protein exhibits its lowest water-binding capacity (WBC) and solubility, accounting for higher water loss through evaporation and drip loss (Swatland, 1984). The cooking loss (27.18 ± 0.62%) and drip loss (1.79 ± 0.08%) mean values were significantly ($p < 0.05$) lower in springbok originating from Caledon than from the other regions (Table 2).

Table 2 Means (± standard error) of the physical attributes of springbok *M. longissimus dorsi* (LD) muscle with age, gender and production region as main effects.

Main effects		$Temp_0$ (°C)	pH_0	$Temp_{24}$ (°C)	pH_{24}	Cooking loss (%)	Drip loss (%)	Shear force (kg. 1.27 cm^{-1} diameter)
Region :	Rustfontein	$37.266^a \pm 0.28$	$6.421^c \pm 0.05$	$8.232^a \pm 0.38$	$5.382^d \pm 0.02$	$29.190^b \pm 0.61$	$2.972^b \pm 0.16$	$1.670^c \pm 0.05$
	Gariep	$34.769^b \pm 0.91$	$6.642^b \pm 0.11$	$4.920^b \pm 0.38$	$5.540^c \pm 0.02$	$32.430^a \pm 0.49$	$2.930^b \pm 0.22$	$2.121^b \pm 0.12$
	WP	$32.111^c \pm 0.82$	$6.508^{cb} \pm 0.06$	$1.711^c \pm 0.15$	$5.712^b \pm 0.06$	$29.761^b \pm 0.89$	$3.664^a \pm 0.30$	$2.674^a \pm 0.16$
	Caledon	$37.526^a \pm 0.22$	$6.926^a \pm 0.06$	$5.344^b \pm 0.10$	$6.296^a \pm 0.07$	$27.180^c \pm 0.62$	$1.793^c \pm 0.08$	$2.659^a \pm 0.04$
Gender:	Male	35.794 ± 0.52	$6.720^a \pm 0.06$	$5.173^b \pm 0.38$	$5.633^b \pm 0.04$	$31.503^a \pm 0.47$	2.796 ± 0.19	2.208 ± 0.09
	Female	36.125 ± 0.42	$6.558^b \pm 0.05$	$5.916^a \pm 0.29$	$5.747^a \pm 0.05$	$28.682^b \pm 0.45$	2.677 ± 0.13	2.151 ± 0.08
Age:	Adult	$36.697^a \pm 0.35$	6.553 ± 0.06	$6.140^a \pm 0.39$	$5.482^c \pm 0.02$	$31.071^a \pm 0.54$	$3.163^a \pm 0.18$	2.036 ± 0.10
	Sub-adult	$35.706^{ab} \pm 0.54$	6.700 ± 0.07	$5.033^b \pm 0.29$	$5.894^a \pm 0.06$	$28.588^b \pm 0.50$	$2.484^b \pm 0.15$	2.312 ± 0.08
	Lamb	$34.594^b \pm 1.19$	6.621 ± 0.14	$5.591^{ab} \pm 0.52$	$5.700^b \pm 0.08$	$31.031^a \pm 0.69$	$2.143^b \pm 0.25$	2.184 ± 0.16

[a,b,c] Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

$Temp_0$ - Initial temperature (45 min. post-mortem)

pH_0 - Initial pH (45 min. post-mortem)

$Temp_{24}$ - Temperature 24 hr post-mortem

pH_{24} - Ultimate pH (24 hr post-mortem)

WP - Willem Pretorius nature reserve

Cooking loss of meat tends to be higher for meat with low WBC (high drip loss, high thawing loss) and low pH_u, with no difference between cooking loss of meat with medium or high WBC and pH_u (Aaslyng *et al*., 2003). Meat that is classified as DFD tends to have smaller cooking losses (Katsaras & Peetz, 1990).

Very low pH_{24} values were obtained in the Gariep (5.54 ± 0.02) and Rustfontein (5.38 ± 0.02) regions, which resulted in high mean cooking loss (%) and relatively high drip loss of the LD muscle. However, springbok originating from Willem Pretorius nature reserve had a mean pH_{24} of 5.71 ± 0.06 and had a significantly ($p < 0.05$) higher drip loss (3.66 ± 0.30%) in comparison with the other production regions. This could possibly be a result of denaturation that occurred.

Linear correlation coefficients between the pH_{24} and the physical attributes of the LD muscle are presented in Table 3. The pH_{24} of the meat correlated inversely with the mean percentage cooking loss ($r = -0.42$, $p < 0.0001$) and drip loss ($r = -0.26$, $p < 0.01$) of the LD muscle (Table 3). This indicates a general decrease in cooking and drip loss (%) with increasing pH_{24} of the meat. Although the correlation coefficients were low, they were significant as a result of the large sample size. The effects brought about by age, gender and production region on the cooking and drip loss (%) of the LD muscle were directly affected by the pH_{24} of the meat.

There is variation in muscle tenderness at slaughter, during post-mortem storage or as a combination of the two (Koohmaraie *et al*., 2003). Various factors may influence meat tenderness, such as pH_0 (initial pH), pH_u and pH decline rate. It has also been suggested that proteolytic activity and hence tenderisation in the early postmortem period decreases at pH 5.8 to 6.3 (Yu & Lee, 1986).

Table 3 Pearson linear correlation coefficients between pH_{24} and the physical attributes of the LD muscle of springbok (n =166).

Characteristic	**r**	**p**
pH_0	0.36	b
Cooking loss (%)	-0.42	b
Drip loss (%)	-0.26	a
Shear force (kg. 1.27 cm^{-1})	0.25	a
CIEL*	0.27	a
CIEa*	0.42	b
Cieb*	-0.22	a
Hue-angle (°)	-0.51	b
Chroma	0.33	b

[a] $p < 0.01$

[b] $p < 0.0001$

r = correlation coefficient

It has been reported that the most tender meat in lambs comes either from lambs with a high pH_u above 6.3 or from young lambs with a pH_u between 5.5 and 5.7 (Devine *et al*., 1993). It was noted, however, that with an increase in pH_u from 5.5 to 5.9, the shear force values increase (Devine *et al.*, 1993). The mean pH_{24} of springbok meat, considering all main effects, varied from 5.4 to 6.3. The pH_{24} of the meat was noted to be positively correlated ($r = 0.25$, $p < 0.01$) with the shear force values obtained. Although the correlation coefficient is relatively low, it was significant as a result of the large sample size evaluated. The above-mentioned result is similar to previous research (Purchas, 1990), which reported that an increase in meat toughness is accompanied by an increase in pH_u from about 5.5 to 6.2, partially as a result of decreased sarcomere length in this pH region.

Springbok cropped at Rustfontein had a significantly ($p < 0.05$) lower mean pH_{24} (5.38 $\pm$ 0.02) and shear force value (1.67 $\pm$ 0.05 kg. 1.27 cm^{-1} diameter) in comparison to those from the other production regions (Table 2). Springbok originating from Gariep had a pH_{24} of 5.54 $\pm$ 0.02 and a mean shear force value of 2.12 $\pm$ 0.12 kg. 1.27 cm^{-1} diameter. Springbok meat originating from Willem Pretorius, however, had a significantly higher pH_{24} than those from Gariep and consequently had a significantly higher shear force value (2.67 $\pm$ 0.16 kg. 1.27 cm^{-1} diameter).

The mean shear force values were not affected by gender in this study. The shear force values were also unaffected by age and varied from 2.04 to 2.31 kg. 1.27 cm^{-1} diameter for the different age categories. Therefore, the effects of age, gender and production region on the shear force measurements of the meat were influenced by the pH_{24} of the meat. The shear force values obtained in this study were lower than those reported for impala *(Aepyceros melampus*) (Hoffman, 2000b). The mean shear force values (kg. 1.27 cm^{-1} diameter) of female and male impala averaged at 3.21 $\pm$ 0.24 and 4.08 $\pm$ 0.51 respectively, although they did not differ significantly (Hoffman, 2000b). The means ($\pm$ standard error) of the constants for the exponential decay model fitted to the adjusted and unadjusted pH decline of the LD muscle as affected by age, gender and production region are presented in Table 4 and Table 5 respectively.

Table 4 Constants for the exponential decay model fitted to the adjusted pH decline of the *M. longissimus dorsi* (LD) muscle (n = 26) as affected by age, gender and production region.

Main effects	**Constants for the adjusted exponential decay model $y = a + be^{(ct)}$**		
	a	**b**	**c**
Region : Rustfontein (n = 17)	5.474[a] ± 0.01	3.387 ± 0.24	-0.952 ± 0.10
Gariep (n = 9)	5.647[b] ± 0.03	3.136 ± 0.32	-0.765 ± 0.12
Gender: Male (n = 14)	5.519 ± 0.02	3.363 ± 0.24	-0.828 ± 0.10
Female (n = 12)	5.547 ± 0.03	3.247 ± 0.30	-0.939 ± 0.11
Age: Adult (n = 17)	5.517 ± 0.02	3.320 ± 0.26	-0.844 ± 0.10
Sub-adult (n = 9)	5.565 ± 0.04	3.264 ± 0.27	-0.971 ± 0.11

[a,b] Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

According to Table 4, there were no significant differences between the constants derived from the non-linear equation fitted to the adjusted pH decline data of the subsample (n = 26) of springbok, except for the a-value pertaining to production region.

No significant ($p > 0.05$) interactions were found between the main effects of the pH decline data. The constants of the non-linear regressions fitted the data, but the data must be interpreted with care, since the calculated pH of these exponential equations is above 8 (t = 0), an improbable value. The regression model (Table 4) indicates that the pH-decline of the LD muscle took place at a rate that varied between -0.765 ± 0.12 and -0.971 ± 0.11 units per hour to reach the asymptotic pH value. The c-values of the unadjusted model were higher and varied between -1.017 ± 0.19 and -1.393 ± 0.19 units per hour (Table 5). Constants of c obtained by Hoffman & Ferreira (2000) for the pH decline of Grey Duiker (*Sylvicapra grimmia*) averaged at -0.228 units per hour. In that study, a stressed animal had a pH decline rate of -0.734 units per hour. The pH decline rate of impala (*Aepyceros melampus*), for example, have been noted to be much higher than that of the Grey Duiker, varying between -0.451 ± 0.05 and -0.711 ± 0.05 units per hour (Hoffman, 2000b). According to Hoffman (2000b), the high pH decline rate of impala may have been a result of ante-mortem stress or a species effect. The asymptotic a-values of springbok were below pH 5.8 (Table 4) and therefore the meat could not be classified as DFD, which indicates stressed conditions. The high c-values for springbok (Table 4) therefore may have been a species effect leading to a very fast pH decline rate.

Table 5 Constants for the exponential decay model fitted to the pH decline of the *M. longissimus dorsi* (LD) muscle (n = 26) as affected by age, gender and production region.

Main effects	Constants for the exponential decay model $y = a + be^{(ct)}$		
	a	**b**	**c**
Region : Rustfontein (n = 17)	$5.380^{a} \pm 0.00$	3.914 ± 0.41	-1.290 ± 0.16
Gariep (n = 9)	$5.642^{b} \pm 0.02$	3.206 ± 0.49	-1.017 ± 0.19
Gender: Male (n = 14)	5.454 ± 0.04	3.650 ± 0.41	-1.103 ± 0.17
Female (n = 12)	5.484 ± 0.04	3.685 ± 0.50	-1.273 ± 0.18
Age: Adult (n = 17)	$5.453^{a} \pm 0.03$	3.549 ± 0.41	-1.090 ± 0.16
Sub-adult (n = 9)	$5.502^{b} \pm 0.05$	3.897 ± 0.53	-1.393 ± 0.19

^{a,b} Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

Linear correlations between the constants of the exponential decay model and physical attributes (drip loss, cooking loss, shearforce, CIEL*, CIEa*, CIEb*, hue angle and chroma) were not significant ($p > 0.05$), probably as a result of limited variations in the pH decline data. The means (± standard error) of the constants for the exponential decay model fitted to the temperature decline data of the LD muscle as affected by age, gender and production region are presented in Table 6. The temperature decline took place at a rate that varied between -0.250 ± 0.04 and -0.350 ± 0.03 units per hour. No significant differences were observed between the constants, except between the a-values.

Meat colour is one of the most important criteria used by the consumer to select meat. Consumers prefer meat with normal colour and discriminates againsts meat which is either too dark or too pale (Issanchou, 1996; Viljoen *et al*., 2002). According to Volpelli *et al*. (2003), the L*, a* and b* values that are characteristic of the dark red colour of venison are L* < 40, high a* values and low b* values. The means (± standard error) of the colour coordinates for springbok meat are presented in Table 7. All four regions delivered meat characteristic of venison with high a* values and low b* values. The mean CIEL*, CIEa* and CIEb* values obtained in this study (Table 7) are similar to those for impala (*Aepyceros melampus*) (Hoffman, 2000b).

It is expected that DFD meat will have low L* values and thus darker meat, as observed by Hoffman (2000b), who observed that a wounded male impala had very dark meat (L* = 25.44, a* = 9.13, b* = 4.88). Although the meat originating from Caledon could be classified as DFD meat according to its mean pH_{24} value, it did not have a significantly ($p < 0.05$) lower mean L* value (Table 7) in comparison with meat originating from the other regions. This region, however, had significantly higher L* and a* values.

Table 6 Constants for the exponential decay model fitted to the temperature decline of the *M. longissimus dorsi* (LD) muscle (n = 26) as affected by age, gender and production region.

Main effects		Constants for the exponential decay model $y = a + be^{(ct)}$		
		a	b	c
Region :	**Rustfontein (n = 17)**	$11.059^{a} \pm 0.29$	35.037 ± 0.51	-0.335 ± 0.04
	Gariep (n = 9)	$2.593^{b} \pm 0.22$	42.763 ± 2.54	-0.276 ± 0.02
Gender:	**Male (n = 14)**	8.192 ± 1.27	38.706 ± 1.49	-0.324 ± 0.04
	Female (n = 12)	8.075 ± 1.14	36.859 ± 1.77	-0.307 ± 0.04
Age:	**Adult (n = 17)**	$8.859^{a} \pm 0.99$	38.107 ± 1.26	-0.350 ± 0.03
	Sub-adult (n = 9)	$6.750^{b} \pm 1.47$	36.963 ± 2.48	-0.250 ± 0.04

[a,b] Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

Springbok meat originating from Caledon had a significantly ($p < 0.05$) lower hue-angle (23.97 ± 1.05), but a higher chroma (20.19 ± 0.61) and CIEa* (18.36 ± 0.60) value in comparison with meat originating from the other production regions. The meat originating from Caledon therefore had redder meat (higher a* values) with higher saturation (vividness) in comparison with the other regions. The above-mentioned tendency is emphasised by the positive correlation (Table 3) observed between the pH_{24} of the LD muscle and the CIEa* ($r = 0.42$, $p < 0.0001$) and chroma ($r = 0.33$, $p < 0.0001$) values of colour. In addition, pH_{24} was also noted to be negatively ($r = -0.51$, $p < 0.0001$) correlated with the hue-angle of colour. In red deer (*Cervus elaphus*), it has been noted (Pollard *et al*., 2002) that meat with lower pH_u values have higher hue-angle measurements, but this is in contrast to the findings in this study, in which the meat of these was redder (higher a* values).

