MEAT QUALITY PARAMETERS OF THE IMPALA (*AEPYCEROS MELAMPUS*)

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: _27/11/02_

SUMMARY

The purpose of this study was to evaluate the effects of age, sex, region and cropping methodology on the meat quality of impala. Forty impala were cropped during separate day and night operations at the Mara Agricultural Development Centre. Carcass pH_{45} (measured in M. longissimus dorsi 45 minutes post mortem) was higher in night cropped animals (6.67 ± 0.111; $P<0.05$) compared to the day cropped animals (6.55 ± 0.236). The ultimate carcass pH (pH_u) of animals cropped at night was lower (5.39 ± 0.081; $P<0.05$) compared to those cropped in the day (5.45 ± 0.108). Non-linear regression analysis showed that the rate of pH decline of the night cropped animals was slower than that of the day cropped animals ($P<0.05$). The cooling rate of the M. longissimus dorsi was twice as fast in the night cropped group ($P<0.05$). Shear force values and drip losses of the night cropped animals were both lower (19.11 ± 5.675 g/mm^2 and $2.93 \pm 1.597\%$ respectively; P0.05) compared to those of day cropped animals (23.42 ± 8.128 g/mm^2 and $4.15 \pm 2.339\%$). The results indicate that nighttime cropping has a beneficial effect on certain meat quality parameters compared to daytime cropping.

A second group of impala was sampled at the Musina Experimental Farm in the Limpopo Province of South Africa. Live weights of the Mara animals (50.23 ± 9.32 kg) were higher ($P<0.05$) than the Musina animals (44.25 ± 10.81 kg). Impala sampled at Mara had significantly higher dressing percentages than those at Musina ($P<0.05$). Impala ewes from both regions had a higher lipid content ($P<0.05$), but the sex of the animal had no effect on the remaining chemical parameters. The crude protein content of impala at Musina ($24.88 \pm 1.044\%$) was higher ($P<0.05$) than the Mara animals ($23.80 \pm 0.840\%$).

Regional differences ($P<0.05$) were found in the amounts of phosphorous and calcium in the meat. Female animals at Mara showed higher proportions ($P<0.05$) of saturated (SFA), and mono-unsaturated fatty acids than the male animals. Males from both regions showed higher proportions ($P<0.05$) of poly-unsaturated fatty acids. Myristic, palmitic and stearic acid formed the greatest proportion of the SFA component for males and females from both regions.

Samples of the *M. semi-membranosus (SM)*, *M. deltoideus (D)*, *M. longissimus dorsi et laborum (LD)*, and *M. psoas major (PS)* were analysed for citrate synthase (CS) and phosphofructo-kinase activities. MHC distribution varied significantly between *D, SM* and *LD* ($P<0.05$). *D* expressed more MHC I, and less MHC IIa than the other three muscle groups. Positive correlations were found between age and MHC I in *D* ($r=0.93$; $P<0.05$) and CS and weight of the animal in *D* ($r=0.76$; $P<0.05$). The enzyme activities and MHC distribution indicate that energy in the impala is produced to a large extent via oxidative pathways.

OPSOMMING

Die doel van hierdie studie was om die invloed van ouderdom, geslag, area, en uitdunmetodes op die vleiskwalitiet van rooibokke te evalueer. Veertig rooibokke is gedurende afsonderlike dag en nag uitdunningsoperasies by die Mara Landboukundige Ontwikkelings Sentrum geoes. Karkas pH_{45} (gemeet in die M. longissimus dorsi 45 minute post mortem) was hoër (P<0.05) in nag-geoesde diere (6.67 $\pm$ 0.11) in vergelyking met die dag-geoesde diere (6.55 $\pm$ 0.23). Die finale pH (pH_u) van diere wat in die nag geoes is (5.39 $\pm$ 0.08) was laer (P<0.05) in vergelyking met die wat in die dag geoes is (5.45 $\pm$ 0.11). Nie-lineêre regressie analise toon dat die tempo van pH-daling van die nag-geoesde diere merkbaar stadiger was as die dag-geoesde diere (P<0.05). Die afkoelings tempo van die *M. longissimus dorsi et lumborum* was twee keer vinniger in die nag geoesde groep (P<0.05). Die gemiddelde skeurkragwaarde en drupverlies was beide laer (P<0.05) vir nag geoesde diere (respektiewelik 19.11 $\pm$ 5.67 g/mm^2 en 2.93 $\pm$ 1.59%) in vergelyking met diere wat in die dag geoes is (23.42 $\pm$ 8.12 g/mm^2 en 4.15 $\pm$ 2.33%). Die resultate toon dat nag-uitdunning 'n voordelige effek op vleiskwaliteit gehad het, in vergelyking met dag-uitdunning.

'n Tweede groep van rooibokke is gemonster by die Musina Eksperimentele plaas in die Limpopo Provinsie in Suid-Afrika. Die gewigte van die Mara diere (50.23 $\pm$ 9.32 kg) was hoër (P<0.05) as die van die Musina diere (44.25 $\pm$ 10.81 kg). Die Mara groep het hoër uitslag persentasies (P<0.05) gehad. Vroulike diere in beide areas het 'n hoër vet inhoud (P>0.05) gehad. Die ru-proteien inhoud van die Musina diere (24.88 $\pm$ 1.04%) was hoër (P<0.05) as die van die Mara diere (23.80 $\pm$ 0.84%).

Area verskille (P<0.05) is gevind in die fosfaat en kalsium inhoud in die vleis. Vroulike diere by Mara het 'n hoër proporsie (P<0.05) van versadigde en mono-onversadige vetsure in die weefsel as manlike diere gehad. Manlike diere van beide areas het 'n hoër proporsie (P<0.05) van poli-onversadige vetsure (P<0.05) as die vroulike diere getoon. Miristien, palmitien en stearien suur was kwantitatief die belangrikste vetsure in manlike en vroulike diere van beide areas.

Monsters van *die M. semi-membranosus* (SM), *M. deltoideus* (D), *M. longissimus dorsi et laborum* (LD), en *M. psoas major* (PS), van die rooibokkarkasse is ontleed vir sitraatsintase (SS) en fosfofruktokinase aktiwiteite (FFK). MSK verspreiding het merkbaar varieer tussen D, SM en LD ($P<0.05$). D toon meer MSK I en minder MSKIIa as die ander drie spiergroepe ($P<0.05$). Postiewe korrelasies is bevind tussen ouderdom en MSK I in D ($r=0.93$; $P<0.05$), asook tussen SS en die gewig van die dier in D ($r=0.76$; $P<0.05$). Die ensiemaktiwiteite en MSK verspreiding toon dat energie in die rooibok tot 'n groot mate deur die oksidatiewe paaie geproduseer word.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

pH_{45} pH reading at 45 minutes post mortem

pH_u Ultimate (final) pH reading

$Temp_{45}$ Temperature of the carcass at 45 minutes post mortem

PSE   Pale Soft and Exudative

DFD   Dark Firm and Dry

PCV   Packed Cell Volume

CK   Creatine Kinase

LDH   Lactate Dehydrogenase

AST   Aspartate Aminotransferase

ES   Electrical Stimulation

SFA   Saturated Fatty Acids

MUFA Mono-unsaturated Fatty Acids

PUFA Ploy-unsaturated Fatty Acids

DFA   Desirable Fatty Acids

LD   *M. longissimus dorsi et lumborum*

PS   *M. psoas*

D   *M. deltoideus*

SM   *M. semimembranosus*

CS   Citrate Synthase

PFK   Phosphofructokinase

MHC   Myosin Heavy Chain

NOTES

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

Results from this study have been presented at the following Congresses/Symposia:

1.   Kritzinger, B., Hoffman, L.C., & Ferreira, A.V. (2002). Night cropping of impala (*Aepyceros melampus*): Does the meat quality benefit from this practice? In: Proc GSSA/SASAS Joint Congress, Christiana Aventura, 13-16 May 2002. p115.

2.   Kritzinger, B., Kohn, T.A., Hoffman, L.C., & Myburgh K.H. (2002). A study to examine the characterisation of four impala (*Aepyceros melampus*) skeletal muscle groups. 30th Annual Congress of the Physiology Society of Southern Africa (PSSA), Stellenbosch, 8-11 September 2002, p18.

CHAPTER 1

Literature review:
The meat quality attributes of impala (*Aepyceros melampus*)

1.1 Introduction

Human survival has always depended on man's ability to farm and produce food. Since the origin of mankind, we have used animals as a means of survival, for food, as a source of clothing and as a trading commodity (Conroy, 2002). It is unfortunate that in man's haste to domesticate certain species in search of maximum production efficacy, other species have been ignored. The myriad of other species that have been overlooked, have tremendous untapped potential, particularly in areas of the world where the prevailing conditions make farming domestic animals less efficient.

In Africa, with its harsh environments and unforgiving conditions, the merits of farming with indigenous species could be reasonably positively compared to those of farming with domesticated stock. There is a high diversity of wild large herbivores on the African continent, and they have become perfectly adapted to its harshness over the millennia. Local communities who have existed along side them have considered this wildlife a valuable natural source of animal protein for countless generations. This has continued to be so, particularly with the expanding human populations and increasing levels of poverty in modern rural communities. This has resulted in greater pressure being placed on natural wildlife populations and is contributing to record declines in wildlife populations (Barnett, 2000).

Africa is not the only place where the indigenous animal populations have been utilised by humans as a food source. The Inuit Indians and the North American Indians depended greatly on the Caribou (*Rangifer tarandus*), Polar Bear (*Ursus maritimus*), various seal species and probably most importantly, the North American Bison (*Bison bison*). There are still several primitive cultures around the world that exist primarily as hunting societies (Peterle, 1977).

In modern times with the ever increasing demand placed on the earth's resources by the burgeoning human population, the demand for game meat is likely to grow both locally and internationally. Game meat is an attractive alternative to health conscious consumers who tend to shy away from other red meats because of the high fat

content in these meats. Modern society has placed an emphasis on the importance of informed and healthy nutrition and it has generated a demand for "healthier" products. This is a powerful marketing tool for game meat and it has created an opportunity for the competitive advancement of the industry, provided that the necessary information pertaining to the quality aspects of the meat is made available.

1.1.1   The importance of game to the commercial farming industry

Many animal husbandrymen and animal scientists have difficulty accepting the concept that indigenous or "unconventional" animals potentially have a very important role to play in modern animal production systems. However, few people would dispute the productive superiority that these animals have over domesticated livestock under natural conditions (Ledger, 1963). Millions of years of evolution have ensured the near perfect adaptation of these animals to the local environment.

With the world population steadily increasing, ever greater pressure is being placed on our natural resources. The world's oceans are being consistently over-fished every year and the traditional meat production industry cannot keep up with the demand (Huntley, Siegfried & Sunter, 1989). In spite of this, there is still very little feeling of urgency when it comes to utilising so-called marginal lands for animal production. Approximately 60% of the world population, largely in the developing countries, suffer from some or other sort of animal protein shortage (Babiker, Khider & Shafie, 1990).

Efforts to meet the food requirements of people have centred on developing intensive forms of production and utilising the world's most fertile lands to do so. Man's endeavours to streamline the commercial farming enterprise have led to impressive advances in the breeding and selection of stock for specific production based objectives. Unfortunately the type of research that has been conducted in these fields has, to a large extent, neglected to give much attention to the potential of the world's less favoured marginal areas. This focused approach has resulted in the indigenous animal species found in these regions also being overlooked. While game animals cannot compete with domestic stock in intensive farming units as far as specific types of production are concerned (Skinner, 1984), depending on what the production aim is, they are much better suited to the utilisation of a harsher environment. Their adaptations make them competitive with domestic stock in terms of natural grazing utilisation and the conversion thereof to protein in extensive circumstances (Fairall, 1984).

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Thornthwaite (1933) estimated that 31% of Earth's surface is covered by semi-arid and arid regions. Most of these areas are found in the sub-tropical latitudes and are defined in terms of their low rainfall. These areas are not usually capable of producing significant traditional agricultural yields. Such areas nevertheless have huge potential and if managed efficiently and sensitively, could be of great agricultural value. The inadequate information base that exists for indigenous animal species in Africa makes it difficult to apply traditional animal husbandry techniques such as those designed to increase production, feed efficiency and decrease disease susceptibility, as one would do with domestic livestock.

Many modern farmers farm with exotic domestic stock in semi-arid regions because such animals are easily managed in terms of being herded, doctored and marketed. These advantages presently outweigh the "meat-per-hectare" productivity of the less manageable indigenous species (Dekker & Van Wyk, 2002). The problem with domestic stock in such areas is that they are not necessarily adapted to eating the naturally occurring vegetation and so may not perform optimally in terms of both health and production. A further complication arises when farmers make use of improper grazing strategies in an effort to bolster the production. Arid and semi-arid areas are usually ecologically sensitive and prone to both over-grazing and concomitant erosion. It would make sense in such cases to utilise free ranging indigenous animals that are adapted to the region. A combination of the naturally occurring species would result in them utilising slightly different feeding niches without much overlap and so they would utilise the vegetation more efficiently. The advantages of a mixed herbivore community and the concomitant complimentary use of the various vegetative components were recognised long ago by traditional pastoralists (Fritz, De Garine-Wichatitsky & Letessier, 1996).

In a study conducted by Hopcraft (2002), it was found that the productivity from wildlife within their ecosystem equalled or exceeded that of cattle, particularly in terms of meat production. The costs of raising wildlife were found to be lower, as the expenses associated with domestic stock such as dipping, inoculation and herding were not applicable with wildlife. Hopcraft (2002) went on to say that the effects of the cattle on the rangeland showed the typical signs of erosion as a result of their concentrations at certain points (like the drinking troughs). It was found that there was a significant decrease in the vegetative cover and species diversity. Due to the inherent ability of game to utilise a much wider variety of plants, the opposite effects were noted with game. Not only was there improvement in the veld condition, but

there was also the added benefit of the lower maintenance costs associated with game. Talbot, Payne, Ledger, Verdcourt & Talbot (1965) published a summary of evidence that shows that wild ungulates are capable of converting the flora of marginal lands into human food. Wild animals are also less dependent on free water for their survival, so they are able to use wider grazing areas.