If the effect of gender is considered, the females had a significantly ($p < 0.05$) higher mean pH_{24} than the males and therefore had significantly ($p < 0.05$) higher CIEa* and chroma values. The same trend was observed in the sub-adults, which had significantly higher pH_{24} values in comparison with the other age categories. The effects of age, gender and production region on the colour coordinates of the meat were therefore overshadowed by the ultimate pH of the meat.

Table 7 Means (± standard error) of CieL*, CIEa*, CIEb*, hue-angle and chroma values of springbok *M. longissimus dorsi* (LD*)* muscle with age, gender and region as main effects.

Main effects		CIEL*	CIEa*	Cieb*	Hue-angle (°)	Chroma
Region :	**Rustfontein**	30.785[b] ± 0.22	13.891[b] ± 0.21	9.010[a] ± 0.22	32.878[a] ± 0.59	16.597[b] ± 0.25
	Gariep	31.241[b] ± 0.39	12.400[c] ± 0.24	8.094[b] ± 0.22	33.137[a] ± 0.79	14.861[c] ± 0.21
	WP	31.173[b] ± 0.65	12.049[c] ± 0.33	7.820[b] ± 0.43	32.665[a] ± 1.46	14.442[c] ± 0.42
	Caledon	34.933[a] ± 0.56	18.361[a] ± 0.60	8.109[b] ± 0.38	23.965[b] ± 1.05	20.193[a] ± 0.61
Gender:	**Male**	31.752 ± 0.28	13.287[b] ± 0.26	8.104 ± 0.22	31.474 ± 0.85	15.632[b] ± 0.27
	Female	32.162 ± 0.37	14.948[a] ± 0.08	8.510 ± 0.20	30.313 ± 0.57	17.348[a] ± 0.38
Age:	**Adult**	30.706[b] ± 0.23	13.390[b] ± 0.18	8.729[a] ± 0.19	32.973[a] ± 0.55	16.033[b] ±0.21
	Sub-adult	32.710[a] ± 0.40	15.364[a] ± 0.50	8.103[ab] ± 0.22	28.619[b] ± 0.84	17.506[a] ± 0.48
	Lamb	33.542[a] ± 0.70	12.973[b] ± 0.57	7.797[b] ± 0.37	31.310[a] ± 1.56	15.255[b] ± 0.54

[a,b,c] Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

WP - Willem Pretorius nature reserve

CONCLUSION

A regional effect on the ultimate pH of the *M. longissimus dorsi* (LD) muscle was observed. This is possibly a result of the higher levels of ante-mortem stress imposed on the animals from the Caledon region during harvesting in comparison with the animals originating from the other production regions. The majority of the meat originating from Caledon was classified as DFD meat. The ultimate pH had a significant effect on the water-binding capacity (WBC) of the meat. Drip loss and cooking loss percentages of springbok originating from Caledon were noted to be significantly lower than the other regions. In addition, these springbok were noted to have tougher meat in comparison with the other regions. The effects of age, gender and production region on the colour coordinates were overshadowed by the ultimate pH of the meat. It was noted that the ultimate pH of the the LD muscle was positively correlated with the CIEa* and chroma values of colour, indicating higher colour saturation (vividness). Age-related effects on tenderness were found to be minor in comparison with pH_{24} effects, with a general increase in shear force as the ultimate pH of the LD muscle increased. The rate of pH decline in the LD muscle of the springbok sub-sample was not significantly affected by either age, gender or region. High pH decline rates were observed, which may have been a species effect.

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CHAPTER 5

THE CHEMICAL COMPOSITION OF SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) MEAT AS INFLUENCED BY AGE, GENDER AND PRODUCTION REGION

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ABSTRACT

The effects of age (adult, sub-adult, lamb), gender and production region on the chemical (moisture, protein, fat and ash), mineral and amino acid composition of the *M. longissimus dorsi* (LD) muscle of 166 springbok were investigated. The springbok were sampled from three nature reserves (Gariep, Willem Pretorius and Rustfontein) and a farm in the Caledon district region of South Africa. Production region had a significant ($p < 0.05$) effect on the chemical composition of springbok meat. The intramuscular fat (IMF) content of the LD muscle varied between 1.32 and 3.46%. The females (3.13 ± 0.28%) had a significantly ($p < 0.05$) higher fat content than the males (1.35 ± 0.08%). The IMF content of the adult (2.45 ± 0.26%) and sub-adult (2.50 ± 0.28%) category was significantly ($p < 0.05$) higher in comparison with the lambs (1.32 ± 0.11%). An inverse correlation was noted between the IMF and the moisture content ($r = -0.49$, $p < 0.0001$) of the meat. The two major amino acids noted were glutamic and aspartic acid, which contributed 2.47 to 2.74 and 2.31 to 2.54 g. 100 g^{-1} muscle, respectively. Phosphorous was the predominant mineral in the LD muscle (122.92 - 159.78 mg. 100 g^{-1}) of springbok, followed by potassium and calcium. Production region had a significant ($p < 0.05$) effect on the mineral and amino acid composition of the meat. However, the effects of age and gender on the mineral and amino acid composition were found to be not significant ($p > 0.05$).

Keywords: game meat; chemical composition; fat; amino acids; minerals

INTRODUCTION

South African game is still untamed and is viewed as organic and exotic. It is therefore distinguishable from the domesticated game species from Australia, New Zealand and Europe (Hoffman & Bigalke, 1999). Springbok (*Antidorcas marsupialis*) is the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999).

Game meat is healthier because it is much leaner than domesticated meat sources that are fed on wheat products (Viljoen, 1999). Venison also has a low energy and cholesterol profile (Stevenson *et al*., 1992). Farmed venison, for example, has been reported to be low in fat and this is confirmed by the low total energy of the meat, which is less than 500 kJ. 100 g^{-1} (Aidoo & Haworth, 1995). The above-mentioned aspects make this meat attractive to the health-conscious consumer (Fisher, 1991) and may therefore be used as a marketing strategy. The low fat content of venison will consequently lead to a higher mean moisture and protein content in comparison with other red meats (Aidoo & Haworth, 1995).

Meat is an important source of protein and is rich in essential amino acids (Higgs, 2000). The amino acid composition of meat has been noted to be influenced by factors such as species, muscle location, age and processing (Lawrie, 1985). If processing conditions are not prolonged, their effect on the amino acid composition of the meat is limited (Lawrie, 1985). Meat is high in iron, especially in terms of the heam form (50 - 60%), which is unaffected by several inhibitors that decrease iron absorption *in vitro* (Higgs, 2000). The mineral composition of meat, however, may be influenced by physiological, genetic and environmental factors (Zarkadas *et al*., 1987). Other factors, such as the concentration of minerals in the diet, hormones, age, gender and region may also cause variation in the mineral composition of meat (Doyle, 1980). Mineral concentrations vary between different muscles due to varying intensity of physical activity and the effects of fibre type (Doornenbal & Murray, 1981; Lin *et al*., 1989).

Factors such as age, gender, muscle type, carcass weight and degree of fatness influence the nutrient content of meat (Sales, 1995) and the effect of these parameters on the quality of domesticated meat is well estabilished, but little data exists on how they affect the quality of game meat (Onyango *et al*., 1998).

Modern consumers want to be informed about the total nutritional composition of the food they consume (Horbañczuk *et al*., 1998). The chemical attributes of game meat and the factors that may influence these attributes need to be researched extensively and species-specific research is a priority.

The purpose of this study was to determine the chemical, mineral and amino acid composition of the *M. longissimus dorsi* (LD) muscle of springbok and to quantify the effects of age, gender and production region may have on the meat quality. Where applicable, correlations between the various attributes of the meat were verified.

MATERIALS AND METHODS

Animals and sampling

Springbok (n=166) were sampled from three nature reserves (Gariep, Rustfontein and Willem Pretorius) in the Free State Province and a farm in the Caledon district of South Africa. At Gariep, Rustfontein, Willem Pretorius and Caledon, 61, 47, 19 and 39 springbok respectively were randomly harvested. At Gariep, the 61 springbok consisted of 21 females and 40 males. The Rustfontein and Willem Pretorius sample groups consisted of 32 females and 15 males, and 7 females and 12 males respectively. A complete herd (n = 39) of springbok, 30 females and 9 males, was harvested at Caledon. This springbok herd was fenced in on a 6 ha paddock and the entire herd was cropped over a 4 hr period at night.

The Free State Province's largest nature reserve is a combination of the 36 487 ha Gariep Nature Reserve on the Orange River and an 11 237 ha game sanctuary on its northern shore. The Gariep Nature Reserve accommodates a large population of springbok, black wildebeest and red hartebeest. The Rustfontein Dam Nature Reserve is a 1000 ha Reserve that accommodates springbok, black wildebeest and blesbok, amongst others (Hocking *et al*., 1983). The Willem Pretorius Nature Reserve (WP) is an 10 520 ha game reserve that accommodates springbok, black wildebeest, blesbok, red hartebeest, eland, zebra, impala and white rhino (Bulpin, 1992).

Springbok originating from the three nature reserves were randomly harvested at night by a professional culling team using spotlights (1 million candela) and small calibre rifles, similar to the method described by Lewis *et al*. (1997). The springbok originating from Caledon were also harvested at night using a similar procedure as described above, except that all the shooters were inexperienced, which resulted in a higher incidence of missed shots and wounded animals (n = 7). Animals were sighted directly or by the reflection of the light from their retinas. The shots were either head or high neck shots, resulting in immediate insensibility.

The ages of the springbok were estimated using the length and size of the horns as parameters (Rautenbach, 1971). The springbok were divided into three age categories, namely adult (2 to 5 years), sub-adult (1 to 2 years) and lamb (0 to 1 year). The adult, sub-adult and lamb categories consisted of 70, 73 and 23 animals respectively.

After harvesting, the animals were exsanguinated within 2 to 5 min. by cutting the throat with a sharp, sterile knife. Each carcass was then individually tagged with an identification number and hung from the Achilles tendons to promote bleeding. After the targeted number of antelope had been harvested the carcasses were taken to a nearby abattoir for processing. This included skinning, evisceration and cleaning of the carcasses according to South African practices (Hoffman, 2000). During commercial cropping procedures, the carcasses are transported to the processing plant with the skin on (Hoffman, 2003). The springbok cropped at Caledon were transported in this manner. The carcasses were cooled to 4°C approximately five to eight hours after cropping (depending on the time the animals were shot).

The LD muscle was dissected 24 hr post-mortem. The samples of the right and left hand side of the carcass were removed between the 12th and 13th rib and anterior to the last lumbar vertebra. All visible connective tissue and subcutaneous fat were removed from the samples. Samples were vacuum packed and subsequently frozen at -20ºC for the chemical analysis of the meat. The chemical composition of all 166 animals was determined. However, the amino acid and mineral composition were determined on a sub-sample (n = 22) of the animals. The distribution of this sub-sample of springbok according to age, gender and production region is presented in Table 1.

Table 1 Distribution of springbok (n=22) used for the determination of the amino acid and mineral composition of the LD muscle according to age, gender and production region.

	Gariep		WP		Caledon		
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Total**
Adult	2	2	3	1	.	.	8
Sub-adult	2	2	2	3	3	2	14
Total	4	4	5	4	3	2	**22**

Chemical analyses

Chemical analyses were carried out on the LD muscle. Meat samples were minced (2 mm sieve) three times prior to analysis. The moisture (100°C, 24 hr) and ash content (500ºC, 5 hr) of the samples were determined according to AOAC methods (AOAC, 1997). Lipids were extracted with a chloroform:methanol (2:1, v/v) solution by the solvent extraction method described by Lee *et al*. (1996). Protein content was determined by the block digestion method and obtained by multiplying Kjeldahl nitrogen by a factor of 6.25 (AOAC, 1997).

Amino acid analyses

The amino acid composition of the defatted, dried meat samples was determined using a modified method of Bidlingmeyer *et al*. (1984). 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) were used. The meat samples were defatted by solvent extraction according to the method of Lee *et al*. (1996). The samples were hydrolysed with a 6 N hydrochloric acid (HCl) solution in a vacuum-sealed tube for 24 hours at 110°C. The samples were then centrifuged (15 krpm for 5 min.) and dried under vacuum for 1.5 to 2 h. The pH was adjusted by adding 20 μl of an ethanol:water:triethylamine (2:2:1) solution, after which the samples were dried for 1.5 to 2 h. The resulting sample was derivatised by adding 20 μl of an ethanol:water:triethylamine:phenylisothiocyanate (7:1:1:1) derivatising solution, which was then allowed to react at room temperature for 10 min. prior to drying under vacuum (minimum of 3 h). The samples were resuspended in 200 μl of Picotag sample diluent (Waters, Millford, MA, USA) and a 8 μl sub-sample was injected for separation by HPLC under gradient conditions. Buffer A was a 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 analyses

The mineral composition of the meat was determined after ashing of the defatted meat samples using the method described by Giron (1973). The fat-free meat samples (1- 3 g) were air dried and ground to pass through a 0.5 - 1.0 mm sieve. The samples were ashed overnight in a muffle furnace at 550°C. A 6 M hydrochloric 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 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 in a waterbath and removed after boiling point was reached. The solution was consequently filtered through filter paper into a 100 cm^3 volumetric flask and diluted to volume with deionised water. Element concentrations were measured on an ICP-Thermo Jarrel Ash, IRIS (AP).

Statistical analyses

A three-factor factorial experiment was performed in a completely randomised design with an unequal number of random replications. The factors were the four regions (Gariep, Willem Pretorius, Rustfontein and Caledon), three age groups (adult, sub-adult and lamb) and two genders (male and female). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to analysis of variance (ANOVA) using SAS version 8.2 statistical software (SAS, 1999). The Shapiro-Wilk test was performed for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference was calculated at the 5% confidence level to compare treatment means (Ott, 1998). Pearson correlation coefficients were determined using the linear regression procedure (Proc CORR) of SAS (1999).

RESULTS AND DISCUSSION

The mean percentages (± standard errors) of the chemical (moisture, fat and ash) composition of the LD muscle of springbok are presented in Table 2. A significant ($p < 0.05$) interaction between production region and gender was noted for the mean protein content (%) of the meat, therefore the protein content of the meat is not presented in Table 2. This interaction is depicted in Figure 1. The moisture percentages of the LD muscle, with regard to all main effects varied between 72.71 ± 0.38 and 75.10 ± 0.25%. The intramuscular fat (IMF) content was noted to range between 1.32 and 3.46% (Table 2). This is in keeping with the finding of Skinner & Louw (1996) that the mean fat content of all age groups of springbok carcasses never exceeds 4%. This species therefore is an attractive product for the health-conscious consumer. According to Jansen van Rensburg (1997), the fat content of springbok loin varies from 0.77 to 5.56%, with a mean fat content of 2.18%. The mean fat content of springbok is lower than that reported for beef (15.6 ± 4.3), lamb (30.2 ± 7.7) and pork (21.1 ± 7.1%) (Enser *et al*., 1996).

Table 2 Mean percentages (± standard error) of the chemical composition (moisture, fat and ash) of the *M. longissimus dorsi* (LD) muscle (n = 166), with age, gender and production region as main effects.

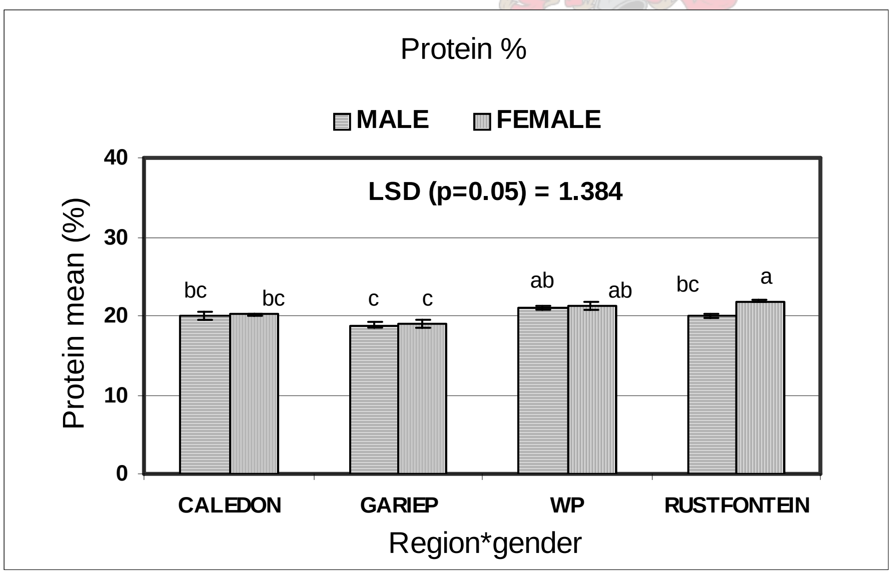
Main effects		**Moisture (%)**	**Fat (%)**	**Ash (%)**
Region :	**Rustfontein (n = 47)**	72.706 ^{c} ± 0.38	3.460 ^{a} ± 0.44	1.274 ^{ab} ± 0.06
	Gariep (n = 61)	73.828 ^{b} ± 0.24	1.770 ^{cb} ± 0.20	1.365 ^{a} ± 0.04
	Willem Pretorius (n = 19)	73.522 ^{bc} ± 0.25	1.258 ^{c} ± 0.12	1.180 ^{b} ± 0.07
	Caledon (n = 39)	75.102 ^{a} ± 0.25	2.292 ^{b} ± 0.37	1.130 ^{b} ± 0.03
Gender:	**Male (n = 90)**	74.239 ^{a} ± 0.16	1.354 ^{b} ± 0.08	1.244 ± 0.04
	Female (n = 76)	73.388 ^{b} ± 0.27	3.127 ^{a} ± 0.28	1.279 ± 0.04
Age:	**Adult (n = 70)**	73.351 ^{b} ± 0.25	2.454 ^{a} ± 0.26	1.273 ± 0.04
	Sub-adult (n = 73)	74.008 ^{ab} ± 0.27	2.495 ^{a} ± 0.28	1.278 ± 0.05
	Lamb (n = 23)	74.396 ^{a} ± 0.33	1.322 ^{b} ± 0.11	1.184 ± 0.04

^{a,b,c} Values in same column (within main effect) with different letters are significantly different (p < 0.05).

The chemical composition of the LD muscle was significantly (p < 0.05) influenced by production region. This may be a result of variations in the vegetation and thus the composition of the diet of the springbok originating from the different production regions. The meat obtained from the Rustfontein Nature Reserve (Table 2) had a significantly (p < 0.05) higher IMF (3.46 ± 0.44%) content and consequently a reduction in moisture content (72.71 ± 0.38%) in comparison with the other regions. Springbok originating from Willem Pretorius (1.26 ± 0.12%) and Gariep (1.77 ± 0.20%) had a significantly (p < 0.05) lower IMF content in comparison with the other production regions. In general, an inverse linear correlation was observed between the IMF and moisture content of the LD muscle (r = -0.49, p < 0.0001). A similar trend has been observed in beef and lamb (Doornenbal & Murray, 1981; Rowe *et al*., 1999). This trend is possibly a result of the fact that water and protein are mainly contained within the lean portion of meat (Aidoo &

Haworth, 1995). It would therefore be expected that meat with a lower IMF content would have a higher mean moisture and protein content (Aidoo & Haworth, 1995).

The female springbok exhibited a significantly ($p < 0.05$) higher IMF content (3.13 ± 0.28%) than the males (1.35 ± 0.08%) and consequently had a significantly ($p < 0.05$) lower moisture content. According to Ledger *et al*. (1967), the female gender of ungulate species generally has a slightly higher IMF content in comparison with the males and a similar tendency has been observed in springbok (Van Zyl & Ferreira, 2003). Hoffman (2000) made a similar finding for impala (*Aepyceros melampus*), where the females have a significantly higher IMF (3.4 ± 0.2%) content in comparison with the males (2.5 ± 0.3%). Twelve of the female adult animals in this investigation had IMF percentages above 5%. It may be speculated that these particular females did not lamb the previous season and therefore had a relatively higher IMF content. In the case of rutting males, field metabolic rates may average at 155% of the predicted rate, leading to weight loss (Nagy & Knight, 1994). This may be one of the factors leading to the lower fat content observed in the males. Timing and duration of the male rut of springbok has been noted to be random and could not be related to any specific factor (Skinner & Van Zyl, 1970; Skinner *et al*., 1996).



[a,b,c] Columns with different letters are significantly different ($p < 0.05$).

Figure 1 Protein (%) means for the production region and gender interaction (Region*Gender).

Age had a significant effect ($p < 0.05$) on the moisture and IMF content of the LD muscle. It was noted that the lambs had a higher mean moisture content (74.40 ± 0.33%) in comparison to the other two age categories, but that it only differed significantly ($p < 0.05$) from the adult group. This result is similar to that reported by Jansen van Rensburg (1997) who found that the moisture content of springbok in the young age group (24 to 60 weeks) was significantly higher than that in the very old age group (312 weeks).

The sub-adult (2.50 ± 0.28%) and adult (2.45 ± 0.26%) springbok had a significantly ($p < 0.05$) higher fat content than the lambs (1.32 ± 0.11%). There is a tendency towards increasing fat content in the carcass with an increase in animal age (Lawrie, 1985; Volpelli *et al*., 2003).

The protein content of the springbok meat originating from the four production regions varied between 18.80 ± 0.35% and 21.16 ± 0.51% (Figure 1). According to Van Zyl & Ferreira (2003), the protein content of the three-rib cut (bone-in) of springbok averaged at 24.2 ± 1.8 and 22.90 ± 1.80% for the males and females respectively. The protein content of impala (*Aepyceros melampus)* has been reported to vary from 23.6 to 24.1% (Hoffman, 2000). Onyango *et al*. (1998) compared the protein content of game species with beef and noted that beef loin had a slightly lower crude protein content (19.4 ± 0.4%).

According to Figure 1, no significant gender differences between the protein content (%) of meat originating from the different production regions were observed, except for that from Rustfontein. The females (21.81 ± 0.15%) from this region were noted to have a significantly ($p < 0.05$) higher protein content than the males (19.93 ± 0.22%). In contrast to the moisture content, no significant linear correlation was observed between the IMF and protein content of the LD muscle. The ash content of the meat originating from the different production regions varied between 1.1 and 1.4% and was found to be not significantly ($p > 0.05$) influenced by gender or age (Table 2). A significant inverse correlation between the moisture and ash content of the LD muscle was observed ($r = -0.32$, $p < 0.0001$).

The chemical composition of springbok meat is in keeping with that reported in farmed deer (Aidoo & Haworth, 1995), a domesticated game species. This game species has been noted to have a mean moisture, fat and protein content of 75.3, 0.8 and 20.1% respectively. The IMF content of farmed deer is therefore lower than that of springbok. The results of this study are also in keeping with that reported in pasture-fed fallow deer (*Dama dama*), except that this domesticated game species has been noted to have a low fat content of 0.55% (Volpelli *et al*., 2003).

Table 3 Mean amino acid composition (g. 100 g^{-1} dry matter) (± standard error) of the *M. longissimus dorsi* (LD) muscle of springbok (n = 22), with age, gender and production region as main effects.

Amino acid	**Production region**			**Age**		**Gender**	
	Caledon	**Gariep**	**WP**	**Adult**	**Sub-adult**	**Male**	**Female**
Essential							
Arginine	1.13 ± 0.05	1.07 ± 0.02	1.17 ± 0.04	1.08 ± 0.03	1.14 ± 0.03	1.14 ± 0.03	1.10 ± 0.04
Histidine	0.53 ± 0.02	0.49 ± 0.02	0.53 ± 0.02	0.50 ± 0.02	0.53 ± 0.01	0.53 ± 0.01	0.51 ± 0.02
Isoleucine	0.94 ± 0.06	0.93 ± 0.05	1.04 ± 0.04	0.96 ± 0.04	0.98 ± 0.04	0.99 ± 0.04	0.96 ± 0.04
Leucine	1.79^{b} ± 0.12	1.81^{ab} ± 0.05	2.04^{a} ± 0.07	1.88 ± 0.06	1.91 ± 0.07	1.94 ± 0.05	1.85 ± 0.08
Lysine	1.41^{b} ± 0.08	1.34^{b} ± 0.09	1.84^{a} ± 0.16	1.46 ± 0.11	1.61 ± 0.12	1.49 ± 0.09	1.64 ± 0.16
Methionine	0.56 ± 0.04	0.58 ± 0.01	0.62 ± 0.02	0.58 ± 0.01	0.60 ± 0.02	0.61 ± 0.01	0.58 ± 0.03
Phenylalanine	0.66^{ab} ± 0.04	0.63^{b} ± 0.02	0.62^{a} ± 0.03	0.67 ± 0.03	0.69 ± 0.03	0.69 ± 0.03	0.67 ± 0.03
Threonine	1.31^{b} ± 0.09	1.37^{ab} ± 0.03	1.48^{a} ± 0.04	1.38 ± 0.04	1.41 ± 0.04	1.44 ± 0.03	1.35 ± 0.06
Valine	1.16 ± 0.07	1.17 ± 0.04	1.28 ± 0.05	1.20 ± 0.04	1.23 ± 0.04	1.24 ± 0.03	1.19 ± 0.05
Non-essential							
Alanine	2.12 ± 0.13	2.10 ± 0.04	2.24 ± 0.07	2.10 ± 0.05	2.20 ± 0.06	2.23 ± 0.03	2.08 ± 0.09
Aspartic acid^{c}	2.31 ± 0.14	2.32 ± 0.04	2.54 ± 0.10	2.36 ± 0.07	2.44 ± 0.08	2.49 ± 0.05	2.32 ± 0.11
Cystine	0.16 ± 0.01	0.17 ± 0.00	0.18 ± 0.00	0.17 ± 0.00	0.17 ± 0.0	0.17 ± 0.00	0.17 ± 0.00
Glutamic acid^{d}	2.47 ± 0.12	2.55 ± 0.05	2.74 ± 0.09	2.57 ± 0.06	2.64 ± 0.07	2.68 ± 0.05	2.53 ± 0.09
Glysine	1.71 ± 0.17	1.43 ± 0.02	1.53 ± 0.05	1.44 ± 0.03	1.59 ± 0.07	1.56 ± 0.05	1.50 ± 0.08
Proline	1.09 ± 0.08	1.04 ± 0.02	1.06 ± 0.03	1.01 ± 0.02	1.09 ± 0.03	1.09 ± 0.02	1.03 ± 0.04
Serine	1.48 ± 0.09	1.44 ± 0.05	1.60 ± 0.05	1.47 ± 0.05	1.53 ± 0.05	1.54 ± 0.04	1.48 ± 0.06
Tyrosine	0.60 ± 0.03	0.59 ± 0.01	0.65 ± 0.02	0.60 ± 0.02	0.62 ± 0.02	0.63 ± 0.02	0.60 ± 0.02

^{a,b} Values in the same row (within main effect) with different letters are significantly different ($p < 0.05$).

WP - Willem Pretorius Nature Reserve.

^{c} Aspartic acid - aspartine + aspartic

^{d} Glutamic acid - glutamine + glutamic

Table 4 Mean mineral composition (mg. 100 g^{-1} dry matter) (± standard error) of the *M. longissimus dorsi* (LD) muscle of springbok (n = 22), with age, gender and production production region as main effects.