Cooper (1995) stated that one of the important perceived benefits of non- or partially domesticated species is their ability to feed the growing number of people on our planet. Workers who have investigated the body compositions of some of these animals (Van Zyl, 1962; Von la Chevallerie, 1970) have found that they produce a higher proportion of edible animal protein (lean carcass meat) than do domestic stock. In areas infested by tsetse flies, game may be the only practical way of making such areas productive.

It may be argued that through efficient management of domestic herds in marginal lands, their productive capacity can be improved. However the fact remains that drought, disease, plant types and distribution and other factors such as distances involved still place a heavy burden on a traditional domestic stock farming enterprise in marginal areas. Game have superior potential productivity in terms of both reproductive and growth rates (Fairall, 1984; Skinner, 1971) and overall increased meat production potential because of superior carcass dressing out proportions (Dasmann & Mossman, 1960; Hoffman, 2000b; Van Zyl & Ferreira, 2002). Game have better disease resilience and show superior physiological adaptation to the environment (Hopcraft, 2002; Barnett, 2000). Aidoo & Haworth (1995) stated that farming of deer in the United Kingdom has become popular in the last few years, particularly in areas where the land is of lesser agricultural value. The strategy is that traditional farm animals would not be produced economically on such land, but the raising of deer becomes viable.

1.2   Game Farming in Southern Africa

Game farming in Southern Africa has a short history as a commercial enterprise. One of the first studies on the viability of wild ungulate populations as a natural resource was conducted in the early 1960's (Dassmann & Mossman, 1960). Since then a number of systems have been implemented to utilise this resource that range from the cropping of unmanaged wild populations to the use of wild ungulates in the more traditional farming systems associated with domestic stock (Fairall, Jooste & Conroy,

1990). Game farming is now recognised by the South African agriculture and conservation authorities as a *bona fide* form of agricultural land use (Eloff, 2002).

Previously, a game ranch was a farming enterprise that set out to utilise existing or reintroduced herds of wild game on large areas of marginal land. However, it is not only the marginal land anymore because the present trend in southern Africa is to use prime agricultural land previously utilised for domestic stock production, for game. The greatest value of game farming lies in its ability to utilise the harsher environments of the country where the naturally adapted features of game make them competitive with domestic stock (Fairall *et al.*, 1990). In Southern Africa the main aims of game ranching is usually to produce trophy animals for foreign and local hunters. Although trophy hunting gives the best return per animal, when one considers the relatively low number of trophy animals that occur within a natural population, it offers the lowest return per unit area. Other ranches sell themselves as ecotourism destinations and also generate income from live game sales. There are few ranches that go in for game meat production as their main production aim. Berry (1986) conducted a study in which a comparison was drawn between the various forms of utilisation of game as a commercial enterprise. At that time, trophy hunting gave the highest net return on capital, live game sales and recreational hunting followed, in that order and game meat production took up the lowest position. In a more recent study conducted by Van Der Waal & Dekker (2000) in the Northern Province of South Africa, they found that game meat production made up approximately 4% of the total turnover of the game farming industry in that province. Berry (1986) found that the enterprises with the highest return were also the most capital intensive and required the most expertise to run. Self-operated trophy hunting offers a greater return than the sale of the hunting rights to an outside operator. The disadvantage to this strategy however, is that it is more capital intensive and one has to find hunting clients in a very competitive market. Live animal sales require substantial financial resources and are labour intensive. It is thus logical that a broadly based utilisation strategy for a wildlife production enterprise would yield a better return.

In a study conducted by Van Der Merwe & Saayman (2002) it was found that in recent years, there has been a noticeable decrease in the number of overseas hunters coming to this country for the hunting experience. The latest statistics of PHASA, the Professional Hunters Association of South Africa, show that there has been a 12% decrease in the number of overseas hunters and a 25% decrease in the

number of hunting days (PHASA, 1999). It could be argued that South Africa's unstable position with crime and the recent stringent moves to restrict firearm ownership could be partly to blame for this downturn in overseas hunting. In light of this therefore, it is necessary to invest effort in discovering other avenues for the utilisation of our wildlife resource.

There are ecological and economic advantages to having multi-species game production systems in a semi-arid and marginal areas (Dekker, 1998). There has been a steady increase in the number of game farming enterprises over the last two decades, and today game ranching is one of the fastest growing agricultural industries in South Africa (Anonymous, 1994; Bothma, 1995; Eloff, 1996, 2002; Gouws, 1995; Stroleny-Ford, 1990). According to Van Der Waal & Dekker (2000) the movement away from domestic livestock production to game production in the Limpopo Province of South Africa is generally acknowledged. Robinson & Lademann (1998) have shown that cattle numbers have declined in favour of game-ranching activities in this province.

Approximately 300 000 hectares of farm ground is fenced for game farming purposes in this country annually (Van Zyl, 2000). There are more than 5 000 so-called exempted game ranches or commercial farms that are fenced. There are a further 15 000 farms that also economically utilise existing wild populations of game (Eloff, 2002). Between 17 and 18 million hectares of the country is already being used for game farming and the industry is growing at the rate of 2.5% per year (Van Zyl, 2000).

South Africa attracts the most foreign tourists in Africa, and tourism is presently the fourth largest industry in the country (Van Der Merwe & Saayman, 2002). Saayman (2000) reported an increase in the number of foreign tourists from 5 730 000 in 1998 to 6 120 000 in 1999. This equates to an increase of 6.7%. The world average contribution of tourism to Gross Domestic Product (GDP) is 11%. There is therefore room for considerable growth in South Africa when one considers that tourism only contributes 4.6% of our GDP (GCIS, 1998), which equates to roughly R45 billion per annum. Of that R45 billion, only R2 billion is derived from ecotourism. Local hunting activities generate around R500 million and foreign hunters contribute a further R200 million (Eloff, 2002).

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There are hopes that wild game in Africa (large size savannah herbivores) could one day replace, or at least compliment domestic cattle in terms of meat production. A big advantage with game farming is that it is not as susceptible to stock theft as domestic stock farming. Wild animals are usually kept in large bushed camps and are not as tame as domestic stock, therefore they are more difficult to steal (Eloff, 2002). There are two serious difficulties presently facing wildlife farming. Firstly, there is the need to prove to a doubting national and international agricultural establishment that wild animals are worth the trouble and money that needs to be invested before they start producing (Kock, 1995). Secondly, there is the need to prove that the production of game from game farming is sustainable. The same criteria that are applicable when producing meat from domestic stock, apply to the meat production from wild ungulates. These criteria include factors such as yields, chemical composition and meat quality (Issanchou, 1996). Not much research has been conducted into the meat production potential of wild ungulates pertaining to dressed yields and especially body chemical compositions.

1.2.1 Sustainable utilisation

The game ranching industry in South Africa operates from a sustainable utilisation ethic and game ranchers base their farming practises on the principles of sustainable utilisation of both the game and the other natural resources (Krynauw, 2002). Thompson (1992) stated that the best way to conserve wildlife is to establish controlled and sustained yield harvest schemes that can provide people with a means of earning a living from natural resources. According to Kock (1996) there needs to be a fine balance between non-use, consumptive use and non-consumptive use with wildlife utilisation.

It should be noted that there is a difference between sustainable utilisation and sustainable agriculture. Agricultural practises based on sustainability are tried and tested principles that have been developed from a vast amount of accumulated experience and knowledge gathered during the conventional agricultural era (Krynauw, 2002). They may be adapted and applied successfully to sustainable utilisation enterprises. Some of the principles of sustainable agriculture include: emphasising the conservation of the natural resource and the enhancement of environmental quality and the emphasis on production that is based on the economic, healthy and efficient use of natural resources.

Sustainable utilisation in terms of game farming should primarily encompass the maintenance of a sound environment, since destruction of the habitat will be detrimental to production. As in any farming operation, but perhaps more importantly in game farming, maintenance of a healthy genetic base is essential. Not only for maximum production potential, but also for the conservation of the species. Therefor a game production system should be managed according to a maximum sustainable yield strategy while maintaining a positive image for the consumer and marketing a consistent and desirable product.

1.3   The impala

1.3.1   Taxonomy

Phylum: Chordata

Subphylum: Mammalia

Order: Artiodactyla

Subfamily: Aepycerotinae

Genus: Aepyceros

Species: melampus melampus

Impala are the only representative of the Subfamily AEPYCEROTINAE, and they are regarded as medium sized antelope. Males have strongly ridged lyrate horns while the females do not have horns. Impala have no pre-orbital, pedal or inguinal glands, and the females have two pairs of mammary glands (Skinner & Smithers, 1990).

The colloquial name of impala is said to have likely been an Anglicisation of the Tswana name "*phala*". It has also been claimed that it is derived from the Zulu name for the species, *Impala*. Ansell (1972) listed six sub-species under AEPYCEROTINAE that are found in Africa. Two of these are found in southern Africa, namely the impala, *Aepyceros melampus melampus* (Lichtenstein, 1812), and the black-faced impala, *Aepyceros melampus petersi* (Bocage, 1879) which is found in northern Namibia and south-western Angola.

1.3.2   Description

The impala is a medium-sized antelope with gregarious habits and it occurs naturally in the tropical and subtropical thornveld savannahs of Southern Africa (Young & Wagener, 1968). They remain in a fairly small home area for much of the year and seem to prefer variegated woodland. They have shiny light brown to brick-red coats with light fawn coloured flanks and white underparts. There is a single black stripe

along the top of their medium length tail and down the back of each thigh. They have white throats and a dark brown patch high on the forehead. Prominent tufts of black hair cover the metatarsal glands on the hind legs just above the ankles. Like the underparts, the tail is white underneath. The ears are white on the inside with black tips that make a conspicuous contrast. The legs are light fawn coloured like the flanks and get lighter closer to the hooves. The insides of the legs are paler in colour, nearly white. They are medium sized antelope with a graceful, slender build and long legs. Adult males measure approximately 0.9m at the shoulder and have an average mass of around 50kg. The females are smaller with an average live mass of 40kg. However, the average mass differs from region to region (Skinner & Smithers, 1990).

Impala hair is shaped like a cricket bat in cross section (Skinner & Smithers, 1990), with triangular, blunted corners. The hair has an irregular waved mosaic cuticular scale pattern from the base to the tip.

1.3.3   Horn Growth

According to Child (1964) the horns of the impala appear at an age of approximately 4 months. With impala, unlike most other antelope, it is only the males that have horns. Thompson (1967) noted that the horns grow in an equiangular spiral similar to those of other antelope. The horns swing back from their heads, bow outwards, then bow inwards to sharp points (Skinner & Smithers, 1990). The horns are strongly ridged for about two thirds of their length but then become smooth towards the points. The rate of growth at the zone of active growth (at the base) is uneven and this creates the acute-angled spiral that gives the characteristic shape of impala horns (Spinage, 1971). The most active period of growth for the horns occurs at about one and a half years and then decreases to reach an asymptotic level of 63.5 cm in the dried horn at about four and a half years. At about six years of age, wear at the tips appears to exceed growth so that in old age the horns get progressively shorter.

1.3.4   Distribution and habitat

Impala occur in a fairly solid pattern from northern Kenya down through Tanzania and Zimbabwe to the north-eastern parts of South Africa. Their most westerly distribution stretches to western Zambia and Zimbabwe (Skinner & Smithers, 1990).

Impala tend to favour an open bushveld type of habitat and are generally absent from montane areas. The availability of water and cover are essential habitat requirements

for impala. They are generally associated with *Acacia* scrub and mopane although they are also found in other woodland types. They tend to avoid open grassland and floodplains (Fairall, 1972).

1.3.5 Breeding

Females become sexually mature at about 17-18 months while males reach physiological sexual maturity at 13 months. Successful mating of 17-18 month old males has been reported (Mentis, 1972). Impala are seasonal breeders and the lambs are usually born between November and January after a gestation period of 194-200 days (Fairall, 1972). According to Fairall (1983) fecundity of mature females (2+ years) averages 95% but is lower and more variable in ewes younger than two years.

1.3.6 Habits of Impala

Impala have been the most popular game species sold at game auctions during the last six years. This is due to the relative abundance of the species and it's fairly rapid reproductive rate. This makes it an ideal species to establish a game population on a farm in a relatively short space of time. Their browsing habit allows a much better utilisation of the large tree and shrub component of the South African bushveld areas (Fairall, 1983) and makes them a good compliment to an extensive cattle ranching operation (Skinner, 1973).

Male impala territory size varies depending on the local population density and region. Where they border on each other, the territories form a mosaic (Jarman, 1976). Females group together into herds that move through the male territories. The home range of the females may extend over several male territories. Territorial males do not tolerate other males in their territories and will evict such males within a female herd. They also try to prevent the female herd from leaving their territory. Non-territorial males form bachelor herds that are tolerated in a male's territory. Impala have a characteristic alarm snort that is given whenever danger is sensed or when an intruder is spotted (Skinner & Smithers, 1990). During the rut, territorial males scent-mark their territories by rubbing their foreheads and faces on twigs. This behaviour does not occur with the females (Jarman & Jarman, 1974).

Impala are diurnal animals but do occasionally have some nocturnal activity. Nocturnal activity occurs more frequently during the rut. When resting, impala either lie down or stand. During the day when it is hot they seek out the shaded areas, but

continue to move around browsing. When alarmed by an intruder outside of their flight distance, impala will merely stand motionless and observe the threat. If this happens within their flight distance, the animals will flea by breaking wildly in all directions (Skinner & Smithers, 1990). They are able to leap high and far, and clearing bushes and cattle fences is accomplished with consummate ease.

Impala are often seen grooming themselves in what looks like an upward licking motion of their flanks. This motion is in fact the impala's way of removing parasites by scraping it's skin with the thin incisors on its lower jaw. This action is limited by the fact that the animals are not able to groom their own neck and head region. They overcome this by reciprocal allo-grooming (McKenzie, 1990). Two impala stand face to face and take turns grooming each other's head and neck regions.