Mineral	Production region			Age		Gender	
	Caledon	Gariep	WP	Adult	Sub-adult	Male	Female
Phosphorus	122.92 [b] ± 9.81	138.03 [a] ± 0.83	159.78 [a] ± 8.38	150.63 ± 12.81	138.28 ± 6.10	148.55 ± 9.53	135.39 ± 6.08
Potassium	127.29 ± 7.62	128.79 ± 8.35	119.44 ± 6.33	131.25 ± 7.39	122.15 ± 5.37	121.75 ± 5.63	128.64 ± 6.80
Calcium	30.50 [b] ± 1.31	6.57 [b] ± 0.49	145.18 [a] ± 18.40	84.67 ± 29.92	51.65 ± 17.83	79.24 ± 23.03	43.77 ± 19.85
Sodium	14.73 ± 0.40	14.81 ± 0.70	12.84 ± 0.76	14.09 ± 0.92	14.08 ± 0.49	14.12 ± 0.67	14.04 ± 0.56
Iron	2.80 ± 0.28	2.89 ± 0.23	2.93 ± 0.17	2.67 ± 0.23	2.98 ± 0.15	2.74 ± 0.21	3.04 ± 0.13
Copper	0.10 ± 0.02	0.08 ± 0.02	0.08 ± 0.01	0.08 ± 0.02	0.09 ± 0.01	0.09 ± 0.01	0.09 ± 0.01
Zinc	1.79 [a] ± 0.37	1.20 [b] ± 0.08	1.16 [b] ± 0.08	1.17 ± 0.10	1.40 ± 0.15	1.29 ± 0.08	1.37 ± 0.20
Magnesium	19.84 ± 1.14	17.84 ± 1.45	18.64 ± 0.64	17.21 ± 1.62	19.26 ± 0.61	17.77 ± 1.08	19.51 ± 0.75

[a,b] Values in the same row (within main effect) with different letters are significantly different ($p < 0.05$).

WP - Willem Pretorius Nature Reserve.

The mean amino acid and mineral content (± standard error) of the springbok sub-sample (n = 22) are presented in Table 3 and Table 4, respectively.

The two major amino acids noted were glutamic and aspartic acid, which contributed 2.47 to 2.74 and 2.31 to 2.54 g. 100 g $^{-1}$ muscle, respectively.

Leucine (1.79 - 2.04 g. 100g $^{-1}$) was the major essential amino acid in springbok meat, followed by lysine (1.34 1.84 g. 100g $^{-1}$) (Table 3). A similar trend has been observed in impala (*Aepyceros melampus*) (Kritzinger, 2002), with leucine and lysine found to be the major essential amino acids. Production region had a significant ($p < 0.05$) effect on the following amino acids: leucine; lysine; phenylalanine and threonine. This trend may be a result of variations in vegetation and thus in the composition of the diet of the springbok originating from the different production regions. No significant differences were observed between gender and age categories with regard to the amino acid composition of the meat. This is in keeping with the finding of Kritzinger (2002) that age and gender had no significant effect on the amino acid composition of impala.

Various factors, such as the concentration of minerals in the diet, hormones, age, gender and region, may cause variations in the mineral composition of meat (Doyle, 1980). Production region had a significant ($p < 0.05$) effect on the phosphorus, calcium and zinc concentrations of the meat. This is probably a result of variations in diet composition and thus in available nutrients. Age has been reported to be an important factor that influences the mineral concentration of animal tissue (Doornenbal & Murray, 1981; Kotula & Lusby, 1982; Lin *et al*., 1989). However, in this study age had no significant ($p > 0.05$) effect on the mineral concentration of the LD muscle. Gender similarly exhibited no significant ($p > 0.05$) effect on the mineral composition of the meat.

Phosphorous occurred in the highest concentration (122.92 - 159.78 mg. 100 g^{-1}), followed by potassium and calcium (Table 4). This finding is similar to that reported on the mineral composition of impala, where it was noted that phosphorus and potassium were the predominant minerals (Kritzinger, 2002). In bovine muscles a higher concentration of potassium, sodium, phosphorus and chlorine and a lower concentration of calcium, magnesium, zinc and iron was noted (Zarkadus *et al*., 1987).

CONCLUSION

The results of this study emphasise the fact that production region may have a significant effect on the chemical composition of springbok (*Antidorcas marsupialis*) meat, as a result of variations in vegetation and hence in the available nutrients. The low IMF content of springbok meat was confirmed in this study. The low fat content of springbok makes this meat an attractive alternative for the health-conscious consumer's diet. Production region had a significant effect on the IMF, moisture and ash content of the meat. The females were noted to have a significantly higher IMF content in comparison with the males, which is in agreement with previous studies. Age influenced the IMF content of the meat, with the adult and sub-adult categories having a significantly higher IMF content in comparison with the lambs. Production region exhibited a significant effect on the amino acid and mineral composition of springbok meat, whereas age and gender exhibited no significant effect.

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CHAPTER 6

FATTY ACID COMPOSITION OF SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) MEAT AS INFLUENCED BY AGE, GENDER AND PRODUCTION REGION

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ABSTRACT

The effects of age, gender and production region on the fatty acid composition of springbok *M. longissimus dorsi* (LD) muscle were investigated. The springbok (n = 19) originated from two nature reserves in the Free State Province of South Africa and were divided into adult and sub-adult categories. The major fatty acid of the LD muscle was stearic acid (C18:0), which contributed 2.08 to 2.94 mg. g^{-1} muscle. C18:1 represented the largest component (1.42 - 2.56 mg. g^{-1}) of the mono-unsaturated fatty acids (MUFA). The major n-6 polyunsaturated fatty acid (PUFA) was C18:2n-6, which contributed 1.61 to 2.31 mg. g^{-1} muscle and was found to be the second major fatty acid after C18:0. The major n-3 PUFA, which is very important in establishing an optimal PUFA n-6:n-3 ratio, was C18:3n-3, which contributed 0.29 to 0.43 mg. g^{-1} muscle. The n-6:n-3 ratio of the meat varied from 3.02 to 3.35, with an average ratio of 3.2, which is well below the recommended maximum of 4. Polyunsaturated to saturated (P:S) ratios varied between 0.96 and 1.18 and averaged at 1.06. Production region had a significant effect ($p < 0.05$) on the fatty acid composition of the meat, especially in terms of certain n-6 and n-3 PUFA's. No significant ($p > 0.05$) age effect was observed, except for a significantly ($p < 0.05$) lower content of C24:1n-9 (MUFA) in the sub-adult group. The C24:1n-9 content of the females was also found to be the only fatty acid that was significantly ($p < 0.05$) higher than that of the males. The cholesterol content of the meat varied from 54.45 to 59.34 mg. $100g^{-1}$ muscle. Linear correlations between the fatty acid and the

intramuscular fat (IMF) content of the LD muscle indicated a significant increase in certain SFA's and MUFA's with increasing IMF content of the meat.

Keywords: game meat; fat; fatty acids; cholesterol

INTRODUCTION

Consumption of meat is associated with the ingestion of fat and consumers are especially conscious of their dietary intake of saturated fats, which elevates the serum cholesterol levels *in vitro* (Flynn *et al*., 1985). An important benefit of game meat in comparison to domestic ruminant meat is that this meat provides lower amounts of intramuscular fatty acids, with a higher composition of polyunsaturated fatty acids (PUFA) and lower amounts of both mono-unsaturated (MUFA) and saturated fatty acids (SFA) (Fisher *et al*., 1998). Important PUFA's of meat include the essential fatty acids, linoleic acid (C18:2 n-6) and α-linolenic acid (C18:3 n-3), as well as the C20 and C22 PUFA's that are present in the phospholipids (Enser *et al*., 1996). People have the enzymatic capacity to produce the latter PUFA's from their n-6 and n-3 precursors, namely linoleic and α-linolenic acid respectively. It is also known that meat, fish and fish oils are the only significant dietary sources of C20 and C22 n-3 PUFA (Enser *et al*., 1996).

Plasma cholesterol levels are influenced by the fatty acid composition of the diet (Flynn *et al*., 1985). In general, MUFA's and PUFA's do not increase cholesterol levels, but high levels of long-chain SFA's do (Grundy & Denke, 1990). However, not all SFA's have cholesterol elevating attributes. It has been reported that lauric (C12:0), myristic (C14:0) and palmitic acid (C16:0) increase serum cholesterol levels, but that stearic acid (C18:0) does not (Rowe *et al*., 1999). The general guidelines for the consumer are to reduce the intake of n-6 PUFA's to n-3 PUFA's and the intake of short- and medium-chain SFA's (Gibney, 1993). According to Enser *et al*. (1996), few studies have reported complete data for the n-6 and n-3 PUFA composition of red meats and very few report that of wild southern Africa ungulates.

The amount of fat consumed and its saturation are very important risk factors for coronary diseases (Girolami *et al*., 2003). The ratio between polyunsaturated and saturated (P:S) fatty acids is below the optimal value of 0.45 in Western countries and ruminant meats are implicated in this imbalance. Rumen microorganisms may increase the degree of fat saturation by performing extensive hydrogenation (Wood & Enser, 1997; Girolami *et al*., 2003).

Springbok (*Antidorcas marsupialis*) is the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999) and therefore has great venison production potential. Springbok meat has a lower total lipid content than that of beef (four-folded) (Viljoen, 1999). According to Skinner & Louw (1996), the mean fat content of springbok carcasses never exceeds 4%. Highly polyunsaturated fatty acids (C20:5, C22:4 and C22:6) were reported to be present in springbok meat that are not found in beef (Viljoen, 1999). Viljoen (1999) used different cuts of only one springbok for his investigation and did not indicate the fat level, age or gender in that study. In addition to species differences, age, sex and diet variation are likely to influence the lipid composition of meat (Rule *et al*., 2002).

The purpose of this study was therefore to investigate any possible effects that age, gender and production region may have on the fatty acid composition and cholesterol content of springbok *M. longissimus dorsi* (LD) muscle.

MATERIALS AND METHODS

Animals and sampling

Springbok (n=19) were sampled from two nature reserves (Gariep and Willem Pretorius) in the Free State Province of South Africa. The springbok were randomly harvested at night by a professional culling team using spotlights (1 million candela) and small calibre rifles, similar to the method described by Lewis *et al*. (1997). Animals were sighted directly or by the reflection of the light from their retinas. The shots were either head or high neck shots, resulting in immediate insensibility.

The Free State Province's largest Nature Reserve is a combination of the 36 487 ha Gariep Nature Reserve on the Orange River and an 11 237 ha game sanctuary on its northern shore. The Gariep Nature Reserve accommodates a large population of springbok, black wildebeest and red hartebeest (Hocking *et al*., 1983). The Willem Pretorius Nature Reserve (WP) is an 10 520 ha game reserve that accommodates springbok, black wildebeest, blesbok, red hartebeest, eland, zebra, impala and white rhino (Bulpin, 1992).

The ages of the springbok were estimated using the length and size of the horns as parameters (Rautenbach, 1971). The springbok were divided into two age categories, namely adult (2 to 5 years) and sub-adult (1 to 2 years). The distribution of the springbok according to age, gender and production region, is presented in Table 1.

After harvesting, the animals were exsanguinated within 2 - 5 min. by cutting the throat with a sharp, sterile knife. Each carcass was individually tagged with an identification number and hung from the Achilles tendons.

Table 1 Distribution of springbok (n = 19) according to age, gender and production region.

	Gariep		**WP**		
	Male	**Female**	**Male**	**Female**	**Total**
Adult	3	2	3	1	9
Sub-adult	2	2	3	3	10
Total	5	4	6	4	**19**

After the targeted number of antelope had been harvested, the carcasses were taken to a nearby abattoir for processing. This included skinning, evisceration and cleaning of the carcasses according to South African practices (Hoffman, 2000). The carcasses were cooled to 4°C approximately five to eight hours after cropping (depending on the time the animals were shot).

The LD muscle was dissected 24 hr postmortem. The meat samples from the right and left hand side of the carcass were removed between the 12^{th} and 13^{th} rib and anterior to the last lumbar vertebra. All visible connective tissue and subcutaneous fat were removed from the samples. Samples were vacuum packed and subsequently frozen at -20ºC for the determination of the fatty acid composition, cholesterol and fat content of the meat.

Fatty acid analyses

The fatty acid content of the meat was determined according to the method described by Tichelaar *et al*. (1998). After thawing, a 2 g sample of meat was extracted with a chloroform/methanol (CM 2:1; v/v) solution according to a modified method of Folch *et al*. (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenise the sample with 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 hr at 70ºC using a methanol/sulphuric acid (19:1; v/v) solution as transmethylating agent. After cooling, the resulting fatty acid methyl esters (FAMEs) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen.

The FAMEs were purified by TLC (silica gel 60 plates) and analysed by gas-liquid chromatography (GLC). A Varian Model 3300 was used that is equipped with flame ionisation detection using 60m BPX70 Capillary columns of 0.25 mm internal diameter (SGE, Australia). Gas flow rates were 25 ml/min. for hydrogen and 2-4 ml/min. for the hydrogen carrier gas. Temperature programming was linear at 3ºC/min., with an initial temperature of 150ºC, a final temperature of 220ºC, an injector temperature of 240ºC and a detector temperature of 250ºC. The FAMEs were identified by comparing the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Cholesterol analyses

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 potassium hydroxide (KOH) was used to saponify the extraction in a heating block for 2 hr at 70ºC. After cooling, distilled water and hexane were added and the resulting extraction was analysed by GLC (Varian Model 3700, equipped with flame ionisation 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 20 ml/min. for hydrogen, 200 ml/min. for air and 25 ml/min. for nitrogen carrier gas. Temperatures were as follows: injector temperature (280ºC); column temperature (255ºC) and detector temperature (290ºC).

Chemical analyses

Proximate chemical analyses were carried out on the LD muscle. Meat samples were minced (2 mm sieve) three times prior to analysis. The moisture (100°C, 24 hr) and ash content (500ºC, 5 hr) of the samples were determined according to AOAC methods (AOAC, 1997). Lipids were extracted with a chloroform:methanol (2:1, v/v) solution by the solvent extraction method described by Lee *et al*. (1996). The protein content was determined by the block digestion method and obtained by multiplying Kjeldahl nitrogen by a factor of 6.25 (AOAC, 1997).

Statistical analyses

A three-factor factorial experiment was performed in a completely randomised design with unequal number of random replications. The factors were two regions (Gariep, Willem Pretorius), two age groups (adult and sub-adult) and two genders (male and female). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to analysis of variance (ANOVA) using SAS version 8.2 statistical software (SAS, 1999). The Shapiro-Wilk test was performed for non-normality (Shapiro & Wilk, 1965). The Student's t-Least Significant Difference was calculated at the 5% confidence level to compare treatment means (Ott, 1998). Pearson correlation coefficients were determined using the linear regression procedure (Proc CORR) of SAS (1999).