The rapid growth and high fecundity of impala are two attributes that make it an excellent game meat production candidate (Fairall, 1983). A number of models have been described for the calculation of the sustainable cropping rate for impala (Hoffman, 2000a) and according to Fairall (1983), a 22% reduction rate is suitable in an area where predators are present. Where predators are absent, Fairall (1983) postulates that 25-30% is sustainable. Manipulation of the age and sex ratios of an impala population can significantly increase production. Fairall (1985) calculated that increasing the sex ratio from 1:3 (1 male to 3 females) to 1:10 would increase the productivity of the herd by 30%. Van Rooyen (1994) found that a sex ratio of 1:5 was the most suitable for a population with no predators and that age selective cropping did not increase production in that case.

A wide range of predators that include all the larger cats, canids and hyenas, as well as baboons, eagles, pythons and crocodiles, prey on impala (Skinner & Smithers, 1990). Many game farms in South Africa are either too small to accommodate such predators, or they are of the opinion that the losses of game that are inflicted by predators outweigh their worth on the farm. Consequently, impala populations on such farms are not controlled by natural predation.

1.3.7 Economics

The importance of impala in the South African game farming industry is beyond question. It is one of the most graceful of the African antelope and its ubiquitous distribution and adaptability makes it well suited to nearly any habitat. It's fairly rapid rate of reproduction (Fairall, 1983) make it a good species to use when establishing a

resident game population on a new farm. This, together with its relative abundance, makes it one of the most economically important species in game farming in South Africa (Figure 1).
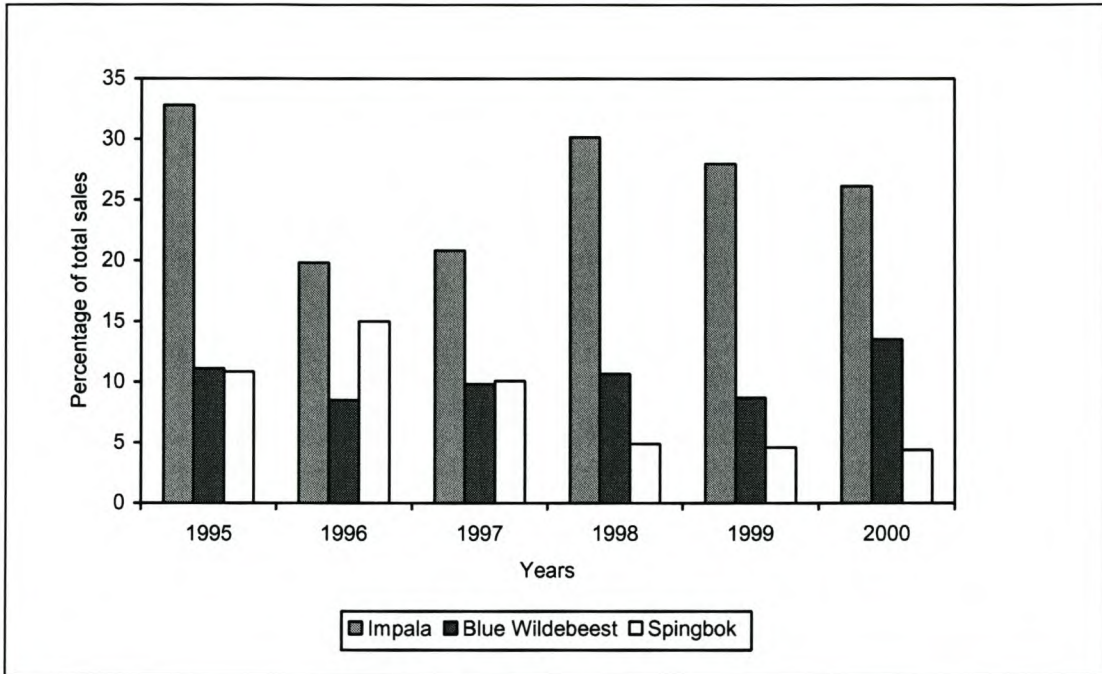
Figure 1: The importance of impala compared to the two closest economically important species as a percentage of total live game sales (Eloff, 2002).
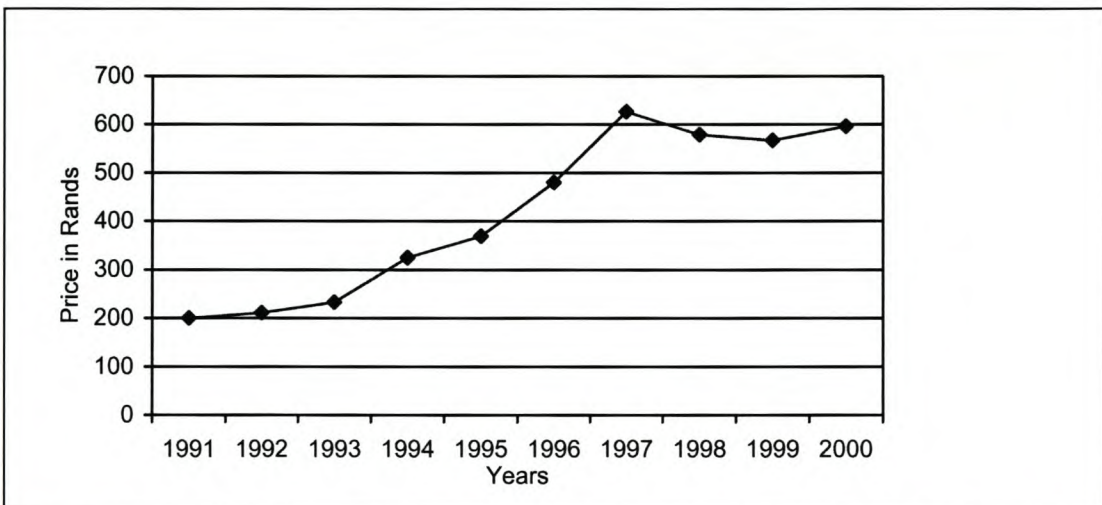
Figure 2: Average auction prices for live impala between 1991 and 2000 (adapted from Eloff, 2002).

The average prices of impala at game auctions have reached a plateau in recent years (Figure 2). The average price increments have also tapered off and the price

has remained relatively stable for the last 3 years (Figure 3). This is partly due to the fact that they are an abundant species and their demand at game auctions has tapered off somewhat. Another likely reason is that recent developments in the South African economy and a lack of confidence in the safety of the country have frightened away the lucrative foreign hunter, hence the demand for animals to restock existing populations to cater for the hunting demand has diminished.
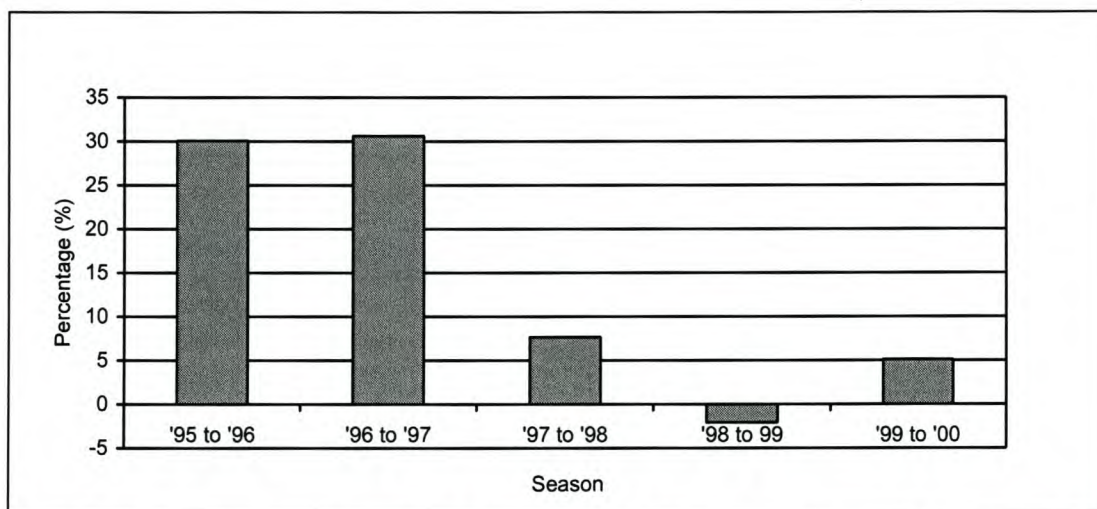
Figure 3: Percentage increase and decrease in the average price of live impala at game auctions in South Africa between 1995 and 2000 (adapted from Eloff, 2002).

1.4   Meat Production

Essentially, a fenced game farm or game reserve is an unnatural system by virtue of the fact that it does not permit the free movement of game. Predator and prey interaction is therefore also affected and in many cases, particularly on the smaller farms, is altogether absent. In order to maintain the apparently unaltered, wild and limitless expanses of country, strict management policies have to be implemented (Hoffman, L.C., 2002, *pers.com.*). Seasonal cropping of animals is an extremely important part of such management policies for a farm.

The specific cropping method should be one that results in the minimum of ante-mortem stress. This is not only to improve the meat quality but is also in the interests of the humane treatment of the animals. Most game farmers who manage their herds with cropping programmes have worked out methods that they believe are the most suitable according to their individual circumstances. No standard for the cropping of animals has been formulated and this is a problem from a meat quality viewpoint.

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The method of cropping can have a profound effect on meat quality (Von la Chevallerie & Van Zyl, 1971). Lewis, Pinchin & Kestin (1997) reviewed the welfare implications of cropping impala at night in the Mkuzi Game Reserve in South Africa. The study indicated that the alert and investigative posture taken by the impala when startled by a spotlight at night make them particularly well suited to nighttime cropping operations.

It has been reported that the calibre of rifle used during a cropping operation (and the associated noise) have an effect on the meat quality of the animals cropped (Hoffman, 2000a). This author went on to suggest that lighter calibre rifles should be used as this would be effective in reducing the noise as well as reducing the cost of the cropping in terms of the less expensive cartridges for lighter calibres.

1.4.1 Production dynamics

During a typical year in the life of a wild herd of impala, the feed intake increases during the spring and reaches a peak in the late summer. It is then when breeding males attain their peak weight in time for the breeding season, or rut. During the rut, the males loose a considerable amount of weight for two reasons: their feed intake is reduced because less time is spent foraging, and they use a significant amount of their energy reserves for courting and mating behaviour. Stevenson, Seman, & Littlejohn (1992) found that deer (*cervus spp.*) may undergo a 25% weight loss and loose more than 80% of their body energy in a six-week period during the rut.

The same criteria that apply to meat production from domestic livestock apply to meat production from game (Hoffman, 2000a). Issanchou (1996) names the criteria as the carcass yields, chemical composition and meat quality. It is therefore necessary to have the cropping period coincide with the time of the year when the condition of the animals is at its peak.

1.4.2 Methods of cropping

1.4.2.1 Night (spotlight cropping)

The method of cropping that seems to be used most often is nighttime cropping (Hoffman, 2000b; Hoffman & Ferreira, 2000; Veary, 1991). The culling operation usually begins directly after dark on moonless evenings. Evenings where the moon is present are avoided because they reduce the efficiency of the spotlight that is used to blind the animals (Bothma, 1995). The operation sometimes continues until dawn the following day to take maximum advantage of the moonless conditions. The

croppers are usually positioned on the back of a truck that is then driven slowly over the terrain where the cropping is to take place. The driver may sometimes also be equipped with a rifle to take part in the cropping, depending on the conditions and on how many marksmen are available. One or two people with spotlights also stand on the back of the truck and sweep the lights over the surrounding bush (Lewis *et al.*, 1997) in a continuous motion on either side of the vehicle. When animals are sighted, either directly or by the reflection of light from their retinas, the spotlights are trained on them and the truck is stopped immediately. Firing commences if clear shots are possible and ceases when the flight response of the herd impedes further accurate shooting. From an ethical aspect, shots are not usually fired from the vehicle whilst it is moving because this severely reduces accuracy and increases the likelihood of wounding animals. In an investigation conducted by Lewis *et al.* (1997) it was shown that, with a single marksman, the average time between the culling of impala within a herd was 28 s. The maximum time was 3 min and 18 s and the minimum time was 2 s. Targeted animals are shot in the head or high in the neck. A head shot destroys the brain and results in instantaneous insensibility. A neck shot usually destroys the spinal column and the arterial blood supply to the brain, thus also rendering instant insensibility. Of the two, a head shot is preferable because of the fact that it causes no meat damage. Neck shots usually cause little or no meat damage, but this is largely dependent on the positioning of the shot. For the export of game meat, according to the European standards, only head or high neck shots are allowed.

Studies have shown that night cropping is effective in reducing the amount of stress that animals are subjected to during a cropping operation (Hoffman, 2000a; Hoffman & Ferreira, 2000; Kritzinger, Hoffman & Ferreira, 2002). These studies have also shown that night cropping has a beneficial effect on certain meat quality parameters of the cropped animals.

1.4.2.2 Day

There are a number of different daytime cropping methodologies, each type having certain advantages and disadvantages. The general daytime method is traditional hunting where the animals are hunted on foot. However this is not usually a method that is used for large scale cropping operations. The problems associated with this method are that it is very time consuming and it severely limits the extent of the operation in terms of the number of animals cropped and the mobility of the croppers.

Another daytime method involves the careful herding of animals towards a cropping line. The cropping line is where the marksmen position themselves in camouflaged bunkers to await the herd (Hoffman, 2000a). The animals are herded along using pick-up trucks, scrambler motorcycles, or horses, and as is noted by Veary (1991), it is the most stressful method for the animals. Final pH values of springbok reported by Veary (1991) using this method, are similar to a value reported by Hoffman (2000a) for a single severely stressed impala ram. This method results in excessive physiological stress to the animals, and as has been witnessed during a cropping operation in the Free State, causes severe sub dermal abrasions and bruising as a result of the animals bumping into each other and falling. The severely negative effects on the meat quality are numerous.