RESULTS AND DISCUSSION

The fatty acid profile of springbok *M. longissimus dorsi* (LD) muscle was examined in this study. The means (± standard error) of the proximate chemical composition of the LD muscle of these springbok (n = 19) are presented in Table 2. The values of the chemical composition of the meat are within the expected ranges. The fat content of the meat varied between 1.07 ± 0.14 and 1.37 ± 0.31%. The protein content differed significantly ($p < 0.05$) between the two regions and between the two age categories. The sub-adults (21.16 ± 0.26) had a significantly higher protein content than the adults (20.16 ± 0.40). The fatty acid composition (mg. g^{-1}) of springbok meat sampled from the two different production regions and divided into age and gender categories is presented in Table 3. The percentage fatty acid composition by weight of the total identified fatty acids of the LD muscle is presented in Table 4. C22:1 was noted to be the only fatty acid of interest that could not be detected in measurable quantities. The total fatty acid content of the meat ranged from 8.052 to 11.841 mg. g^{-1} (Table 3). Region had a significant effect on the latter, although no significant differences were observed between the total fat content of the meat originating from the two regions.

Table 2 Means (± standard error) of the proximate chemical composition of the *M. longissimus dorsi* (LD) muscle (n = 19),with age, gender and production region as main effects.

Main effects		**Moisture (%)**	**Protein (%)**	**Fat (%)**	**Ash (%)**
Region :	**Gariep (n = 10)**	72.951 ± 0.53	20.180^{a} ± 0.36	1.190 ± 0.26	1.345 ± 0.13
	W.P (n = 9)	73.329 ± 0.31	21.240^{b} ± 0.27	1.220 ± 0.19	1.197 ± 0.11
Gender:	**Male (n = 10)**	73.101 ± 0.46	20.818 ± 0.30	1.072 ± 0.14	1.197 ± 0.10
	Female (n = 9)	73.101 ± 0.44	20.578 ± 0.44	1.367 ± 0.31	1.361 ± 0.14
Age:	**Adult (n = 9)**	72.788 ± 0.45	20.156^{a} ± 0.40	1.222 ± 0.31	1.177 ± 0.12
	Sub-adult (n = 10)	73.348 ± 0.42	21.163^{b} ± 0.26	1.191 ± 0.16	1.363 ± 0.12

[a,b] Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

The production region had a significant ($p < 0.05$) effect on the total fatty acid content of the meat, although the IMF content of the springbok originating from the two regions did not differ significantly. Age and gender had no significant ($p > 0.05$) effect on the total fatty acid content of the meat. The SFA content of springbok meat contributed 38.40 to 42.69% of the total identified fatty acids in the meat (Table 4). A relative high SFA content is expected in ruminant meat resulting from the hydrogenating action of the rumen bacteria, which may convert high forage PUFA's to SFA's (Wood & Enser, 1997). The major fatty acid in the LD muscle was noted stearic acid (C18:0), which contributed 2.08 to 2.94 mg. g^{-1} muscle (Table 3). Palmitic acid (C16:0) was found to be the second major SFA present. Stearic and palmitic acid have also been found to be the major SFA's in domesticated deer (Aidoo & Haworth, 1995). According to Rowe *et al*. (1999), lauric, myristic and palmitic acid raise both lowdensity (LDL) and highdensity (HDL) serum cholesterol, although stearic acid has little effect. The major fatty acid found in springbok meat therefore does not have cholesterol-highering attributes.

The major MUFA in the present study was oleic acid (C18:1), which contributed 1.42 to 2.56 mg. g^{-1} muscle (Table 3). A high oleic acid content and low saturated to polyunsaturated ratio are important in reducing the risk of cardiovascular diseases (Harrington, 1994), adding another health benefit to springbok meat. This fatty acid was also noted to be the major MUFA in domesticated deer (Aidoo & Haworth, 1995). In lamb *longissimus dorsi* (LD) muscle, palmitic, stearic and oleic acid comprise the greatest proportion of the fatty acid composition (Enser *et al*., 1996; Rowe *et al*., 1999). These fatty acids have also been reported to be the most abundant fatty acids in beef and pork (Enser *et al*., 1996). The adult category of springbok had a higher MUFA content (19.20 $\pm$ 2.36%) in comparison to the sub-adults (17.98 $\pm$0.80%), although this was not significant ($p > 0.05$) (Table 4). According to Volpelli *et al*. (2003), older domesticated deer *(Dama dama*) show an increase in MUFA's, with younger animals having higher n-3 and n-6 PUFA's. C24:1n-9 was noted to be the only fatty acid that had a significantly higher concentration in the adult versus the sub-adult category. C24:1n-9 was found to be the only fatty acid that was significantly ($p < 0.05$) higher in the female than in the male category (Table 3).

The PUFA content (36.34 to 40.98%) of the meat was very close to the range of the SFA's and optimal P:S ratios were therefore expected. According to Enser *et al*. (1996), the *M. longissimus thoracis et lumborum*, in general, is low in phospholipids and therefore will have lower concentrations of both C20 and C22 PUFA's, as these fatty acids are mainly present in the phospholipids.

The major n-3 PUFA was the essential α-linolenic acid (C18:3n-3), which is very important in establishing optimal n-6:n-3 ratios. This fatty acid contributed 0.29 to 0.43 mg. g^{-1} muscle. This fatty acid is also the major fatty acid found in grass lipids (Marmer *et al*., 1984). These PUFA's receive greater protection from the hydrogenating action of the rumen by natural seed coats and organelles (grass chloroplasts) that enclose the lipids (Wood & Enser, 1997). Grass is an important part of the diet of springbok (Bigalke, 1972) and therefore will contain a relative high percentage of α-linolenic acid. Important grass species grazed on by springbok have been noted by Furstenburg (2002). The other n-3 PUFA's found in springbok LD muscle were C20:5n-3, C22:5n-3 and C22:6n-3.

The major n-6 PUFA was linoleic acid (C18:2n-6), which contributed 1.61 to 2.31 mg. g^{-1} muscle and was also noted to be the second major fatty acid after stearic acid (C18:0) (Table 3).

Table 3 Mean fatty acid composition (mg. g^{-1} muscle) (± standard error) of the intramuscular fat (IMF) of springbok *M. longissimus dorsi* (LD) (n = 19) according to age, gender and production region.

Fatty acid	Production region		Age		Gender	
	Gariep	WP	Adult	Sub-adult	Male	Female
C16:0 (palmitic)	1.567 ± 0.28	1.197 ± 0.09	1.568 ± 0.28	1.196 ± 0.10	1.220 ± 0.10	1.581 ± 0.31
C16:1 (palmitoleic)	0.028 [a] ± 0.01	0.002 [b] ± 0.00	0.020 ± 0.01	0.009 ± 0.01	0.006 ± 0.00	0.025 ± 0.02
C18:0 (stearic)	2.944 ± 0.59	2.079 ± 0.09	2.866 ± 0.58	2.150 ± 0.55	2.236 ± 0.15	2.836 ± 0.67
C18:1 (oleic)	2.510 ± 0.79	1.421 ± 0.14	2.310 ± 0.81	1.601 ± 0.16	1.487 ± 0.14	2.555 ± 0.89
C18:2n-6 (linoleic)	2.311 [a] ± 0.16	1.613 [b] ± 0.15	1.908 ± 0.22	1.976 ± 0.18	1.974 ± 0.19	1.903 ± 0.20
C18:3n-6 (γ-linolenic)	0.019 [a] ± 0.00	0.009 [b] ± 0.00	0.014 ± 0.00	0.013 ± 0.00	0.014 ± 0.00	0.014 ± 0.00
C18:3n-3 (α-linolenic)	0.426 [a] ± 0.03	0.293 [b] ± 0.04	0.340 ± 0.05	0.370 ± 0.04	0.355 ± 0.04	0.356 ± 0.05
C20:0 (arachidic)	0.049 ± 0.02	0.026 ± 0.00	0.050 ± 0.02	0.025 ± 0.00	0.051 ± 0.00	0.051 ± 0.02
C20.1n-9 (eicosenoic)	0.018 ± 0.00	0.007 ± 0.00	0.014 ± 0.00	0.010 ± 0.00	0.009 ± 0.00	0.016 ± 0.00
C20:2n-6	0.031 ± 0.00	0.020 ± 0.00	0.026 ± 0.00	0.025 ± 0.00	0.025 ± 0.00	0.025 ± 0.00
C20:3	0.023 ± 0.00	0.020 ± 0.00	0.023 ± 0.00	0.020 ± 0.00	0.022 ± 0.00	0.021 ± 0.00
C20:4n-6 (arachidonic)	0.946 ± 0.00	0.710 ± 0.09	0.796 ± 0.00	0.845 ± 0.08	0.838 ± 0.08	0.799 ± 0.11
C20:5n-3 (eicosapentaenoic)	0.269 [a] ± 0.02	0.176 [b] ± 0.02	0.193 ± 0.03	0.244 ± 0.02	0.217 ± 0.02	0.224 ± 0.03
C22:0	0.026 ± 0.00	0.022 ± 0.00	0.024 ± 0.00	0.023 ± 0.00	0.023 ± 0.00	0.025 ± 0.00
C22:1	ND	ND	ND	ND	ND	ND
C22:4n-6	0.042 [a] ± 0.00	0.017 [b] ± 0.00	0.030 ± 0.00	0.028 ± 0.00	0.027 ± 0.00	0.031 ± 0.00
C22:5n-3 (docosapentaenoic)	0.299 [a] ± 0.03	0.182 [b] ± 0.02	0.224 ± 0.03	0.249 ± 0.03	0.237 ± 0.03	0.238 ± 0.03
C22:6n-3 (docosahexaenoic)	0.123 ± 0.03	0.078 ± 0.02	0.100 ± 0.03	0.099 ± 0.02	0.083 ± 0.02	0.123 ± 0.03
C24:0	0.046 ± 0.00	0.043 ± 0.00	0.047 ± 0.00	0.043 ± 0.00	0.043 ± 0.00	0.046 ± 0.00
C24:1n-9	0.024 ± 0.00	0.017 ± 0.00	0.028 [a] ± 0.00	0.014 [b] ± 0.00	0.015 [b] ± 0.00	0.029 [a] ± 0.00
Fatty acid total	11.841 [a] ± 1.83	8.052 [b] ± 0.51	10.699 ± 2.02	9.080 ± 0.55	8.981 ± 0.55	11.038 ± 2.24
DFA	10.131 [a] ± 1.54	6.744 [b] ± 0.44	9.266 ± 1.94	7.681 ± 0.48	7.647 ± 0.53	9.313 ± 1.90
SFA	4.630 ± 0.88	3.370 ± 0.17	4.508 ± 0.99	3.574 ± 0.24	3.551 ± 0.23	4.539 ± 0.99
MUFA	2.578 ± 0.81	1.450 ± 0.14	2.453 ± 0.95	1.645 ± 0.15	1.519 ± 0.15	2.625 ± 0.92
PUFA	4.606 [a] ± 0.35	3.213 [b] ± 0.30	3.943 ± 0.47	3.823 ± 0.35	3.891 ± 0.37	3.849 ± 0.44
PUFA n-6	3.350 [a] ± 0.26	2.367 [b] ± 0.23	2.920 ± 0.34	2.769 ± 0.26	2.877 ± 0.28	2.771 ± 0.32
PUFA n-3	1.115 [a] ± 0.09	0.727 [b] ± 0.08	0.903 ± 0.13	0.917 ± 0.09	0.892 ± 0.09	0.938 ± 0.13
P:S	1.178 ± 0.17	0.960 ± 0.09	0.969 ± 0.12	1.132 ± 0.14	1.141 ± 0.13	0.956 ± 0.12
n-6:n-3	3.020 ± 0.09	3.347 ± 0.16	3.341± 0.17	3.084 ± 0.11	3.278 ± 0.12	3.073 ± 0.16

[a,b] Values in same row (within main effect) with different letters are significantly different ($p < 0.05$).

Table 4 Mean fatty acid composition (percentage of total fatty acids) (± standard error) of the intramuscular fat (IMF) of springbok *M. longisimus dorsi* (n = 19) according to age, gender and production region.