A third method that was evaluated by Veary (1991) is that of helicopter cropping. This is usually done using a 2-seater helicopter with a pilot and a marksman. The helicopter then flies low over the herd (approximately 6m altitude) and the animals are shot in the upper neck and head with a 12-bore shotgun. This method is dangerous in terms of the extreme skill involved for the manoeuvring of the helicopter and is expensive. Apart from these two factors it also causes severe stress to the animals.

1.4.3   Responses to cropping

An important aspect that will affect the management strategies of a game farm or reserve, is the question of whether an impala herd develop an avoidance response to cropping vehicles as a result of cropping operations. Lewis *et al.* (1997) suggested that impala herds were more inclined to show an avoidance response to a hunting vehicle than an ordinary saloon car when driven through the reserve. It is thus clear that on farms where tourism is an important economic consideration, culling vehicles should not be the same shape, size or colour as that of vehicles driven by tourists. The culling vehicles should also not sound the same as tourist vehicles.

1.4.4   Losses during cropping

Von la Chevallerie & Van Zyl (1971) report that losses that occur during a culling operation are usually as a result of three factors: Firstly, bullet damage to the meat that makes it unfit for human consumption; secondly, animals that are wounded and never recovered from the field, and thirdly, some animals suffer from excessive ante mortem stress that leads to a serious decline in meat quality.

Von la Chevallerie & Van Zyl (1971) found that meat loss as a result of bullet damage can be considerable (up to 22% of carcass weight) when small antelope like springbok and impala are shot. Such wastage as a result of bullet damage, arises from the use of body-shots. In a commercial cropping situation, body-shots are the exception to the rule because head and neck shots are favoured for their effectiveness. Work done by Hoffman (2000a, 2000b) and Hoffman & Ferreira (2000) found that there was no wastage of meat in a cropping operation where headshots were used. These authors went on to say that high neck shots also result in little, if any, meat damage (less than 2%).

Head and neck shots produce better meat quality from cropped animals because when they are shot through the neck or in the head, they usually collapse instantly with the minimum of stress (Von la Chevallerie & Van Zyl, 1971). The traditional shot used by most biltong hunters is one that hits the chest area of the animal and sometimes both shoulders. This shot results in significant meat damage on the carcass and does not always result in immediate death for the animal (Table 1). Head and neck shots necessitate a high degree of marksmanship, but effective game conservation and efficient cropping require careful selection of the animals to be cropped and therefore allow close range shooting.

Table 1: Bullet damage from shots at various localities as a percentage of total carcass weight (adapted from Von la Chevallerie & Van Zyl, 1971)

Locality of the bullet wound	Percentage of carcass damaged
Neck	3.18
Ribs	5.47
Back	12.47
Neck and shoulder	15.66
Shoulders	20.58
Shoulders and ribs	22.22
Other (e.g., stomach, hind quarters)	15.61

In a study conducted by MacDougall, Shaw, Nute & Rhodes (1979), it was found that venison from farmed red deer (*Cervus elaphus*) slaughtered after overnight holding was more likely to produce DFD meat than that of animals shot in the wild. It was found that slaughtering male animals (which are prone to produce DFD meat) immediately upon their arrival at the abattoir could reduce the incidence of DFD. The results of such studies point to the benefits of the immediate slaughter of wild

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animals either in their environments, or after the minimum possible amount of transport and exposure to human contact. Therefor an efficient cropping method should provide the best possible meat quality of wild ungulates.

1.4.5 Processing of harvested game

The harvested game are either processed in the field, or in an abattoir depending on the available facilities. During large scale cropping operations when large numbers of animals are shot in an evening, the carcasses are usually hung on steel frames erected in the field. The dressing procedure for game in the field usually consists of the removal of the head, hooves, red offal (heart, lungs and liver) and white offal (gastro-intestinal tract) (Bourgarel, Des Clers, Roques-Rogery, Matabilila & Banda, 2002). The skin is usually left on to save time and prevents excessive moisture loss as a result of exposure to the environment.

Butchers in the field have to follow a strict set of procedures in order to ensure the hygienic integrity of the processed carcasses. Bourgarel *et al.* (2002) devised a system whereby there is a hygiene inspection chart for the carcasses and for the quality of the hides. Bonuses are paid in order to motivate the butchers to adhere to the hygiene procedures. This is particularly important where potential export markets are concerned, or where the carcasses are destined for large retail groups who demand strict hygiene standards. With large-scale operations that have the infrastructure in place to facilitate it, animals are transported to a commercial abattoir where they are processed.

1.4.6 Yield

The region of the country where the impala are from seems to have an influence on their body weights. Von la Chevallerie (1970) reports widely varying average body weights for impala harvested in various parts of southern, central and eastern Africa. The lowest average body weights were reported by Hoffman (2000b) for animals harvested in central Zimbabwe. This variation is probably a result of a combination of prevalent local climatic and nutritional factors. The age of the animals harvested also has a considerable effect on the dressing percentage. In a study on eight impala, Van Zyl & Ferreria (2002) noted that the dressout percentage of impala increased from 57% to ± 66% when expressed as a percentage of empty body weight. This variation was a result of the difference between the animals being weighed with empty and full gastro-intestinal tracts respectively. One would expect there to be a

variation in dressing percentage between the sexes owing to the sexual dimorphism of impala, however this does not seem to be true (Hoffman, 2000b).

Table 2: The mean (± se) carcass yields and South African commercial trade cut yields of male and female impala (*Aepyceros melampus*) (Hoffman, 2000b)

Parameter	Female (n=8)	Male (n=8)	p
Live weight (kg)	33.5 ± 3.417	49.4 ± 4.606	0.015
Dressed weight (kg)	19.5 ± 1.998	28.3 ± 2.571	0.017
Dressout[a] (%)	58.0 ± 0.621	57.5 ± 0.548	0.496
Cold carcass weight (24 hrs, kg)	19.0 ± 1.960	27.6 ± 2.551	0.018
Moisture loss in cooler[b] (%)	2.5 ± 0.203	2.6 ± 0.211	0.579
Heart[b] (%)	0.7 ± 0.023	0.6 ± 0.032	0.014
Liver[b] (%)	1.5 ± 0.073	1.3 ± 0.080	0.173
Spleen[b] (%)	0.3 ± 0.039	0.3 ± 0.023	0.532
Kidneys[b] (%)	0.3 ± 0.025	0.3 ± 0.025	0.435
Cleaned Omasum[b] (%)	0.6 ± 0.042	0.4 ± 0.017	0.016
Rest of the cleaned stomach[b] (%)	2.4 ± 0.105	2.0 ± 0.166	0.026
Cleaned intestine[b] (%)	2.4 ± 0.223	1.7 ± 0.107	0.017
Perirenal fat depot[b] (%)	0.3 ± 0.100	0.1 ± 0.088	0.323
Skin[b] (%)	3.9 ± 0.093	4.5 ± 0.240	0.030
Head[b] (%)	4.7 ± 0.172	5.8 ± 0.225	0.002
Feet[b] (%)	2.7 ± 0.109	2.5 ± 0.141	0.214
Neck[c] (%)	5.1 ± 0.170	6.9 ± 0.547	0.006
Breast & shank[c] (%)	25.9 ± 0.215	27.9 ± 0.379	<0.001
Flank[c] (%)	9.6 ± 0.263	8.9 ± 0.183	0.048
Rib[c] (%)	8.4 ± 0.236	8.1 ± 0.203	0.377
Loin[c] (%)	7.9 ± 0.267	7.4 ± 0.215	0.155
Chump[c] (%)	10.5 ± 0.249	9.6 ± 0.240	0.034
Leg[c] (%)	28.7 ± 0.410	27.6 ± 0.521	0.127
Total Leg[c] (Chump + leg; %)	43.0 ± 0.445	40.5 ± 0.637	0.007
Shank[c] (%)	3.9 ± 0.231	3.3 ± 0.166	0.024

[a] percentage of dressed weight

[b] percentage of live weight

[c] percentage of cold carcass mass

Most researchers agree that the average dressing percentage of mature impala is in the vicinity of 58% (Hoffman, 2000b; Monro & Skinner, 1979; Van Zyl, Von la Chevallerie, & Skinner, 1969; Von la Chevallerie, 1970). Table 2 contains data on the various carcass components of male and female impala harvested in Zimbabwe (Hoffman, 2000b).

1.4.7   Marketing

The production and consumption of game meat in South Africa is poorly documented (Hoffman, 2000b). The amount of animals taken by hunters and farmers for their own consumption or local sale is very difficult to quantify and it is virtually impossible to obtain reliable figures for this type of trade. Jansen van Rensburg (1992) reports that game meat is fairly well known and is consumed by approximately 5.625 million people around the country. Even so, few people know how to prepare game meat correctly and many people dislike the taste of game meat. This author went on to say that only 39% of the total population had ever eaten game meat in a form other than dried raw meat (biltong).

The current global trend is that people desire natural products. This is particularly the case when it comes to food products. Game meat has been almost entirely ignored as a food source in the modern world. However it has and still does provide the main meat source to many people in developing countries (Bourgarel et al., 2002). The recent agricultural catastrophe that happened in the UK and Europe with the outbreak of diseases such as Bovine Spongiform Encephalitis (BSE or Mad Cow Disease) and the discovery of banned residues in meat, has created a fear of beef, mutton and pork meat products. In turn it has created a potentially massive opportunity for game meat with its natural image and healthy characteristics. The low value of the Rand to the European and American currencies makes the prospect of game meat production a very attractive one for the export market. The production of quality processed game meat products that are well packaged and innovatively marketed could become a massive and lucrative industry.

Fisher (1991) reported that some of the qualities of game meat that make it attractive to the modern health conscious consumer are its robust "gamey " flavour and the leanness of the meat. While the attractive qualities of the "gamey" flavour are debatable, the leanness of game meat is beyond question. One of the key differences between game meat and other red meat is that there is relatively little

marbling fat in game meat. This factor may have an effect on the inherent moistness of the meat but appropriate cooking methods can reduce any negative effect that this may have on the palatability. Clearly the low total fat content of game meat should encourage consideration of its contribution to healthy eating (Aidoo & Haworth, 1995).

Another aspect that carries a great deal of importance with the modern consumer is the fact that game meat can be marketed as a truly organic product. The modern consumer wants meat products that are free of "contaminants" like anti-biotics, growth stimulants, medicines and artificial feed residues (Eloff, 2002). Game meat is considered to be the purist form of meat because none of the previously mentioned substances that are associated with meat derived from domestic animals can be found in free ranging game (Jansen van Rensburg, 2002). This is because of the type of extensive systems where they are produced where no dipping of the animals takes place, no fertilizers or growth stimulants are used and the animals do not have any form of medication administered to them. Mineral blocks are sometimes provided for game herds on a farm, but this is usually just to balance a naturally occurring mineral deficiency.

With this in mind, game meat could be marketed much more effectively and innovatively. Larger retail chains and conservation authorities involved in game culling and production could employ well known chefs to write recipes for the correct preparation of game meat, and thereby create interest in the product. Effective marketing of game meat should therefore focus on the health and organic aspects of the meat.

1.5   Meat Quality

In Europe, venison is a well-known and traditional meat product. There it is a product that consumers are willing to pay a premium price for because of its long-standing tradition in European culture. The South African taste for game meat seldom ventures beyond biltong (Woods, 1999). The reason for this is that many view game meat in South Africa as a lower grade product. This stems from a negative perception of game meat generally, not only in terms of its culinary appeal, but also because of the popular but erroneous idea that the consumption of game meat in some way contributes to the destruction of irreplaceable wildlife and the environment. This kind of "green" perception is one of the major stumbling blocks that stands in the way of game meat production becoming a much bigger industry. Gouws (1999) is of

the opinion that the way forward for the game meat industry in South Africa is through value adding. Biltong immediately comes to mind when game meat and value adding are put into the same sentence together. Biltong however, is something with which South Africans are already very familiar and the market for it needs very little encouragement. Value adding should encompass the production of cured products and various types of sausage to create a wide variety of choice for the consumer. This would be an effective strategy to familiarise meat consumers with the game product and perhaps encourage a sense of adventure as far as new products are concerned. Value adding could also remove the sometimes negative visual appeal that game meat has because of it's dark colour.

1.5.1   Factors that affect meat quality

Variations in meat quality usually result because of two things: Firstly, the interaction of intrinsic variation, like genetic (between and within species variance), nutritional, physiological, biochemical and histological factors. Secondly, as a result of extrinsic variation, such as pre-slaughter handling, slaughter methodology, storage and processing (Swatland, 1994). These variations usually manifest themselves as differences in terms of the physical meat quality.

1.5.1.1 Species

The species of the animal is probably the factor that is most easily seen to be a factor that affects the composition of muscle, but it should be borne in mind that there are a number of related intrinsic and extrinsic factors that also have an influence. Proximate compositions of muscle in all ungulate species are fairly similar, however, certain parameters differ from species to species and they differ for non-ungulate species.

The levels of myoglobin in the muscles of different species result in differences that have a bearing on meat quality. According to Lawrie (1998), levels of myoglobin in seal and whale muscle can make up as much as 5-8% of the wet weight of the muscle. This is because the musculature of these animals is constrained to operate anaerobically for prolonged periods. According to Haas & Bratzler (1965), the amounts of myoglobin contained in pig and in ox muscle differs quantitatively. This results in differences in the rates of oxygenation of exposed surfaces of freshly cut meat and has a bearing on the colouration of the meat.

Rates of enzyme activity also differ between species. It has been found that the ratio of calpain to calpastatin is higher in pig muscle than in either ox or lamb muscle (Ouali & Talmant, 1990). The authors continue by saying that this difference is reflected in the fact that post mortem tenderisation is faster in pork than in the other species. Information pertaining to specific enzyme activities is not yet available for game species and it is an aspect of meat research that needs attention.

1.5.1.2 Sex

Sex differences are most obvious in the differing levels of fat, both intra-muscular and sub-cutaneous. Hoffman, (2000b) reported significantly ($P<0.05$) higher levels of lipid content in female impala (33.9 ± 1.705 g/kg) than in males (24.5 ± 3.171 g/kg). This was ascribed this to differences in the levels of physical activity of the animals during the rut, as males are more active with courtship behaviour. Differences between the sexes seem not to be significant for relative moisture, protein and ash contents, as is reflected in the results of Hoffman (2000b).

1.5.1.3 Age

Regardless of the species and sex, the composition of muscle varies with increasing animal age. Lawrie (1961) states that there is a general increase in most parameters other than water but the rates of increment vary in different muscles. According to Lawrie (1998), the increase in intramuscular fat and in myoglobin content of muscle is evident. Also evident is the lesser increase of total nitrogen and a decrease in moisture with age.

Age has an influence on the level of connective tissue in muscle. The connective tissue content in young animals is less than in older animals (Wilson, Bray & Philips, 1954). The concentrations of both collagen and elastin diminish with increasing animal age. Tests conducted on the meat from animals of various ages have shown that tenderness varies with age, indicating differences in the connective tissue content and form (Hill, 1966). There seem to be a higher concentration of "salt-soluble" collagen in young or actively growing muscle. The degree of intra- and inter-molecular cross-linking between the poly-peptide chains in collagen increases with increasing animal age (Hill, 1966; Bailey, 1990). In young animals, most of these cross-links are reducible, but after about two years of age, they are gradually replaced by thermally stable linkages (Shimokomaki, Elsden & Bailey, 1972). This has a great influence on the tenderness of the meat.

1.5.1.4 Plain of nutrition

Unlike domestic stock, it is unusual for game farmers to provide supplementary feeding for their game. Game are left to glean all their nutritional needs from the available veld. Drought, overpopulation and altered habitat are factors that are common on many farms, and they can cause variations in the quality of the available graze and browse material. These differences in the plane of nutrition at any stage starting from the late foetal development, alter the growth of an animal, as well as affect the different regions of the carcass, tissues and organs (Lawrie, 1998). When one considers that the development of an animal takes place in a series of "waves", the principle growth wave starting at the head of the animal and spreading down the trunk to meet a secondary wave that begins at the extremities of the limbs, it is clear that nutritional constraints would have direct bearing on such development. This in turn affects the condition of the animals and the dressing percentages.

The nutritional status of an animal determines not only it's physical condition, but it is also the limiting factor on it's muscular energy reserves. Wiklund, Anderson, Malmfors & Lundstöm (1996) found that the nutritional status and physical condition of reindeer had a considerable effect on their muscle glycogen content. Limitations in muscular glycogen reserves affect the post mortem muscle chemistry, in particular, the pH. Therefore a lowering of the nutritional status of an animal predisposes them to the subsequent effects of pre-slaughter stressors (Bray, Graafhuis & Chrystall, 1989). Therefore, animals that are cropped during marginal nutritional shortages are likely to have a poorer meat quality.

Despite the hydrogenising effects of rumen microorganisms diet influences the fatty acid profile of the meat of the animal (Enser *et al.,* 1998). Ruminants that are fed high forage diets tend to have high levels of α-linoleic acid (C:18n3) (Rule, Broughton, Shellito & Maiorano, 2002; Whitney, Hess, Kaltenbach, Harlow & Rule, 1999) The (n-6)/(n-3) PUFA ratio is affected by the proportion of grass in the diet because grass is high in fatty acids of the n-3 series (Rule *et al.,* 2002).

1.5.1.5 Stress

Muscle glycogen is the main metabolic substrate responsible for post mortem lactic acid accumulation and therefore is one of the main factors responsible for the post mortem drop in pH (Immonen, Ruusunen & Puolanne, 2000; McVeigh & Tarrant, 1982). The amount of glycogen available for post mortem glycolysis varies considerably depending on the muscle, species and nutritional status of the animal.

The factor that has the greatest influence is the level of pre-slaughter stress that the animal experiences. Pollard *et al.* (2002) found that red deer (*Cevus elaphus*), that had been subjected to minimal handling and shot in a paddock under calm, humane conditions showed higher levels of muscle glycogen and lowered plasma and serum variables than animals that had been slaughtered at a commercial slaughtering plant. The handling of the animals at a commercial slaughtering plant was associated with increases in blood metabolites, which is indicative of injury and stress. They also had lower muscular glycogen levels than the paddocked animals, which suggests that glycogen mobilisation had taken place as a result of a stress reaction.

Ante mortem stress to animals has been a cause for major concern to farmers for many years because of its negative effect on meat quality. It is of particular concern to pig farmers and a great deal of research has gone into this problem and its associated effects on meat quality, such as Pale Soft and Exudative meat (PSE) and DFD meat. DFD meat is a direct result of low muscle glycogen at the time of slaughter (McVeigh & Tarrant, 1982). This reduced glycogen level affects the post mortem acidification process and results in a higher ultimate pH. This process can lead to the rapid onset of rigor mortis (Bate-Smith & Bendall, 1949). This will cause the early release of Ca ions and will produce very active calpains that are short lived at the prevailing high temperature of a freshly slaughtered animal (Etherington, Taylor, Wakefield, Cousins & Dransfield, 1990).

Hoffman (2000a) reported that wounded impala often show meat quality attributes similar to that classified as dark, firm and dry (DFD) meat. DFD meat normally has poor processing characteristics, colour development is uneven and the flavour is poor. DFD meat also has high spoilage potential, so it does not keep well and it has a short shelf life (Newton & Gill, 1981).

A number of workers have found that normal handling associated with yarding and transport of red deer (*Cervus elaphus*) leads to changes in plasma cortisol, glucose, lactate, packed cell volume (PCV), haemoglobin, red blood cell count, creatine kinase (CK), lactate dehydrogenase (LDH), aspartate aminotranferase (AST), calcium, sodium and plasma osmolarity (Carragher, Ingram & Matthews, 1997). In similar experiments done by Pollard *et al.* (2002) it was found that some of the carcasses showed an elevated ultimate pH (pH_u), which would indicate stress prior to slaughter. The tenderness and the colour of the meat are negatively affected in these

cases and a high pH_u is likely to have additional undesirable affects (Pollard, Stevenson-Barry & Littlejohn, 1999).

According to Shaw & Thume (1992) plasma cortisol levels are considered to be reliable indicators of pre-slaughter stress in livestock. Pollard *et al.* (2002) found that plasma cortisol levels with paddocked deer were consistent with an unstressed state, while those animals that had been slaughtered at the commercial plant showed levels that indicated moderate stress. Elevated blood lactate levels result from a breakdown of muscle glycogen and this, in turn, is a result of muscle exertion and from catecholamine release that leads to rapid glycogenesis. Immonen, Ruusunen & Puolanne (2000) found that animals that had a higher muscle glycogen level post mortem, also had lower shear force values. Lundström, Andersson & Hansson (1996) reported similar results for pork.

1.5.1.6 pH

It is known that the post mortem pH of meat is determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis. Post mortem muscle that undergoes rapid anaerobic glycolysis usually reaches its ultimate pH while the temperatures are still high (≈ 20 °C) and might sometimes even show an increase in the apparent muscle pH as it cools (Bruce *et al.*, 2001). According to Hertzmann, Olsson & Tornberg (1993), low pH values at high muscle temperatures increase shear force values. A fast rate of pH decline or a low ultimate pH tends to denature muscle proteins, thus lowering their water binding capacity. Offer (1991) showed that the denaturation of myosin is likely to be the main cause of exudation in PSE muscle and that the severity of the denaturation increases with both the rate and extent of post mortem pH fall.

The rate of pH decline in post mortem muscle influences the tenderness of the meat, particularly when the muscle is susceptible to cold shortening (Currie & Wolfe, 1979; O'Halloran, Troy & Buckley, 1997). O'Halloran *et al.* (1997) showed that a slow pH decline increases the shear force values of meat. Work published by Marsh, Ringkob, Russel, Swartz & Pagel (1987) showed that a moderate rate of pH decline, produced tender meat.

The ultimate pH influences not only the tenderness of meat, but is an important determinant of microbial growth. It has been shown that a higher ultimate pH can lead to microbial spoilage and thus shortened shelf life. Muscle with a high ultimate

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pH, because of a deficiency of glycogen at death, has a lack of available carbohydrate substrate, and so the micro-organisms attack amino acids immediately, causing early spoilage, off-odours and discolouration (Newton & Gill, 1978).

1.5.1.7 Temperature

The initial cooling of the carcass is very important when the temperature is reduced from 37 °C to that of the temperature in a chiller. During the first 24 hours after slaughter, the holding of carcasses at high temperature (≈ 30° C) post rigor can produce up to 85% of the ageing. At colder temperatures proteolytic enzyme activity in the muscle is inhibited. Indeed if the temperature of a carcass falls to below 10 °C while the post mortem pH is still above 6.0, cold shortening is likely to occur causing decreased tenderness. It is therefore important to ensure that the chilling process does not occur too rapidly.

The rate of post mortem glycolysis reaches a minimum at about 17 °C. At lower temperatures, Ca ions are released from the sarcotubular system causing muscle contraction. This is the phenomenon known as cold shortening (Dransfield, 1994). The ability of meat to cold shorten remains until the pH falls below the 6.0 threshold. During this time the contraction is reversible, however when rigor sets in it becomes irreversible. The positioning or hanging of the carcass affects the degree of shortening. The physical stretching of the muscles by the hanging carcass will obviously inhibit excessive shortening. Leading on from this concept of shortening, the deboning of a hot carcass will increase the likelihood of shortening. Research has shown that the effects of ageing (pertaining to the meat and not chronological animal age) decrease with increased muscle shortening (Davey, Kuttel & Gilbert, 1967). Maximum toughness is reached when muscles are shortened by 40% (Marsh & Leet, 1966). At this point, Dransfield (1994) reported that ageing has no effect on tenderness. It can be concluded that ageing does not take place following severe cold shortening and therefore, no matter how long the carcasses are stored, the meat will remain tough. Dransfield (1994) states that the lack of effect of ageing in such an instance is the result of structural changes that occur, preventing enzyme proteolysis from producing tenderisation.

The higher the temperature of the meat, the greater the potential for microbial growth and spoilage (Lawrie, 1998). Bendall & Lawrie (1964) reported that a high ambient

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temperature or struggling prior to slaughter will delay the carcass cooling and can lead to the PSE condition.

1.5.1.8 Storage

Meat tenderness improves with post mortem storage (Dransfield, Jones & MacFie, 1981). This method has been in use to improve the texture of meat for generations. It is a phenomenon that is very well known and was described more than a century ago. Subsequently, scientists have conducted a great deal of research to determine exactly what the mechanisms are that are responsible for this improvement in meat tenderness. This research has shown that the changes that occur in meat post mortem to cause the improved tenderness are small, but significant.

Ageing of meat for as long as three weeks in a chiller can result in significant improvements in meat tenderness, but the costs involved and the risk of spoilage make such long maturation periods impractical in a commercial operation (Dransfield, 1994). Meat ageing is a variable process by virtue of the fact that there are a number of physical and biological factors that come into play during the process. These factors include age and sex of the animal, muscle type, conditions at slaughter, temperature and duration of storage, to name only a few (Ouali, 1990).

Most meat responds well to post mortem storage, as far as tenderisation is concerned, but the extent of tenderisation varies such that some meat may not benefit from extended storage. This variation can be minimised by increasing the length of post mortem storage. Meat that is vacuum packed for storage undergoes tenderisation at the same rate as dry aged meat, which is an indication that the process occurs independently of oxygen. During the conditioning of meat, changes can be observed in the sarcoplasmic proteins, actomyosin (Penny, 1968; Goll, 1970) and connective tissue (Kruggel & Field, 1971).

1.5.1.9 Electrical Stimulation

This is a process that has had success in some commercial abattoirs for some time and has become a consideration for some game farmers. Chrystall & Devine (1983) and Drew, Crosbie, Forss, Manley & Pearce (1988) showed that there was an increase in the rate of pH decline in the *longissimus dorsi* of red deer (*Cervus elaphus*) following electrical stimulation (ES). Deer carcasses show accelerated tenderisation following ES and according to Chrystall & Devine (1983), ES is now standard practice in New Zealand deer abattoirs.

Wiklund, Stevenson-Barry, Duncan & Littlejohn (2001) demonstrated that shear force values were lower during the first three weeks of ageing in electrically stimulated deer. However, ES of deer resulted in a significant loss of display life.

Electrical stimulation of slaughtered game animals has great potential in terms of the short term improved meat quality, but it is a difficult procedure to administer under normal field cropping conditions, and further research is needed in this area.

1.5.2   Parameters that define chemical and physical meat quality

1.5.2.1 Colour

Colour of meat is probably the most important factor that consumers take into consideration when they buy meat. Meat that is too dark or too pale is discriminated against in favour of normally coloured meat (Issanchou, 1996). The colour of fresh meat is closely linked to the pH of the meat. At a high ultimate pH, the light transmittance through the muscle fibres is high and the light diffusion is small, so this makes the meat colour appear darker (Swatland, 1990). The level of marbling fat that is present, also influences the colour of fresh meat.

High final pH of meat is usually associated with two things: Dark colour and increased rate of bacterial spoilage. Game meat that has a high ultimate pH and which can be distinguished from other game meat by it's darker colour, will be rejected by consumers. Colour is a critically important visual characteristic of meat because it gives the consumer an all-important first impression when a cut is viewed (Clydesdale, 1991; Gašperlin, Žlender & Abram, 2000). The colour of fresh red meat is determined to a large extent by the relative proportions and distribution of oxymyoglobin and metmyoglobin (Seideman, Cross, Smith & Durland, 1984). The amount of myoglobin contained in the muscle is influenced by the level of physical activity of the animal (Vestergaard, Oksbjerg & Henckel, 2000; Diaz *et al.,* 2002). According to Wiklund *et al.* (2001) colour stability is defined by the rate of metmyoglobin accumulation in the surface layer of meat.

When myoglobin, oxymyoglobin and metmyoglobin are heated in muscle with normal pH (5.3 – 5.7), they produce globin ferrihemochrome, the grey-brownish pigment of cooked meat (Mendenhall, 1989). Trout (1989) states that the appearance of the grey-brownish pigment depends on the internal temperature of the cooked meat.