Fatty acid	Region		Age		Gender	
	Gariep	W.P	Adult	Sub-Adult	Male	Female
C16:0 (palmitic)	13.343 ± 1.41	14.902 ± 0.60	15.058 ± 1.13	13.369 ± 0.95	13.931 ± 1.20	14.484 ± 0.69
C16:1 (palmitoleic)	0.196[a] ± 0.06	0.027[b] ± 0.03	0.107 ± 0.06	0.107 ± 0.04	0.067 ± 0.03	0.161 ± 0.07
C18:0 (stearic)	24.079 ± 1.46	26.560 ± 1.64	27.017 ± 1.61	23.916 ± 1.47	25.315 ± 1.51	25.480 ± 1.76
C18:1 (oleic)	18.809 ± 2.04	17.398 ± 0.82	18.732 ± 2.01	17.467 ± 0.89	16.334[b] ± 0.72	20.449[a] ± 2.05
C18:2n-6 (linoleic)	21.229 ± 2.00	19.688 ± 2.00	19.177 ± 1.76	21.535 ± 1.25	21.615 ± 1.33	18.773 ± 1.67
C18:3n-6 (γ-linolenic)	0.152 ± 0.03	0.091 ± 0.03	0.114 ± 0.03	0.125 ± 0.02	0.128 ± 0.03	0.109 ± 0.03
C18:3n-3 (α-linolenic)	3.880 ± 0.34	3.493 ± 0.38	3.328 ± 0.32	3.990 ± 0.37	3.371 ± 0.29	3.898 ± 0.46
C20:0 (arachidic)	0.348 ± 0.06	0.328 ± 0.03	0.404[a] ± 0.06	0.277[b] ± 0.02	0.306 ± 0.03	0.381 ± 0.07
C20.1n-9 (eicosenoic)	0.121 ± 0.02	0.084 ± 0.02	0.098 ± 0.03	0.105 ± 0.01	0.099 ± 0.02	0.105 ± 0.03
C20:2n-6	0.254 ± 0.04	0.253 ± 0.04	0.254 ± 0.04	0.253 ± 0.03	0.276 ± 0.03	0.223 ± 0.04
C20:3	0.209 ± 0.03	0.227 ± 0.03	0.212 ± 0.03	0.224 ± 0.03	0.236 ± 0.03	0.195 ± 0.03
C20:4n-6 (arachidonic)	8.518 ± 0.82	8.672 ± 0.65	7.848 ± 0.06	9.275 ± 0.65	9.304 ± 0.73	7.630 ± 0.61
C20:5n-3 (eicosapentaenoic)	2.507 ± 0.27	2.139 ± 0.22	1.887[b] ± 0.24	2.697[a] ± 0.20	2.382 ± 0.21	2.219 ± 0.33
C22:0	0.236 ± 0.05	0.274 ± 0.03	0.261 ± 0.03	0.251 ± 0.03	0.256 ± 0.02	0.256 ± 0.04
C22:1	ND	ND	ND	ND	ND	ND
C22:4n-6	0.368 ± 0.06	0.205 ± 0.05	0.276 ± 0.06	0.288 ± 0.06	0.271 ± 0.06	0.289 ± 0.06
C22:5n-3 (docosapentaenoic)	2.709 ± 0.31	2.226 ± 0.17	2.188 ± 0.20	2.695± 0.28	2.589 ± 0.26	2.270 ± 0.25
C22:6n-3 (docosahexaenoic	1.159 ± 0.26	0.999 ± 0.23	1.024 ± 0.27	1.120 ± 0.23	0.940 ± 0.20	1.260 ± 0.30
C24:0	0.390 ± 0.06	0.633 ± 0.11	0.520 ± 0.11	0.516 ± 0.08	0.525 ± 0.08	0.509± 0.12
C24:1n-9	0.178 ± 0.03	0.251 ± 0.10	0.288[a] ± 0.11	0.152[b] ± 0.03	0.172 ± 0.03	0.276 ± 0.13
SFA [c]	38.400 ± 2.57	42.690 ± 2.15	41.702 ± 2.32	39.899 ± 2.46	41.108 ± 2.11	40.331 ± 2.57
MUFA [d]	19.304 ± 2.10	17.761 ± 0.82	19.202 ± 2.36	17.975 ± 0.80	20.994[a] ± 2.10	16.672[b] ± 0.72
PUFA [e]	40.984 ± 3.91	37.995 ± 3.16	37.890 ± 3.18	40.517 ± 3.01	36.342 ± 3.37	41.643 ± 2.75

[a,b] Values in same row (within main effect) with different letters are significantly different ($p < 0.05$).
ND - Not detected

[c]SFA - Saturated fatty acids

[d]MUFA - Mono-unsaturated fatty acids

[e]PUFA - Polyunsaturated fatty acids

The second major n-6 PUFA was arachidonic acid (C20:4n-6). This highly polyunsaturated fatty acid has been noted to have cholesterol-lowering attributes *in vitro* (Viljoen, 1999). The high amounts of linoleic and arachidonic acid are similar to that reported in ostrich meat (Girolami *et al*., 2003). The presence of the highly polyunsaturated fatty acid C22:4n-6 (0.02 - 0.04 mg. g^{-1}) is in agreement with previous research conducted on springbok meat (Viljoen, 1999).

Springbok meat originating from Gariep Nature Reserve had a significantly higher PUFA content (40.98 ± 3.91%) than the meat originating from Willem Pretorius (38.00 ± 3.16%). This region therefore delivered significantly ($p < 0.05$) higher amounts of both n-6 and n-3 PUFA's. Springbok meat originating from Willem Pretorius had significantly ($p < 0.05$) lower amounts of the following unsaturated fatty acids: palmitoleic, linoleic, γ-linolenic (C18:3n-6), α-linolenic (C18:3n-3), eicosapentaenoic (C20:5n-3), C22:4n-6 and C22:5n-3 (Table 3). The varying composition of the diet of springbok originating from the different regions may have attributed to this phenomenon. It is known that diet influences the fatty acid composition of ruminant meat, despite the hydrogenating effect of the rumen bacteria (Wood & Enser, 1997; Rowe *et al*., 1999). Age and gender had no significant effect on the PUFA content of the meat (Table 3).

The P:S ratios of springbok meat varied between 0.96 and 1.18 and averaged at 1.06 (Table 3). The P:S ratios of chicken leg (0.97), chicken breast (0.85) and veal (0.35) have been reported to be optimal in comparison with those that of pork (0.30), lamb (0.26) and beef (0.11) (NLSMB, 1992). In contradiction to the above finding, Enser *et al*. (1996) reported that pork and lamb have a P:S ratio of 0.58 and 0.15 respectively. The recommended value for P:S ratios is 0.45 (Wood & Enser, 1997). According to Raes *et al*. (2004), the recommended P:S ratio is 0.7 or higher. The P:S ratio of springbok is higher than the recommended ratio of 0.7 and therefore springbok meat may be seen as an essential component of the health conscious consumer's diet.

In Western diets the n-6:n-3 ratio averages at 10, which is well below the preferred ratio of 5 (Sañudo *et al*., 2000). According to Girolami *et al*. (2003), the ideal n-6:n-3 ratio is 1 and the recommended maximum is 4. The n-6:n-3 ratio of springbok meat varied between 3.02 and 3.35 (Table 3), with an average ratio of ± 3.2, which is well below the recommended maximum. It has been reported by Rule *et al*. (2002) that game meat is seen as a healthy meat option because its high n-3 and n-6 PUFA content contributes to its nutritional benefits. According to Rhee (1992), the Desirable Fatty Acid (DFA) content is the sum of all the unsaturated fatty acids and stearic acid. Meat originating from Gariep had a significantly ($p < 0.05$) higher DFA content (10.13 ± 1.54 mg. g^{-1}) in comparison to meat from Willem Pretorius (6.74 ± 0.44 mg. g^{-1}). Age and gender exhibited no significant ($p > 0.05$) effect on the DFA content of the meat (Table 3).

The cholesterol content of the meat varied between 54.45 and 59.34 mg. $100g^{-1}$ and did not differ significantly ($p > 0.05$) between production region, gender and age categories. The cholesterol content of springbok meat is therefore lower than that reported for grazed lambs (62.03 ± 4.46 mg.100 g^{-1}) (Rowe *et al*., 1999). C22:0 was found to be the only fatty acid that was positively correlated ($r = 0.55$; $p = 0.02$) with the cholesterol level of the meat.

The linear relationship between the intramuscular fat (IMF) content and the fatty acid profile of the LD muscle is presented in Table 5.

Table 5 Linear relationship between intramuscular fat (IMF) content and the fatty acid composition (mg. g^{-1}) of the LD muscle of springbok analysed (n = 19).

Fatty acid	r	p
C16:0 (palmitic)	0.73	[b]
C16:1 (palmitoleic)	0.60	[b]
C18:0 (stearic)	0.69	[b]
C18:1 (oleic)	0.72	[b]
C18:2n-6 (linoleic)	0.24	NS
C18:3n-6 (γ-linolenic)	0.47	[a]
C18:3n-3 (α-linolenic)	0.36	NS
C20:0 (arachidic)	0.65	[b]
C20.1n-9 (eicosenoic)	0.67	[b]
C20:2n-6	0.14	NS
C20:3	0.41	NS
C20:4n-6 (arachidonic)	0.43	NS
C20:5n-3 (eicosapentaenoic)	0.29	NS
C22:0	-0.08	NS
C22:1	ND	NS
C22:4n-6	0.22	NS
C22:5n-3 (docosapentaenoic)	0.23	NS
C22:6n-3 (docosahexaenoic)	-0.15	NS
C24:0	-0.14	NS
C24:1n-9	0.22	NS
Fatty acid total	0.66	[b]

[a] $p < 0.05$
[b] $p < 0.01$
NS = not significant
ND = not detectable
r = correlation coefficient

A significant ($p < 0.01$) increase in the following SFA's were observed with an increase in the IMF content of the LD muscle: palmitic acid ($r = 0.73$); stearic acid ($r = 0.69$) and arachidic acid ($r = 0.65$). Palmitoleic acid ($r = 0.60$), oleic acid ($r = 0.72$) and C20:1n-9 ($r = 0.67$) were the only MUFA's that increased significantly ($p < 0.01$) with an increase in the IMF content of the meat. Only one PUFA, α-linolenic (C18:3n-6), showed a significant increase ($r = 0.47$; $p< 0.05$) with an increase in the IMF content of the LD muscle. This observation is similar to reports for pork (Van Oeckel *et al*., 1996), in which the IMF content was positively correlated with SFA's and MUFA's, although it was found to be negatively correlated with the PUFA content of the meat. The results of this study contradict previous research conducted on beef and lamb, in which it was reported that stearic acid (C18:0) decreased with an increase in the lipid content of the meat (Wood & Enser, 1997). However, the total lipid content of the latter was significantly higher than in the present investigation.

There is an increase in triacylglycerols with increasing total lipid content of the meat. Triacylglycerols are less unsaturated in comparison with the more constant phospholipids in muscle membranes (Marmer *et al*., 1984). There was a significant ($p < 0.01$) increase in SFA's and MUFA's with increasing IMF content of the meat. However, linear relationships between IMF content and fatty acids have been found to be not significant in grazed lambs (Rowe *et al*., 1999).

CONCLUSION

This study investigated the effects that age, gender and production region have on the fatty acid content of the *M. longissimus dorsi* (LD) muscle of springbok. Although only one muscle was analysed, the results gave a good indication of the effect that age, gender and production region may have on the fatty acid composition of the meat.

The predominant fatty acid found in springbok was stearic acid, a saturated fatty acid that does not have serum cholesterol-highering attributes *in vitro*. Oleic acid represented the largest component of the MUFA's and this fatty acid has been reported to decrease the risk of cardiovascular diseases. P:S ratios of springbok meat with regard to production region, gender and age effects were found to be higher than the recommended ratio and the mean PUFA n-6:n-3 ratio was found to be well below the recommended maximum ratio. All the above-mentioned attributes, together with the low fat content of springbok meat, makes it an attractive addition to the health conscious consumer’s diet. The significant effect of production region on the fatty acid composition of the meat may be attributed to variations in the diet of springbok originating from the different regions. The effects of age and gender on the fatty acid composition of the meat were found to be minor in comparison to regional effects.

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CHAPTER 7

SENSORY CHARACTERISTICS OF SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) MEAT AS INFLUENCED BY AGE, GENDER AND PRODUCTION REGION

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ABSTRACT

The effects of age, gender and production region on the sensory characteristics of springbok *M. longissimus dorsi* (LD) muscle were investigated in this study. The springbok (n = 19) originated from two Nature Reserves in the Free State Province of South Africa and were divided into age (adult, sub-adult) and gender categories. The sensory characteristics evaluated were game meat aroma, juiciness, residual tissue, tenderness and game meat flavour. Sensory rankings were obtained by a trained tasting panel and were linearly correlated with certain physical and chemical attributes of the LD muscle. Warner-Bratzler shear force (kg. 1.27 cm^{-1} diameter) values were noted to be inversely correlated with the sensory attributes of tenderness ($r = -0.70$, $p < 0.01$), residual tissue ($r = -0.68$, $p < 0.01$) and sustained juiciness ($r = -0.43$; $p < 0.05$). Age-related effects on perceived tenderness were minor in comparison with pH effects. There was a decreased acceptance of meat with an increase in ultimate pH (pH_{24}) from 5.4 to 5.8. As the ultimate pH of the meat increased, tenderness ($r = -0.46$, $p < 0.05$) and sustained juiciness ($r = -0.54$, $p < 0.05$) rankings decreased significantly. No significant linear correlations were noted between the intramuscular fat (IMF) content and the sustained juiciness rankings of the meat. The linear correlation between the fatty acid composition (mg. g^{-1} muscle) and the game meat flavour rankings showed that only one polyunsaturated fatty acid (PUFA), α-linolenic (C18:3 n-3), was positively ($r = 0.47$, $p < 0.05$) correlated with the overall game meat flavour of springbok meat.

Keywords: game meat; fatty acids; sensory; flavour; tenderness

INTRODUCTION

According to Jansen van Rensburg (1992), game meat is fairly well known in South Africa and is eaten by approximately 5.625 million people in the country, although 39% of the total population in South Africa had only eaten game meat in the dried, raw form (biltong). Even so, venison production is an increasing, regular activity that constitues a growing industry in both urban and rural areas of Southern and Eastern African countries (Anon, 2000).

Consumers are showing a growing interest in the quality of meat and in the system from which it is produced. Meat is required to be safe in terms of its composition, preferably with no artificial additives added to the animals' (domesticated) diet or to the product (Volpelli *et al*., 2003). The prevailing factor that determines the consumers' choice and the acceptability of different meat sources is the quality of the meat (Homer *et al*., 1997). The consumers' desire for natural products leaves a niche in the market for game meat that could be marketed as an organic meat product. In comparison with domesticated game species, South African game is still untamed and is seen as an organic and exotic meat that can distinguish itself from the domesticated game species from Australia, New Zealand and Europe (Hoffman & Bigalke, 1999). Springbok (*Antidorcas marsupialis*) has been reported to be the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999) and therefore has great venison production potential.

The mean fat content of springbok carcasses never exceeds 4% and the meat therefore has the potential to be marketed as a health product (Skinner & Louw, 1996). However, some fat is necessary to impart juiciness and flavour to meat (Melton, 1990). Relationships between fat composition and flavour have been observed for lamb, beef and pork (Kemp *et al*., 1981; Larick & Turner, 1990; Cameron *et al*., 2000).

Components of the palatability of meat include tenderness, juiciness and flavour. Of these attributes, tenderness is considered by consumers to be the most important factor influencing meat quality (Strydom *et al*., 2000; Koohmaraie *et al*., 2003). Trained or consumer sensory panels are used extensively for the evaluation of unprocessed meat (Toscas *et al*., 1999). However, very little data is available on the meat quality attributes of springbok and as far as could be ascertained, no research results on the sensory attributes of springbok meat have been published.

The purpose of this study was to investigate any possible effects that age, gender and production region may have on the sensory characteristics of springbok *M. longissimus dorsi* (LD) muscle. Where applicable, linear correlations between the sensory rankings and certain physical and chemical attributes of the meat were verified.

MATERIALS AND METHODS

Animals and sampling

Springbok (n = 19) were sampled from two nature reserves (Gariep and Willem Pretorius) in the Free State Province of South Africa. Springbok were randomly harvested at night by a professional culling team using spotlights (1 million candela) and small calibre rifles, similar to the method described by Lewis *et al*. (1997). Animals were sighted directly or by the reflection of the light from their retinas. The shots were either head or high neck shots, resulting in immediate insensibility.

The Free State Province's largest nature reserve is a combination of the 36 487 ha Gariep Nature Reserve on the Orange River and an 11 237 ha game sanctuary on its northern shore. The Gariep Nature Reserve accommodates a large population of springbok, black wildebeest and red hartebeest (Hocking *et al.*, 1983). The Willem Pretorius Nature Reserve (WP) is an 10 520 ha game reserve that accommodates springbok, black wildebeest, blesbok, red hartebeest, eland, zebra, impala and white rhino (Bulpin, 1992).

The ages of the springbok were estimated using the length and size of the horns as parameters (Rautenbach, 1971). The springbok were divided into two age categories, namely adult (2 to 5 years) and sub-adult (1 to 2 years). The distribution of these springbok according to age, gender and production region is presented in Table 1.

After harvesting, the animals were exsanguinated within 2 to 5 min. by cutting the throat with a sharp, sterile knife. Each carcass was individually tagged with an identification number and hung from the Achilles tendons. After the targeted number of antelope had been harvested, the carcasses were taken to a nearby abattoir for processing. This included skinning, evisceration and cleaning of carcasses according to South African practices (Hoffman, 2000a). The carcasses were cooled to 4°C approximately five to eight hours after cropping (depending on the time the animals were shot).

Table 1 Distribution of the springbok (n=19) according to age, gender and production region categories.

	Gariep		WP		
	Male	**Female**	**Male**	**Female**	**Total**
Adult	3	2	3	1	9
Sub-adult	2	2	3	3	10
Total	5	4	6	4	**19**

The LD muscle was dissected 24 hr post mortem to assess the physical attributes (pH_{24}, cooking loss and Warner-Bratzler Shear) of the meat. The samples from the right and left hand side of the carcass were removed between the 12th and 13th rib and anterior to the last lumbar vertebra. The left hand side of the LD muscle was used for the physical and chemical attribute assessment and the right hand side for the sensory evaluation of the meat. All visible connective tissue and subcutaneous fat were removed from the samples. Samples were vacuum packed and subsequently frozen at -20ºC for the sensory and chemical analysis of the meat.

Physical analyses

The pH measurements of the LD muscle were taken between the 12th and 13th rib at 0.75 and 24 hr post mortem by means of a calibrated (standard buffers pH 4.0 and 7.0) Crison 506 portable pH-meter as described by Hoffman (2000b).

Cooking loss of the LD muscle was determined by placing approximately 50 - 70 g of meat (± 15 mm diameter) in a sealed plastic bag in a water bath (preset at 80°C) for 1 hr (Honikel, 1998). Meat samples were cut perpendicular to the longitudinal axis on the caudal side of the LD muscle. The samples were then cooled to 25°C under running water. The weight of the dried cooked samples was recorded and the cooking loss was calculated. Three to four 1.27 cm diameter (cylindrical core) muscle samples were randomly removed from the cooked meat. The samples were cut perpendicular to the longitudinal axis of the LD muscle. Maximum shear force values (kg. 1.27 cm^{-1} diameter) to shear a cylindrical core of cooked meat (at a crosshead speed of 3.80

mm/s) were recorded for each sample and a mean was calculated for each individual animal using a Warner-Bratzler Shear attachment fitted to an electrical scale (Honikel, 1998).

Chemical analyses

Proximate chemical analyses were carried out on the LD muscle. Meat samples were minced (2 mm sieve) three times prior to analysis. The moisture (100°C, 24 hr) and ash content (500ºC, 5 hr) of the samples were determined according to AOAC methods (AOAC, 1997). Lipids were extracted with a chloroform:methanol (2:1, v/v) solution, using the solvent extraction method described by Lee *et al*. (1996). The protein content was determined by the block digestion method and obtained by multiplying Kjeldahl nitrogen by a factor of 6.25 (AOAC, 1997).

Fatty acid analyses

See Chapter 6 (Materials and Methods).

Sensory analyses

Cooking procedure

The LD muscle was thawed at 2 to 5°C over a 12 hr period before the sensory analyses were done. The meat was roasted (180°C) using a high velocity, forced-air convection oven. Roasting took place in two conventional electric Defy 835 ovens that were connected to a computerised electronic temperature control system (Viljoen *et al*., 2001). Samples were placed in individual cooking bags and placed on an open roasting pan. Roasting took place until an internal temperature (T_i) of 71°C measured by a thermocouple probe inserted into the meat was reached.

Sensory evaluation

The meat samples were rated on predetermined adjective scales by a trained panel of six tasters previously selected for their flavour and texture sensitivity. Two training sessions were used to develop the attributes and train the assessors for attribute intensity evaluation. Numerical scaling (8-point scale) with certain endpoints (8 = extremely tender/juicy, 1 = extremely tough/dry) were used to express the intensity or degree of an attribute. The definitions of the attributes for the sensory analyses of springbok meat are presented in Table 2. Sensory evaluation was conducted in a sensory laboratory fitted with six individual sensory booths, following standard sensory practices (AMSA, 1995). Game meat aroma, initial juiciness, sustained juiciness, tenderness, residual tissue and overall game flavour of the meat were evaluated.

The sensory evaluation was carried out on three consecutive days with two sessions per day. Cubed samples (± 1 cm diameter) were taken from the middle of each sample and wrapped in aluminium foil. Samples were coded with randomly selected three digit codes and the serving sequence was randomised. The samples were placed in glass ramekins in a preheated oven (100°C) and evaluated within 5 to 10 min.

Table 2 Definitions of attributes for the sensory analyses of springbok meat.

Attribute	Definition
Game meat aroma 1=Extremely bland; 8=Extremely intense	Aroma associated with game species
Initial juiciness 1=Extremely dry; 8=Extremely juicy	The amount of fluid exuded on the cut surface when pressed between fingers
Sustained juiciness 1=Extremely dry; 8=Extremely juicy	Degree of juiciness perceived after mastication (2-3 chews)
Tenderness 1=Extremely tough; 8=Extremely tender	Impression of tenderness after mastication (2-3 chews)
Residue 1=Abundant; 8=None	The amount of residual tissue after most of the sample has been masticated (15 chews)
Overall game meat flavour 1=Extremely bland; 8=Extremely intense	Flavour associated with game species

Distilled water and saltless crackers were used as mouth cleansers before tasting and in between tasting the samples. Lamb loin was used as a standard reference for comparison with the game meat during the training of the panel.

Statistical analyses

A three-factor factorial experiment was performed in a completely randomised design with unequal number of random replications. The factors were two regions (Gariep and Willem Pretorius), two age groups (adult and sub-adult) and two genders (male and female). An experimental unit was a single carcass. The variables were recorded as scores. The scores were ranked before subjected to analysis of variance (ANOVA) using SAS version 8.2 statistical software (SAS, 1999). The Shapiro-Wilk test was performed for non-normality (Shapiro & Wilk, 1965). Tukey's t-Least Significant Difference (LSD) was calculated at the 5% confidence level to compare treatment means (Ott, 1998). Pearson correlation coefficients were determined using the linear regression procedure (Proc CORR) of SAS (1999).

RESULTS AND DISCUSSION

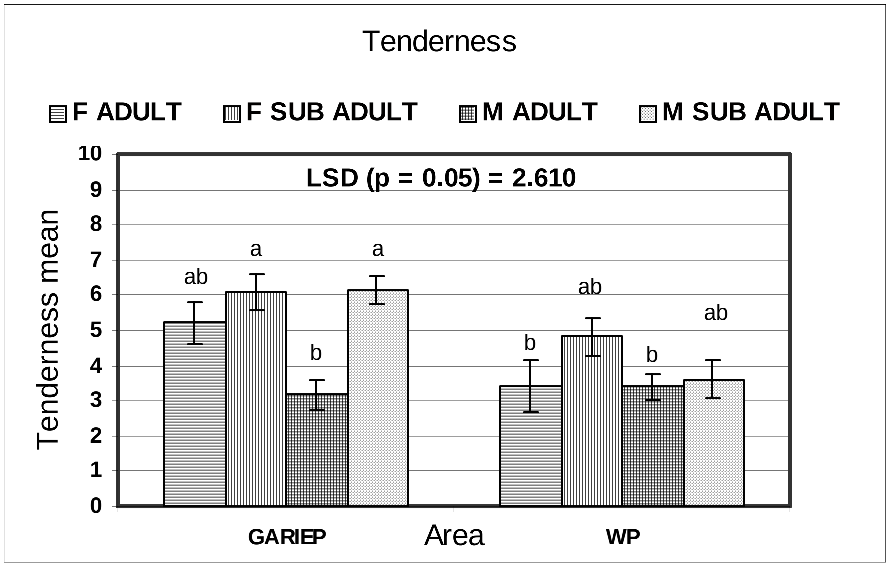
The means (± standard error) of the proximate chemical composition of the springbok LD muscle (n = 19) are presented in Table 3. The values of the chemical composition of the meat are within the expected ranges. The protein content differed significantly ($p < 0.05$) between the two productions regions and age categories. The sub-adults (21.16 ± 0.26) had a significantly higher protein content than the adults (20.16 ± 0.40).

Table 3 Means (± standard error) of the proximate chemical composition of the *M. longissimus dorsi* (LD) muscle (n = 19), with age, gender and production region as main effects.

Main effects		**Moisture (%)**	**Protein (%)**	**Fat (%)**	**Ash (%)**
Region :	**Gariep (n = 10)**	72.951 ± 0.53	20.180[a] ± 0.36	1.190 ± 0.26	1.345 ± 0.13
	WP (n = 9)	73.329 ± 0.31	21.240[b] ± 0.27	1.220 ± 0.19	1.197 ± 0.11
Gender:	**Male (n = 10)**	73.101 ± 0.46	20.818 ± 0.30	1.072 ± 0.14	1.197 ± 0.10
	Female (n = 9)	73.101 ± 0.44	20.578 ± 0.44	1.367 ± 0.31	1.361 ± 0.14
Age:	**Adult (n = 9)**	72.788 ± 0.45	20.156[a] ± 0.40	1.222 ± 0.31	1.177 ± 0.12
	Sub-adult (n = 10)	73.348 ± 0.42	21.163[b] ± 0.26	1.191 ± 0.16	1.363 ± 0.12

[a,b] Values in same column (within main effect) with different letters are significantly different ($p < 0.05$).

The means of the sensory attribute rankings (± standard error) are presented in Table 4. A significant ($p < 0.01$) age, gender and production region interaction was observed for the tenderness attribute and the tenderness rankings therefore are not presented in Table 4. This interaction is depicted in Figure 1.



[a,b] Columns with different letters are significantly different ($p < 0.05$).

F - Female

M - Male

Figure 1 Tenderness rank means of the age, gender and production region interaction ($p < 0.01$).

The males from the Gariep Nature Reserve were the only gender that delivered a significantly ($p < 0.05$) higher tenderness ranking in the sub-adult than in the adult category (Figure 1). The female sub-adults from this region were also rated as more tender than the adults, although this was not significant ($p > 0.05$). Male and female sub-adults originating from the Willem Pretorius Nature Reserve received higher tenderness rankings in comparison with the adults from this region, but this was also not significant ($p > 0.05$). No significant differences between the two age categories of the two genders were observed for the tenderness rankings for both regions .

Age, gender and production region were noted to have a significant ($p < 0.05$) effect on the sensory rankings of the meat (Table 4).

Table 4 Mean sensory rankings (± standard error) of springbok *M. longissimus dorsi* (LD) muscle as affected by age, gender and production region.

Sensory characteristic	Production region		Age		Gender	
	Gariep	**WP**	**Adult**	**Sub-adult**	**Male**	**Female**
Game meat aroma	5.492 [a] ± 0.29	4.458 [b] ± 0.23	5.167 ± 0.35	4.847 ± 0.22	4.815 ± 0.28	5.164 ± 0.26
Initial juiciness	5.241 [a] ± 0.31	4.250 [b] ± 0.28	4.719 ± 0.35	4.764 ± 0.29	4.415 ± 0.29	5.136 ± 0.34
Sustained juiciness	5.158 [a] ± 0.32	4.033 [b] ± 0.28	4.479 ± 0.37	4.674 ± 0.27	4.208 ± 0.27	5.055 ± 0.34
Residual tissue	5.033 [a] ± 0.28	4.158 [b] ± 0.32	3.781 [b] ± 0.29	5.139 [a] ± 0.29	4.192 [b] ± 0.29	5.073 [a] ± 0.32
Game meat flavour	5.008 ± 0.30	4.542± 0.25	4.882 ± 0.31	4.615 ± 0.25	4.654 ± 0.28	4.918 ± 0.27

[a,b] Values in same row (within main effect) with different letters are significantly different ($p < 0.05$).

WP - Willem Pretorius nature reserve

Production region had a significant ($p < 0.05$) effect on the game meat aroma, initial juiciness, sustained juiciness and residual tissue rankings of the meat. The residual tissue ranking of the meat was the only sensory attribute that was significantly ($p < 0.05$) influenced by gender and age.

The physical attributes (pH_{24}, Warner-Bratzler Shear force and cooking loss percentage) of the meat are presented in Table 5. In general, an increase in animal age is associated with a decrease in meat tenderness (Lawrie, 1985). However, no significant differences were found between the Warner-Bratzler shear force values (kg.1.27 cm^{-1} diameter) of the meat with regard to the two age categories, gender and production region effects.

Linear correlation coefficients were calculated for the sensory attribute rankings and certain physical attributes of the LD muscle. The mean shear force values of the springbok meat varied between 2.31 ± 0.14 and 2.70 ± 0.20 kg. 1.27 cm^{-1} diameter and were inversely correlated ($r = -0.70$; $p < 0.01$) with the tenderness rankings of the meat. This indicates a decrease in tenderness rankings with an increase in the shear force values of the meat. This finding confirms previous ones that Warner-Bratzler shear force assessments give good correlations with sensory panel tenderness ratings (Tornberg, 1996). A similar regression coefficient ($r = 0.70$) was reported between the shear force values and the tenderness rankings of lambs (Devine *et al*., 1993).

Table 5 Means (± standard error) of the physical attributes (pH_{24}, shear force and cooking loss percentage) of the *M. longissimus dorsi* (LD) muscle, with age, gender and production region as main effects.