When cooked to the same temperature, high pH meat (pH > 6.0) will appear more red than low pH meat (Gašperlin *et al.*, 2000).

1.5.2.2 Tenderness

Inconsistency in meat tenderness at the consumer level has been identified as one of the major problems facing the meat industry today (Koohmaraie, 1994). This is in spite of a vast amount of research that has been conducted on all aspects of meat quality. The problem facing the game meat industry is much greater because of the fact that the industry is still relatively new compared to the beef and pork industry and there has not been a great deal of research done specifically for game meat.

At the US Meat Animal Research Centre, Koohmaraie (1994) and his co-workers found that the focus of meat research should fall on meat tenderness because consumers consider tenderness to be the most important component of meat quality. As a result of this consumer perception, people are willing to pay premium prices for tender meat. Inadequate or inconsistent tenderness is the most common cause of consumer dissatisfaction in the beef industry and the same would apply to the game meat industry. A meat product that is not only tender, but also consistently tender, will be a product of higher value.

Meat tends to be tender directly after slaughter because the muscle has not yet had an opportunity to undergo the changes associated with rigor mortis. When rigor mortis does set in, it results in a shortening of the sarcomeres in the muscle. This shortening is one of the main factors responsible for the toughness in meat, which develops with rigor mortis during the first 12 to 24 hours after death. Rigor is an extremely important process that has a profound influence on the tenderisation and maturation of meat. Variations in rigor can alter the structure of the muscle, the release of calcium ions and the activity of calpains significantly (Dransfield, 1994).

While the rigor mortis sets in, the opposite effect, tenderisation, also takes place in muscle. The post mortem tenderisation process takes place as a result of the degradation of key structural proteins. The process is known as post mortem proteolysis and is set in motion by endogenous enzymes that are released from ribosomes upon the "death" of the cell itself. The proteins that degrade as a result of the proteolytic action of these enzymes are involved in inter- and intra- myofibrillar linkages. Koohmaraie (1994) states that it is this degradation that is responsible for post mortem tenderisation. Variation that occurs between animal species and

individuals of the same species in terms of post mortem proteolysis of the myofibrillar proteins, is a major source of variation and inconsistency of meat tenderness.

Data available to date suggests that of all the proteolytic systems endogenous to skeletal muscle, the only enzyme system involved in meat tenderisation is the calpain proteolytic system (Koohmaraie, 1994). Tenderisation appears to be regulated to a large extent by this proteinase system (Pringle, Harrelson, West, Williams, Johnson, 1998). This system has three components: a low calcium-requiring enzyme (u-calpain) a high calcium requiring enzyme (m-calpain) and an inhibitor (calpastatin). Calpastatin specifically inhibits the activity of the calpains. The calpain system is absolutely dependent on calcium for its activity (Koohmaraie, 1990).

Research on the relationship of the calpain proteinase system and tenderness has shown that u-calpain is primarily responsible for the breakdown of the structural proteins of the muscle, resulting in increased tenderness during post mortem storage of carcasses at lower temperatures (Pringle *et al.*, 1998). Conversely, m-calpain activity does not change appreciably over time post mortem. This is indicative that insufficient calcium is present in post mortem muscle to activate this enzyme. This would suggest that a significant tenderising potential remains in the muscle in the form of non-activated m-calpain. Attempts have been made to utilise the tenderising potential of m-calpain through the addition of calcium to post mortem muscle. This process has been successful in shortening the time necessary for ageing to occur in beef (Koohmaraie, 1990). This post mortem process could be used effectively in improving the tenderness of game meat by the injection of a calcium solution directly into the meat.

1.5.2.3 Collagen content

Inconsistencies in the meat tenderness of game abound and the reasons for it are multifaceted (Koohmaraie, 1990; Dransfield, 1994). It is very important to determine the biological factors that influence and regulate meat tenderness. It is generally agreed that connective tissue in meat is an extremely important variable. Both the amount and solubility of the connective tissue in meat have an influence on meat tenderness. The exact interaction between these two factors is still a matter of some debate but recent research has shown that collagen plays an important roll in the toughening of meat during cooking (Ngapo, Berge, Culioli, Dransfield, De Smet & Claeys, 2002). Wilson, Bray & Philips (1954) found that the collagen content of the *longissimus dorsi* muscle of veal was greater than that of steers or cows. Later work

by Dransfield (1977) demonstrated that muscles in the same animal with relatively high collagen contents, were tougher than those with lesser amounts of collagen. Horgan, Jones, King, Kurth & Kuypers (1991) showed with their study of goat muscle that the major determinant of collagen toughness in meat appeared to be the quantity, and not the quality of the collagen.

High collagen contents in meat have been shown to possess higher crosslink concentrations per unit of collagen than muscles with lower collagen content (Light, Champion, Voyle & Bailey, 1985; Shimokomaki *et al.*, 1972). In age related toughening of meat it has been stated that it is the quality of collagen that is responsible for progressive toughening of the meat as the animals get older (Bailey, 1990). Hill (1966) found that during cooking, less collagen was solubilised in meat from older animals than in meat from younger animals and that this resulted in an increased sensation of toughness when meat from older animals was consumed. This progressive toughening that occurs in the meat from animals of increasing age has been linked to the progressive maturation of muscle collagen (Bailey, 1990; Shimokomaki *et al.*, 1972). As the age of the animal increases, intermediate thermally labile crosslinks are converted into thermally stable, mature crosslinks (Ngapo *et al.*, 2002). The degree of solubility of collagen and the total amount of collagen present in meat should be examined when biochemical explanations for the toughness of meat are considered.

1.5.2.4 Proximate composition

The composition of meat in terms of its levels of moisture, fat and protein are important determinants not only in it's nutritional value, but also go a long way in defining certain physical characteristics of the meat, such as toughness and juiciness. The mean proximate composition of the 9-10-11-rib cut of the impala has been reported in a study by Hoffman (2000b). It was found (for pooled samples) that the moisture (724.0 ± 14.00 g/kg), protein (238.3 ± 7.46 g/kg) and ash (21.2 ± 3.74 g/kg) did not differ significantly between the sexes. However this study did not take into account the age of the animal. The lipid content however was found to be higher in the females (33.9 ± 1.70 g/kg) than in the males (24.5 ± 3.171 g/kg) (P<0.05). Hoffman (2000b) ascribed this difference to the heightened activity of the male animals during the rut and this conclusion is supported by the work of Dunham & Murray (1982) and Van Rooyen (1994).

Von la Chevallerie & Van Zyl (1971) showed that the fat percentage of the buttock of the springbok (*Antidorcus marsupialis*) increased from 0% just after birth to around 3% in the adult animal indicating that age plays an important role in the amount of fat present on a carcass. In the study done by Dunham & Murray (1982), it was found that the deposition and mobilisation of fat reserves in the impala are closely related to the reproductive cycle. This association has also been noted in other ungulates (Sinclair & Duncan, 1972). Caughley (1971) suggested that seasonal fluctuations in fat reserves could be as a result of hormonal rather than environmental influences. The relatively higher ratio of metabolically active tissue to fatty tissue in game meat is probably responsible for the variation between red meat and game meat in terms of protein, sodium and moisture contents (Aidoo & Haworth, 1995). The low level of marbling fat in game meat increases the cell density that may also affect the levels of water, protein and sodium.

1.5.2.5 Fatty acid, mineral, and amino acid composition

No published data on the fatty acid profile of impala could be sourced and it is this type of information that is of tremendous importance to meat scientists and nutritionists alike. Healthy eating is a major driving factor in the buying strategy of the modern meat consumer. The fatty acid profile of meat, along with ratios of saturated-to mono- and poly-unsaturated fatty acids is vital to the success of promoting impala meat.

Baseline data on the amino acid and mineral content of impala meat has not yet been published. It is of considerable importance because this data will not only be of value to animal physiologists, nutritionists and meat scientists, but also to human dieticians. It is of importance in both the formal dietary sector as well as the informal sector where this species is regularly consumed as bush meat (Bourgarel *et al.,* 2002).

Information regarding amino acid composition is of importance in determining the nutritional value of impala meat. The nutrient value of meat lies in it's ability to satisfy amino acid (and essential amino acid) requirements of humans (Casey, 1993). Amino acid profiles do not vary much between species (Sales, 1995). Mineral values are of importance to animal nutritionists because these will allow any possible deficiencies that may affect the animals' meat production to be pinpointed and then corrected with the formulation of supplementary licks. Such supplementary licks could be formulated in such a manner that they are compliant with organic standards.

1.5.2.6 Muscle characteristics

The muscle fibre is the essential structural unit of all muscle. The diameter of the muscle fibres of healthy animals differ between muscles because of inherent differences between species and sexes (Joubert, 1956). According to Essen-Gustavsson & Rehbinder (1985), the metabolic characteristics of the different fibre types show that type I fibres have a high oxidative, but low glycolytic capacity. Type IIa and type IIx both have high glycolytic capacities and show large variations in oxidative capacities (Reichmann & Pette, 1982). There is evidence that the relative susceptibility of animals to develop the DFD condition is positively correlated with the number of slow, oxidative fibres in their muscles (types I and IIa) (Zerouala & Stickland, 1991).

The size of the muscle fibres determines the texture of the muscle (Lawrie, 1998). In muscles that are capable of finely adjusted movement like those in the eye, the texture is usually fine. In muscles that specialise in larger and less controlled movement, the texture is coarse. The age of the animal plays a role in determining the size of the fibres as well as the amount of systematic exercise. Older animals have thicker muscle fibres than younger animals. It should be noted that the amount of connective tissue varies between muscles and that this could also partly account for the relative toughness of meat from different muscles (Lawrie, 1998).

1.6   Conclusion and Objectives

The growth of the game farming industry in South Africa has proved the importance of indigenous game species in commercial agriculture. It can be seen from the literature that many aspects of game production and farming are poorly documented or wholly unknown for impala. Taking into consideration the rapid growth of the game industry in South Africa and other parts of Africa, it has become imperative that specific aspects pertaining to impala production and farming be documented and quantified, as has taken place in the past with other commercially important domestic species. The objective of this study is to quantify aspects of impala meat quality and to determine the effects of some of the intrinsic and extrinsic factors on impala meat production.

In Chapter 2, the effects of the cropping method on the meat quality of impala were investigated. Specifically, nighttime (or spotlight cropping) was compared to daytime

cropping and the effects on pH parameters, colour and tenderness of the meat were documented.

Chapter 3 focused on the physicochemical carcass composition of the impala. The proportional carcass representation, carcass dimensions and carcass proximate chemical composition of two regions were documented and compared to detect differences in these parameters as a result of age, sex and region.

In Chapter 4 the mineral, amino acid, collagen, myoglobin and fatty acid contents of impala meat were documented in order to provide better insight into aspects of their nutritional value as meat producing animals. The effects of age, sex and region were also determined for these parameters.

The Myosin Heavy Chain isoform composition of four of the commercially important muscles of the impala was documented in Chapter 5. Metabolic enzyme activity of these four muscles was also investigated in order to provide some insight into the enzyme activities and fibre type composition of impala muscle and the possible effects they may have on the meat quality.

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CHAPTER 2

A COMPARISON BETWEEN THE EFFECTS OF TWO CROPPING METHODS ON IMPALA (*AEPYCEROS MELAMPUS*) MEAT QUALITY.

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Abstract

Quantitatively, impala (*Aepyceros melampus*) is one of the most commercially important species in game farming in South Africa. The purpose of this study was to compare the effects of day and night cropping on the meat quality characteristics of impala. Special emphasis was placed on the influence of the cropping method on the muscle pH_{45}, pH_u (ultimate pH), pH decline, and the related influence on drip loss, cooking loss, toughness and colour of the meat in the *M. longissimus dorsi*. All animals were either shot in the head or the neck. Measurements taken from 16 animals harvested at night were compared to the measurements taken from 24 animals cropped in daytime. A mean pH_{45} of 6.67 ± 0.111 was recorded for the night cropped animals compared to a mean pH_{45} of 6.55 ± 0.236 for the day cropped animals ($P<0.05$). A mean pH_u of 5.39 ± 0.081 was recorded for animals cropped at night and this compared to a mean pH_u of 5.45 ± 0.108 for the animals cropped in the day ($P<0.05$). Non-linear regression analysis showed that the rate of pH decline of the night cropped animals was significantly slower than that of the day cropped animals ($P<0.05$). This difference persisted when the pH values were adjusted to correct for the ambient temperature ($P<0.05$). The cooling rate of the *M. longissimus dorsi* was also found to be twice as fast in the night cropped group ($P<0.05$). The mean shear force value and drip loss, respectively, for the night cropped animals were $19.11 \pm 5.675g/mm^2$ and $2.93 \pm 1.597\%$, whereas for the day cropped animals the values were $23.42 \pm 8.128g/mm^2$ ($P<0.05$) and $4.15 \pm 2.339\%$ ($P < 0.04$). No significant colour differences (Chroma, hue, L*, a*, and b* values) were noted between the groups. The results of this study indicate that nighttime cropping as opposed to daytime cropping does indeed have a beneficial effect on certain meat quality parameters and can therefore yield improved meat quality.

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Introduction

Game ranching is recognised by the South African agriculture and conservation authorities as a *bona fide* form of agricultural land use (Eloff, 2002). To date, there are more than 9000 fenced commercial game farms in the country. A further 15000 farms have game on them that are economically utilised in some form or another (Van Zyl, 2000). The game industry increased by an average of 5.6% between 1993 and 2000 in terms of the size of exempted game ranches (Eloff, 2002) and excluding Provincial and National Parks, these game farms comprise 12.5% of South Africa's agricultural land. Van Der Waal & Dekker (2000) calculated that the game ranches in the Northern Province alone covered a total surface area of 3.6million ha in August of 1998, which represents 26% of the total area of the province. According to these authors, this is part of the generally recognized trend away from conventional livestock production to game production. The reasons for this, when compared to a traditional domestic stock farming operation, are that there is a perceived greater financial return from a game farming operation, it is aesthetically pleasing and ostensibly more environmentally friendly.

The potential of wild ungulates for meat production is something that has been realized for some time now (Ledger, 1963; Ledger, Sachs & Smith, 1967; Skinner, 1984). The impala's wide distribution in southern Africa and its relative abundance make it well suited to continuous cropping for game meat production (Bourgarel, des Clers, Roques-Rogery, Matabilila, & Banda, 2002). In South Africa, the impala is the single most important species in the Lowveld and Bushveld areas in terms of its population numbers (Hoffman, 2000a). A recent study by Eloff (2002) showed that impala are the most popular game species at game auctions, making up almost a third of the total animals sold. This is the case because of their relative abundance when compared to other species and the fact that new game farmers who wish to establish game populations on their farms are able to buy them without stretching their financial resources. They tend to be seen as the "bread and butter" of a game farming operation because of their rapid population growth rates (Fairall, 1985) and so they are easily traded. The smaller and newer game farms do not usually have resident predator populations because of restrictive farm sizes and certain financial

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implications. Without this natural form of population control it soon becomes necessary to crop animals in order to prevent overgrazing and destructive interspecies competition. In the light of this growing industry the development of efficient cropping methods for game has become an aspect that requires urgent attention.

Culling methodologies such as the two used in this study are generally accepted practice in South Africa. This is because of the fact that game farming for meat production has not yet reached the same level of sophistication as it has in other parts of the world, like New Zealand and Europe. There, deer farming has become a finely honed industry where partially tame animals are kept in paddocks and slaughtered in commercial abattoirs (Aidoo & Haworth, 1995; Bradshaw & Bateson, 2000; Pollard *et al.*, 2002; Stevenson, Seman & Littlejohn, 1992; Wiklund, Stevenson-Barry, Duncan & Littlejohn, 2001). In South Africa, because of the variability of size and area of the farming terrain, and the long distances between production centres and markets, it is necessary to implement other practical methods to crop game.

Studies on the effects of night shooting on southern African game meat quality have been conducted in the past by Hoffman (2000b) and Hoffman & Ferreira (2000). There has also been some work done on the effects of shooting on the meat quality of wild ungulates by Veary (1991) and Von la Chevallerie & Van Zyl (1971) but apart from that very little data could be found on the subject. This study was conducted to determine the effects of day- and nighttime cropping on the meat quality parameters of impala, since there is no such information available. To our knowledge, this is the first study that makes a qualitative comparison between animals harvested at night and those harvested in the day.

Materials and methods

The cropping of impala herds took place at the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l.) in the Limpopo Province, South Africa. The study area is located 50 km west of Louis Trichard, just south of the Soutpansberg mountain range. The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988) and is 11 000 ha in extent. The vegetation found there inlcudes the woody species *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and *Grewia* spp. The grass species found include *Eragrostis rigidior, Panicum maximum,*

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Urochloa mosambicensis and *Digitaria eriantha.* The mean annual rainfall is 452mm, of which approximately 80% occurs from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January (Dekker, Kirkman & Du Plessis, 2001). The type of work done there is primarily concerned with research on extensive cattle production. Impala occur naturally in the area and as they are in competition with the cattle for grazing, they are subject to yearly population reductions.

For this study, two cropping methods were used namely nighttime (or spotlight cropping) and daytime. During the nighttime (spotlight cropping) operation sixteen animals of random age and sex were harvested. Two marksmen (armed with .30 calibre high velocity rifles) and an observer (operating a 1 million-candela spotlight) went out on moonless evenings in a pick-up truck (Lewis, Pinchin, & Kestin, 1997). Animals were sighted either directly or by the reflection of light from their retinas. Targeted animals were shot high in the neck so that the bullet destroyed all arterial blood supply to the head as well as the spinal connection to the body. This rendered instantaneous insensibility and resulted in almost no wastage of meat (Von La Chevallerie & Van Zyl, 1971). Ambient temperatures varied between 2-11 °C.

Daytime: 24 animals of random age and sex were harvested. During the daytime cropping, the animals were hunted on foot and high neck shots were once again used. Each marksman went out alone using the same rifle and ammunition (.30 calibre) as used during the nighttime operation. Ambient temperatures varied between 19-27 °C.

Following the shooting, the dead animals were immediately exsanguinated by cutting the throat with a sharp knife. pH (pH_{45}) and temperature ($temp_{45}$) readings were taken in the *M. longissimus dorsi et lumborum* using a calibrated (standard buffers at pH 4.0 and pH 7.0) Crison 506 portable pH meter (Hoffman, 2000b). The animals were then transported to the slaughtering facility where they were skinned, eviscerated and the carcasses cleaned according to standard South African and Zimbabwean practices (Hoffman, 2000b). The carcasses were then hung by their Achilles tendons in a cooler set at 4°C. pH profiles were taken from five animals selected randomly from those shot in the day and ten randomly selected animals from those cropped at night. This was done by measuring the pH and temperature of the carcasses every two hours for the first 12h, and then every four hours for the

following 12h post mortem. PH$_u$ readings were taken from all of the carcasses 24 hours post mortem.

Physical analyses

Loin samples for physical analysis were taken from the carcasses 36 hours after cropping. The samples were removed from the *M. longissimus dorsi et lumborum* between the 1st and 4th lumbar vertebrae. Steaks (15mm in thickness and weighing ± 70g) were cut perpendicular to the longitudinal axis of the muscle on the caudal side of the sample. These were used to determine the drip loss and cooking loss according to the methods set out by Honikel (1998). Cooking loss was determined by placing the weighed samples, sealed in polythene bags, into a water bath set at 80°C for 1h. Following this they were cooled under running water to 25°C. They were then removed from the bags, blotted dry with Carlton® paper toweling and weighed. The cooking loss was calculated using the amount of fluid lost during cooking and was expressed as a percentage of the uncooked sample.

For the Warner Bratzler shear force test, five 12.7mm diameter samples were cut randomly from the cooked block of meat. Care was taken to ensure that no visible connective tissue was included in the cut section. The samples were cut perpendicular to the longitudinal axis of the muscle fibre so that the influence of the myofibrillar proteins on the shear force could be measured (Voisey, 1976). An average maximum shear force value was calculated based on the shear force (g/mm^2) required to shear the 12.7-mm diameter cylindrical core of cooked meat perpendicular to the grain, at a crosshead speed of 200mm/min.

For the colour measurement of the meat, freshly cut steaks were allowed to bloom for 20 minutes whereafter the colour was measured three times, at random positions on the steak surface (Stevenson, Seman, Weatherall & Littlejohn, 1989) using a Color-guide 45°/0° colorimeter (BYK-Gardener, USA). The colour was expressed in terms of L*, a* and b* values (Commission International de L' Eclairage, 1976), with L* indicating brightness or reflectance, a* the red-green range and b* the blue-yellow range. The hue angles (h$_{ab}$) and chroma values (C*) were calculated for the samples using the following equations (Commission International de L' Eclairage, 1976):

$$\text{Hue angle:} \qquad H_{ab} = \tan^{-1}(b^*/a^*)$$
$$\text{Chroma value:} \qquad C^* = [(a^*)^2 + (b^*)^2]^{1/2}$$

Statistical analysis

Analyses of variance were performed on all the variables measured within treatments using the software package Statistical Analysis System (SAS, 1989). No significant age or sex differences were found and so the data were pooled for further analysis. Standard t-tests were then conducted with the time of cropping as the main effect. The non-linear regression procedure (Proc NLIN) of SAS (1989) was used to fit exponential decay models to the rate of pH decline and the rate of temperature decline for both the day and night cropped groups. The model used was in the form of:

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

where: y is the dependent variable (pH or temperature) and t is the time (h). The a, b, and c values from the above mentioned regression model were then analysed using the t-test procedure of SAS (1989) to test for differences between the time of cropping.

As a result of the fact that there were differences found in the rate of muscle temperature decrease between the day and night treatments, the pH readings were standardized at 4 °C using the formula of Bruce, Scott, & Thompson (2001):

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

where: pH_t is the actual pH measured at time = t, T_t is the muscle temperature at time = t and $T_{adjusted}$ is the muscle temperature (4 °C) to which the data is being adjusted. The $pH_{adjusted}$ was then re-analysed as explained above using Proc NLIN (SAS, 1989).

Results and discussion

Night cropping is perceived to be one of the most efficient ways of minimising stress on animals during cropping operations (Lewis *et al.*, 1997). It is of prime importance that cropping operations take place as humanely as possible and so it is necessary to utilise a strategy that best suits the individual circumstances on a particular farm. Tinley (1972) and more recently Veary (1991) review the methods used for cropping and the technique that is most often used is to shoot at night from a vehicle using spotlights. The impalas' alert and investigative posture that they adopt when caught in the spotlight makes them particularly well suited to night cropping (Lewis *et al.*,

1997). This is in contrast to an animal like the kudu (*Tragelaphus strepsiceros*) that tends to look away from the spotlight and take flight.

During the entire cropping operation only one loss occurred: that of an animal that was wounded during the night and never recovered from the veld. As a percentage of the total number of animals harvested, this loss makes up less than 2.5%. According to Lewis *et al.* (1997) this is well within the expected losses of ≤ 8% for a cropping operation. All the animals were shot high in the neck and died instantly. There was no wastage of any of the meat owing to the positioning of the shots (Von la Chevallerie & Van Zyl, 1971). Contrary to a study conducted by Hoffman (2000a), statistical analysis of these data did not show any significant sex differences. The sample sizes used for this study were larger than those sampled by Hoffman (2000a) and the age and sex of animals were randomized.

pH

According to Bruce *et al.* (2001), the pH decline of muscle on a carcass deviates from a linear function. This is because when the muscle enters rigor, hydrogen ion production decreases as the rate of anaerobic glycolysis and myosin ATPase activity slow during the muscle cooling. Bendall & Davey (1957) found that post mortem pH decline is also slowed by the buffering effect of ammonium generated by the deamination of adenosine monophosphate (AMP). Therefore, because of this slowing in the rate of pH decline, it is best represented by an exponential decay curve (Bruce *et al.*, 2001).

O'Halloran, Troy & Buckley (1997) noted that the rate of pH decline influences the toughness of meat particularly if the meat is susceptible to shortening. They went on to show that a slow pH decline increases the shear force value. However, work published by Marsh, Ringkob, Russel, Swartz & Pagel (1987) showed that a slow rate of post mortem glycolysis produced tender meat. The results of this study are in agreement with the latter. The animals cropped at night show a slower pH decline than those shot in the day (Table 1, Figure 1), however their shear force values are significantly lower ($P<0.05$) (Table 2). According to the findings of Marsh, Lochner, Takahashi & Kragness (1981) moderate rates of pH decline produce tender loin steaks and they cautioned that rapid pH decline would produce tough meat.
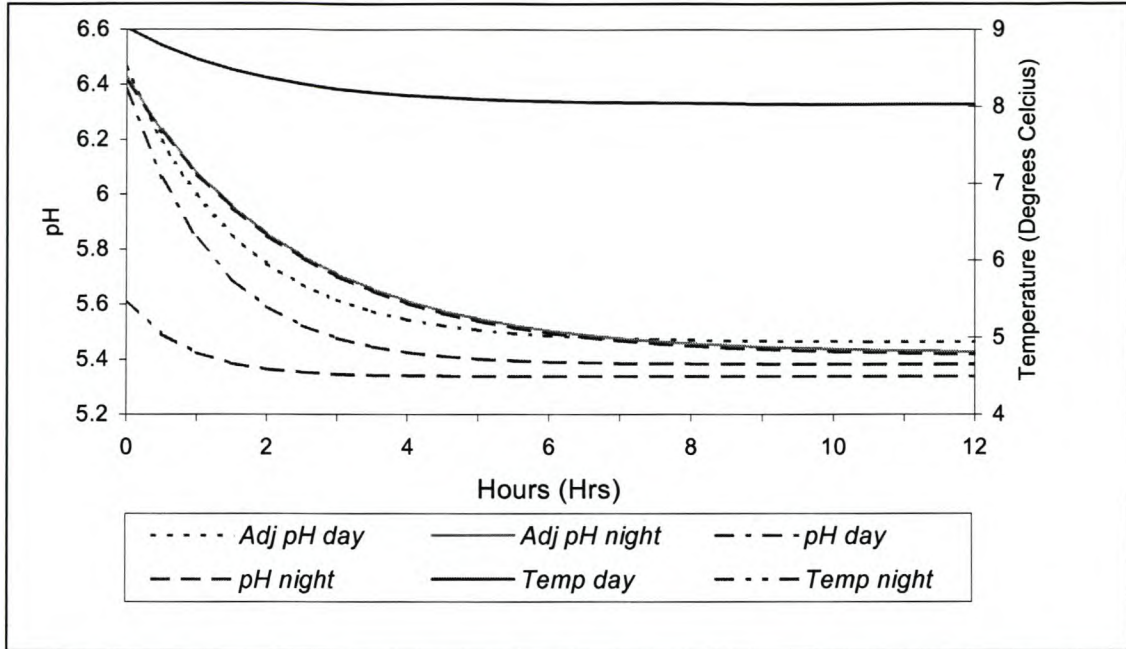
Figure 1: Mean *M. longissimus dorsi et lumborum* temperature and pH profiles for day (n = 5) and night (n = 10) cropped impala at Mara.

Table 1: The calculated constants (LS Mean ± SE) for the exponential equations fitted to the pH decline under normal temperature conditions and under adjusted standard temperature (4 °C) for day (n = 5) and night (n = 10) cropped impala

$y = a + be^{-ct}$ constants	T	Normal pH decline	P < |t|	pH decline adjusted to std temp	P < |t|
a	D	5.38 ± 0.006	< 0.01	5.46 ± 0.006	< 0.01
	N	5.41 ± 0.004		5.42 ± 0.004	
b	D	2.93 ± 0.124	< 0.01	2.90 ± 0.086	< 0.01
	N	2.14 ± 0.083		2.47 ± 0.057	
c	D	-0.72 ± 0.040	< 0.01	-0.58 ± 0.027	< 0.01
	N	-0.53 ± 0.026		-0.45 ± 0.018	

T (Time) = D (Day) or N (Night)

Non-linear regression analysis of the temperature drop for the animals revealed that the temperature drops for both treatments could be represented by an exponential decay model (Day: a = 8.03, b = 31.66, c = -0.15; Night: a = 4.49, b = 45.33, c = -0.31). The temperature drop of the night cropped group fell twice as fast as that of the day cropped group, thus indicating rapid cooling in the night cropped muscles (Figure 1).