Main effects		**pH_{24}**	**Shear force (kg. 1.27 cm^{-1} diameter)**	**Drip loss (%)**	**Cooking loss (%)**
Region :	**Gariep (n = 10)**	5.439 ± 0.05 [a]	2.219 ± 0.22	3.441 ± 0.69	34.731 ± 1.50 [a]
	WP (n = 9)	5.757 ± 0.10 [b]	2.700 ± 0.20	3.243 ± 0.37	28.134 ± 1.49 [b]
Gender:	**Male (n = 10)**	5.651± 0.10	2.634 ± 0.22	2.727 ± 0.27	31.808 ± 2.16
	Female (n = 9)	5.533 ± 0.09	2.247 ± 0.20	3.979 ± 0.69	30.973 ± 1.19
Age:	**Adult (n = 9)**	5.576 ± 0.11	2.638 ± 0.29	3.731 ± 0.63	32.902 ± 1.93
	Sub-adult (n = 10)	5.616 ± 0.08	2.314 ± 0.14	3.050 ± 0.54	30.230 ± 1.14

[a,b] Values in same row (within main effect) with different letters are significantly different ($p < 0.05$).

The shear force values for the springbok meat were found to be inversely correlated with the sustained juiciness ($r = -0.43$; $p < 0.05$) rankings. As the shear force values of the meat increased, sustained juiciness scores decreased, indicating a decrease in perceived juiciness with increasing toughness of the meat. It has been reported that more tender meat releases juices more rapidly and leaves less residual tissue after mastication (Tshabalala *et al*., 2003).

Shear force values were found to be inversely correlated with the residual tissue ($r = -0.68$; $p < 0.01$) rankings of the springbok meat. Lower residual tissue rankings indicate more abundant residue remaining after mastication and this is probably as a result of higher perceived toughness of the meat.

The ultimate mean pH (pH_{24}) values of the meat, considering all main effects, ranged from pH 5.4 to 5.8 (Table 5). An inverse correlation ($r = -0.46$; $p < 0.05$) was noted between pH_{24} and perceived tenderness, as well as between pH_{24} and sustained juiciness ($r = -0.54$; $p < 0.05$) rankings of the meat. Therefore, tenderness rankings decreased with an increase in pH_{24} from 5.4 to 5.8. The extent of postmortem glycolysis has been noted to have an effect on the tenderness of beef, pork and lamb, with a general decrease in meat tenderness as the ultimate pH increases from 5.5 to 6.0 (Lawrie, 1985). However, at pH_u values above 6, meat tenderness increases again. It was noted in lamb, for example, that the shear force values increase with an increase in pH_u from 5.5 to 5.9 (Devine *et al.*, 1993). A decreased sensory acceptance of meat was noted with an increase in pH_u between 5.8 and 6.0 (Devine *et al.*, 1993).

Intermediate dark, firm and dry (DFD) meat is normally defined as meat with a pH that ranges between $5.8 \leq pH_u \leq 6.2$ and DFD with a $pH_u \geq 6.2$ (Wiklund *et al*., 1995). High temperature conditions and low pH in postmortem muscles lead to protein denaturation and consequently a decrease in the water-binding capacity (WBC) of the meat (Offer & Knight, 1988; Honikel, 1998). High pH_u values will therefore lead to little protein denaturation. As the pH_{24} of the springbok meat increased, the intermediate DFD range was reached and this could explain why the meat may have been perceived as being drier, leading to lower sustained juiciness rankings. Springbok meat originating from Willem Pretorius, for example, had a mean pH_{24} of 5.76 ± 0.10 and consequently had lower initial and sustained juiciness rankings (Table 3).

The moisture content (%) of the meat was not significantly ($p > 0.05$) influenced by age, gender or production region and varied between 72.7 and 73.4% (Table 3). No significant correlation was noted between the moisture content and any juiciness ranking of the meat. The juiciness and tenderness of meat are known to depend to a great extent on its water content (Offer & Trinick, 1983). Meat juiciness is a combination of both moisture chewed out of the meat and saliva production during mastication (Aaslyng *et al*., 2003). Intramuscular fat (IMF) is necessary to impart juiciness and flavour (Melton, 1990) and the intramuscular fat content is therefore very closely related to the juicy sensation of cooked meat (Tshabalala *et al*., 2003). The negative influence of the IMF content of meat on health aspects competes with the positive influence on meat juiciness and flavour (Issanchou, 1996). The IMF content of the LD muscle of springbok was not significantly influenced by age, gender or production region and varied between 1.07 ± 0.14 and 1.37 ± 0.31% (Table 3). In addition, no significant ($p < 0.05$) correlation was observed between the IMF content and sustained juiciness rankings of the meat. This phenomenon is probably a result of the relative low total fat (< 2%) content of the springbok meat (Table 3).

The cooking loss of the meat varied between 28.13 ± 1.49 and 34.73 ± 1.50% (Table 5) and was significantly influenced by production region, probably as a result of the ultimate pH (pH_{24}) of the meat. The meat from Willem Pretorius had a significantly higher pH_{24} of 5.76 ± 0.10 in comparison with that from Gariep and consequently had a significantly lower cooking loss (%) (Table 5). The cooking loss of meat tends to be higher for meat with a low water-binding capacity (WBC) and low pH_u (Aaslyng *et al*., 2003). In beef, it has been assessed that juiciness and cooking loss are negatively correlated (Toscas *et al*., 1999). In this study, however, no significant ($p > 0.05$) correlation was noted between cooking loss and any juiciness ranking of the meat.

Lipid fatty acids are very important in the flavour development of meat, since various flavour precursors are produced from n-6 and n-3 polyunsaturated (PUFA) and saturated fatty acids (SFA) (Wood & Enser, 1997). Changes in the composition of ruminant fat may contribute to the sensory properties of meat by influencing the degree of fat saturation of the meat (Webb *et al*., 1994). These researchers observed a negative correlation between mutton flavour intensity and higher proportions of unsaturated fatty acids in the meat. According to Swanson & Penfield (1991), the high level of polyunsaturated fatty acids contributes to the gamey flavour of venison, which many consumers find unacceptable. In this study, no significant flavour differences ($p < 0.05$) were found between production region, gender and age categories. Linear correlations between the fatty acid composition ($mg.\ g^{-1}$ muscle) and game meat flavour intensity showed that α-linolenic acid (C18:3n-3) was the only polyunsaturated fatty acid that was positively ($r = 0.47$, $p < 0.05$) correlated with the overall game flavour intensity of springbok meat.

CONCLUSION

This study investigated the effects of age, gender and production region on the sensory attributes of the *M. longissimus dorsi* (LD) muscle of springbok. The production region exhibited a significant effect on the sensory attributes evaluated, whereas the effects of age and gender were found to be minor. Age-related effects on meat tenderness were found to be minor in comparison with pH effects. The pH_{24} and tenderness rankings were inversely correlated, indicating a decreased acceptance with an increase in the pH_{24} of the meat. With an increase in pH_{24}, the juiciness rankings of the meat decreased. It was noted that moisture and fat content had no significant effect on the perceived sustained juiciness of the meat. Warner-Bratzler Shear force values had a significant effect on the tenderness, sustained juiciness and residual tissue rankings of the meat. The latter attributes decreased with an increase in shear force of the meat. Game meat flavour intensity was not significantly influenced by age, gender or production region. The effect of the polyunsaturated fatty acid (PUFA) proportions of the meat on the game meat flavour intensity was found to be minor, with the exception of a positive correlation with α-linolenic acid. All the above mentioned facts indicate that the effects of age, gender and production region were overshadowed by the effects that certain physical attributes of the meat had on the sensory characteristics.

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CHAPTER 8

GENERAL DISCUSSION AND CONCLUSION

It has been reported (Anon, 2000) that game meat is an important source of protein in Eastern and Southern African countries, where domesticated meat supply is sometimes reduced due to the effect of animal diseases. Game meat production in these countries has the potential to be the primary utilisation form for many ranches that do not possess the management or capital expertise required for the other forms of utilising game (Anon, 2000).

In South Africa, the game industry utilisation forms such as biltong hunting, trophy hunting, live game sales and ecotourism deliver a much higher gross profit to the game industry than that from game meat production (Eloff, 2002). Although game meat production in South Africa is relatively underdeveloped in comparison with the other utilisation forms, it has the potential to be one of the most profitable sources of income for the industry (Bothma, 2002). Hoffman (2003) noted that game meat exports from South Africa to the European Union are increasing rapidly and this is a favourable phenomenon for the South African game industry.

Jansen van Rensburg (1992) reported that game meat is fairly well known and that it is eaten by approximately 5.625 million people in South Africa, although 39% of the total population had only eaten game meat in the dried, raw form (biltong). It is therefore evident that game meat should be marketed extensively and that strict quality control has to be employed to ensure a constant, safe meat product (Bothma, 2002). The health benefits of game meat, in terms of its low fat content (Aidoo & Haworth, 1995; Bothma, 2002) and its organic appeal (Hoffman & Bigalke, 1999; Bothma, 2002) may be used as a marketing tool to exploit its potential.

Springbok (*Antidorcas marsupialis*) has been reported to be the game species most extensively cropped in South Africa (Jansen van Rensburg, 1992; Hoffman & Bigalke, 1999). Investment in research on the nutritional composition of the various ungulate species of South Africa is of invaluable importance to the game industry (Bothma, 2002). In addition, the possible effects of age, gender, habitat and season on the meat quality of wild ungulates need to be a research priority (Jansen van Rensburg, 2002).

The aim of this investigation was therefore to quantify the effects that age, gender and production region may have on the morphological, physical, chemical and sensory characteristics of springbok. The physical, chemical and sensory attributes of the *M. longissimus dorsi* (LD) muscle of springbok were evaluated for this purpose.

The live mass of the different age categories of springbok was noted to vary geographically, which is in accordance with the information obtained from the literature review. Variation in the live weight of wild ungulates may occur because different localities have an effect on the quality and quantity of the vegetation and hence on the available nutrients (Von la Chevallerie, 1970; Furstenburg, 2002). In the adult category, the male and female springbok differed significantly in their live mass, but no such differences were observed in the sub-adult category. It is known that live mass differences between sexes of wild ungulates become apparent in the adult category (Von la Chevallerie, 1970; Hoffman, 2003). Estimations of the dressing percentage of springbok revealed that the values obtained were similar to previous findings (Fairall *et al*., 1990; Van Zyl & Ferreira, 2003). The male gender of springbok was noted to have a significantly higher dressing percentage in comparison to the females.

The effects of ante-mortem stress on the physical attributes of meat were confirmed in this study. Severe ante-mortem stress imposed during the cropping of springbok originating from the Caledon region led to significantly higher ultimate pH (pH_{24}) values of the meat, and this meat consequently had significantly lower drip and cooking loss (%) values, as well as relatively tougher meat. Although this meat did not have lower L* (lightness) values in comparison with the other production regions, it had higher a* values, indicating redder meat with higher colour saturation. The influence of age on the Warner-Bratzler Shear (WBS) measurements (toughness) was noted to be minor in comparison with pH_{24} effects. A positive correlation was observed between the WBS and pH_{24} of the LD muscle. Although this correlation coefficient was noted to be relatively low, it was significant as a result of the large sample size. This specific investigation revealed that the effect of age, gender and production region on the physical attributes of the meat is directly influenced by the ultimate pH of the meat.

Production region was noted to be a significant determiner of the chemical composition of springbok meat, especially in terms of the intramuscular fat (IMF) content. Differences between the IMF and moisture content of the meat could partially be attributed to a gender effect, as the female gender of ungulate species tends to have a significantly higher IMF content than the males. In addition, a tendency towards increasing IMF content was noted for the sub-adult and adult animals. Variation in the amino acid and mineral profile of the meat was noted to be mainly due to regional effects. Various factors, such as the concentration of minerals in the diet, hormones, age, gender and region have been noted to cause variation in the mineral composition of meat (Doyle, 1980). The effects of age and gender on the amino acid and mineral profile of the meat were negligible in all instances.

Game meat is seen as a healthy meat option because of its low fat content and high concentration of polyunsaturated fatty acids (PUFA's) in comparison with saturated (SFA's) and mono-unsaturated fatty acids (MUFA's). The results obtained in this investigation indicate that springbok meat has polyunsaturated to saturated fatty acid (P:S) ratios that are above the optimal ratio of 0.70 (Raes *et al*., 2004). Low saturated to polyunsaturated ratios are important in reducing the risk of cardiovascular diseases (Harrington, 1994). The mean n-6:n-3 PUFA ratio of springbok meat was below the recommended maximum of 4 (Girolami *et al*., 2003), adding another health attribute to springbok meat. The fatty acid profile of springbok originating from the different production regions differed significantly, possibly as a result of varying diet composition of the animals. It is known that diet influences the fatty acid composition of ruminant meat, despite the hydrogenating effect of the rumen bacteria (Wood & Enser, 1997; Rowe *et al*., 1999). Age and gender effects on the fatty acid profile of the meat were in most instances found to be negligible.

Results obtained for the sensory characteristics of springbok meat indicated that the effects of age and gender were overshadowed by the effects of certain physical atttributes of the meat and production region on these characteristics. WBS values and pH_{24} were noted to be significant indicators of the sensory quality of springbok meat. The mean WBC values of the meat were inversely correlated with the tenderness rankings of the meat. This indicates a decrease in tenderness rankings with an increase in the shear force values of the meat. This finding confirms previous findings that Warner-Bratzler Shear force assessments give good correlations with sensory panel tenderness ratings (Tornberg, 1996). The tenderness and sustained juiciness rankings of the LD muscle were noted to decrease significantly with an increase in pH_{24}. The effect of the polyunsaturated fatty acid proportions of the meat on the game flavour intensity was found to be minor in this investigation.

This investigation has provided insight into the extent that age, gender and production region may influence the quality of springbok meat. These effects are valuable to the game industry, since they could influence the consistency and quality of game meat produced. The cropping of ungulate species takes place randomly and selection of specific gender and age combinations to ensure better meat quality is therefore an impossible option. The data obtained in this investigation will provide invaluable information for the game industry with regard to variations that may occur in the quality of springbok meat as a result of age, gender and production region categories.

This study indicates great scope for future research on the effects of age, gender and production region on the meat quality of wild ungulates. Continuous scientific investigations and species-specific research will result in valuable information for the rapidly growing game industry of South Africa.

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