Post mortem muscle that undergoes rapid anaerobic glycolysis usually reaches its ultimate pH while the temperatures are still high (≈ 20 °C) and might sometimes even show an increase in the apparent muscle pH as it cools (Bruce, et al., 2001). Owing to the differences between the prevailing day and night ambient temperatures, it was necessary to adjust the temperatures for both treatments to a standard 4 °C. This was done to remove the variation brought about by the effect of ambient temperature on the pH declines.

The pH decline under the prevailing ambient temperatures in the day and night differed significantly, with the day cropped group having a more rapid rate of pH decline. The analysis was repeated after the temperature was adjusted to a standard 4 °C for both treatments (Figure 1, Table 1). This difference persisted with the standardised temperature and is likely as a result of the difference in ante mortem conditions experienced by the animals prior to death between the day and night treatments. It is likely that the difference arose as a result of the heightened stress level of the day cropped animals because of their awareness of the hunters. Another influence could be the heightened level of physical activity during the day, particularly during the rut, which would cause the glycolytic enzyme activity to remain high for a longer period inducing a more rapid pH decline. The relative unawareness of the animals of the croppers (and thus unstressed state) during the night cropping, would result in a lowered glycolytic enzyme activity and a slower rate of pH decline.

The pH_{45} of the animals cropped at night were significantly higher than those shot in the day ($P<0.05$; Table 2). However, the pH_u of the day cropped animals were higher than those of the group harvested at night ($P<0.05$). The fact that the day-cropped pH_{45} (6.55 ± 0.235) were lower than those of the night cropped animals (6.67 ± 0.111) may be attributed to the daytime activities of the animals. The study took place during May and June, and coincided with the two month impala rut, or mating period (Fairall, 1985). This period is characterised by heightened physical activity for both sexes associated with mating behaviour (such as fighting, mounting, oestrus and gestation) and such activity necessitates the mobilisation of a certain amount of muscle glycogen (both aerobically and anaerobically, depending on the intensity of the activity).

Table 2: Mean pH values and physical meat quality parameters (LS Mean ± SE) for the day (n = 24) and night (n = 16) cropped impala at Mara

	Day cropped	Night cropped	P < |t|
Mean pH_{45}	6.55 ± 0.235	6.67 ± 0.111	0.05
Mean pH_u	5.45 ± 0.108	5.39 ± 0.081	0.05
Drip loss (%)	4.15 ± 2.339	2.93 ± 1.597	0.05
Cooking loss (%)	32.87 ± 4.101	32.99 ± 5.109	0.90
Warner Bratzler shear force (g/mm^2)	23.42 ± 8.128	19.11 ± 5.675	0.05

A second aspect that would most certainly constitute a stress factor to the day-cropped animals is their awareness of the hunter. Lacourt & Tarrant (1985) mimicked the effect of this type of stress by administering exogenous doses of adrenaline to young bulls. Among the physiological responses that they reported, they found that there was a decline in the muscle glycogen content of such animals. This is in keeping with similar findings by Pollard et al. (2002) for red deer (Cervus elaphus). Muscle glycogen is the main metabolic substrate that is responsible for the formation of lactic acid, and thus normal post mortem pH decline of muscle (Immonen, Ruusunen & Puolanne, 2000). The depletion of glycogen by one or other chronic form of stress before death will result in less lactic acid being formed and consequently the meat will not acidify properly and the pH_u will remain high (Viljoen, De Kock & Webb, 2002). The relationship between elevated pH_u and physical activity or chronic stress in deer has been observed in several studies (Kay, Sharman, Hamilton, Goodall, Pennie & Coutts, 1981; Macdougall, Shaw, Nute, & Rhodes, 1979; Smith & Dobson, 1990). Knox, Hattingh & Raath (1991) found that the stress and exertion associated with the live capture of impala significantly raised the plasma lactate concentration in the blood and muscles. They attributed this to the heightened muscular activity during the capture, which resulted in anaerobic glycolysis and the subsequent accumulation of lactic acid in the muscle tissue and blood. Hattingh, Pitts & Ganhao (1988) have reported similar findings. Increases in lactic acid levels in the tissue have been reported by Gericke, Hofmeyer & Louw (1978) for springbok (Antidorcas marsupialis), Hofmeyer, Louw & Du Preez (1973) for zebra (Equus burchelli) and Harthoorn (1975) for eland (Taurotragus oryx) and tsessebe (Damaliscus lunatus). Ruminant animals usually have a lower blood glucose level than non-ruminant animals (Schaefer, Jones & Stanley, 1997) and this contributes to a lower muscle glycogen content as well as a slower rate of glycogen repletion.

However, at night glycogen stores are replenished causing the muscle pH_{45} to be slightly higher (McViegh & Tarrant, 1982). It is therefore probable that the pH_u of the night-cropped animals is lower because of the greater amount of muscle glycogen available for post mortem glycolysis. The amount of muscle glycogen available for post mortem glycolysis, together with the temperature regime, also affects the rate of pH decline.

Water binding capacity and tenderness

An important aspect of the meat quality that ties in with the ultimate pH is the water binding capacity of the meat. The point of minimum water binding capacity is the iso-electric point, which is pH 5.4 – 5.5. Post mortem glycolysis will usually bring meat to an ultimate pH of around 5.4 – 5.5, so some moisture loss due to loss of water binding capacity is inevitable. A large proportion of the water present in muscle is found in the myofibrils between the actin and myosin filaments (Lawrie, 1998). Roughly 5% of it is bonded to the hydrophilic groups on these proteins (Hamm, 1966). The higher the ultimate pH, the less water will be released by the tissue. Offer & Knight (1988) showed that drip loss is formed primarily from the extracellular space and that the latter increases with decreasing pH. Guignot, Vignon & Monin (1993) confirmed this in veal muscle. The night-cropped animals had a higher mean pH_u and lower average drip-loss compared to the day-cropped animals (P<0.05; Table 2). Numerous other reports have noted the association between decreased water holding capacity and increased pH_u (Dransfield, Jones & MacFie 1981; Purchas, 1990). The higher pH_u of the day-cropped animals is conducive to lowered water binding capacity and therefore a greater percentage of drip-loss. In a study conducted by Hoffman (2000b), drip loss values of 2.61 ± 1.240% and cooking loss values of 23.98 ± 1.410 % were reported for impala cropped at night in central Zimbabwe. The drip loss reported by this author is very similar to the drip loss for the night cropped group of the present study.

The amount of cooking loss did not differ significantly between the day and night cropped groups (Table 2). The Warner-Bratzler shear force tests showed that the meat from the night cropped group was significantly more tender than that of the day cropped group (P<0.05). Devine, Graafhuis, Muir, & Chrystall (1993) found the same trend towards decreasing tenderness with increasing pH_u in lambs. A higher pH_u can lead to the association of the actin and myosin filaments of the day-cropped animals leading to shortening and decreased tenderness (Ouali, 1990).

Colour

The colour of meat is of critical importance in creating an impression when meat is viewed (Clydesdale, 1991; Gasperlin, Zlender & Abram 2000) and is used as an indicator of flavour, tenderness and freshness (Naumann, Rhodes, Brady & Kiehl, 1957). No significant differences between the two treatments were noted in so far as the colour of the meat was concerned (Table 3). The hue angle (h_{ab}) and chroma (C^*) values were also calculated for the samples using the a* and b* values, but they did not show any significant difference between the groups. Hoffman (2000b) recorded similar colorimetric values of *L = 29.22, *a = 11.26 and *b = 7.76 for impala that were also cropped at night.

It is well known that game meat is darker in colour than other meat. The darker colour of game meat may be ascribed to the elevated levels of myoglobin present in the muscle (Diaz *et al.*, 2002; Kritzinger, Hoffman & Ferreira, 2002; Vestergaard, Oksbjerg & Henckel, 2000). This elevated myoglobin content and thus darker meat colour is possible as a result of the fact that wild ungulates are a lot more active than traditionally farmed domestic animals like cattle and sheep. Studies have shown that there is an increase in myoglobin levels in muscle as a result of systematic exercise (Diaz *et al.*, 2002; Lawrie, 1998; Vestergaard, *et al.*, 2000). However, the darker colour of the meat may also, in part, be as a result of the relatively less intra-muscular fat present (Janicki, Kolaczyk & Kortz, 1963) as impala have been found to have less than domestic livestock (Hoffman, 2000a). When carcasses have a higher (≥ 5.7) pH_u, light transmittance through the fibres is high and the diffusion of that light is small, so meat colour appears darker (Swatland, 1990). It is likely that the darker colour of game meat makes it difficult to measure possible subtle differences in the colour that may have arisen as a result of marginally stressful conditions.

Consumer perception of game meat in South Africa is often unfavourable because of its dark colour (Von la Chevallerie, 1972). This has a negative effect on its popularity because many consumers prefer meat that is neither dark nor pale (Jeremiah, Carpenter & Smith, 1972). DFD (Dark, Firm and Dry) meat is a common occurrence with game meat because of the often highly stressful conditions in which game is harvested. Hoffman (2000b) recorded values of L* = 25.44, a* = 9.13 and b* = 4.88 for a male animal that was wounded and subsequently subjected to severe ante mortem stress for a period of ten minutes. The animal had the darkest meat and the fastest pH decline and was said to have the DFD condition. All of the animals

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cropped for this study looked to be in a calm state directly prior to death and so it is unlikely that any of them experienced the type of circumstances conducive to the DFD condition. Their relatively higher colorimetric values (Table 3) than those reported for the stressed animal by Hoffman (2000a) are evidence of this.

Table 3: Colorimetric values (LS Mean ± SE) for the day (n = 24) and night (n = 16) cropped impala

	Day cropped	Night cropped	P > |t|
L*	30.53 ± 2.758	30.10 ± 1.296	0.50
a*	12.52 ± 1.361	13.19 ± 1.475	0.15
b*	8.75 ± 1.422	9.42 ± 1.780	0.20
C*	15.85 ± 2.159	15.99 ± 1.856	0.80
h_{ab}	0.59 ± 0.084	0.62 ± 0.058	0.20

Conclusions

From the results of this study it is evident that night cropping of impala has a beneficial effect on the meat quality as opposed to day cropping. The slower rate of pH decline of the night cropped group shows that conditions during night cropping are more favourable for meat quality. The results of the pH data, drip loss and shear force analyses clearly show that the method of night cropping yields a better meat quality than the day cropping method. Night cropping does not seem to have any detrimental effects on meat quality and it can be deduced that this is as a result of lower ante mortem stress to the animals.

Night cropping is a more practical method for harvesting game than day cropping. Factors that confound daytime operations such as noise and visibility of the croppers, are largely eliminated with nighttime operations. The animals are more restful at night, which facilitates greater accuracy of shooting and reduces the chances of wounding. The use of the spotlight also allows the croppers to get closer to the herds without unduly alarming them. This further facilitates a higher degree of accuracy.

Owing to the very low nighttime ambient temperatures, it is possible that animals cropped at night could develop cold shortening, however this specific aspect requires further research.

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CHAPTER 3

THE EFFECTS OF SEX AND REGION ON THE CARCASS YIELD AND CHEMICAL COMPOSITION OF IMPALA (*AEPYCEROS MELAMPUS*)

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Abstract

The physical and chemical composition of the impala (*Aepyceros melampus*) and the effects of age, sex and region on those parameters were investigated. Impala were randomly sampled from two regions (Mara and Musina) in the Limpopo Province of South Africa. The live weights of the Mara (50.23 ± 9.32kg) animals were found to be higher (P<0.05) than those of the Musina animals (44.25 ± 10.81kg). The male animals from both regions were found to be significantly heavier than the females (P<0.05); however, the dressing percentages between the sexes did not differ. There was a regional difference in the mean dressing percentages of the Mara and Musina animals, with the Mara group having significantly higher values (P<0.05). The mean proportions of external and internal offal were found to be relatively higher in the Musina animals. The impala were divided into five age groups, 8, 18, 30, 42 and 54 months. No significant differences in the dressing percentages between the age groups could be found. Carcass measurements were found to increase linearly with age. The age of the animals showed no effect on the chemical carcass composition. Female animals were found to have higher lipid contents for both regions (P<0.05) but the sex of the animal had no effect on the remaining chemical carcass composition parameters. The crude protein content of the Musina animals (24.88 ± 1.044%) was higher (P<0.05) than for the Mara animals (23.80 ± 0.840%).

Keywords: Game meat; physical composition; chemical composition; carcass measurements; dressing percentages; age; lipid content

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Introduction

Game farming is a relatively new agricultural industry that has become well established in South Africa. Despite economic recessions and frequent droughts, game farming is growing in popularity and many cattle farms are being game-fenced to accommodate game (Ebedes, 2002). Eloff (2002) reported that the estimated gross income from the game industry in 2000 was R843m. According to Van Der Waal & Dekker (2000) game ranches cover 26 % of the surface area of the Limpopo Province alone. This equates to approximately 3.6m ha which is more than the combined surface area of the National and Provincial parks in the province.

Indigenous animals are well adapted to the vegetation, excessive temperatures and limited water supply in Africa (Cole, 1990). They have lower nutritional requirements and are more resistant to diseases and parasites than domestic animals. In addition, they show higher yields of meat per unit area and they yield greater financial return from both meat and hide production (Hopcraft, 1980). Impala have been the most popular game species sold at game auctions during the last six years (Eloff, 2002). This is due to the relative abundance of the species and its fairly rapid reproductive rate (Fairall, 1984). This makes it an ideal species to use to establish a game population on a farm in a relatively short space of time. Impala are able to utilise the large tree and shrub component of the South African bushveld very effectively because of their browsing habits (Fairall, 1983).

The culling of game is an essential management strategy to curb over population on game farms and prevent environmental damage (Conroy, 2002). The impala's wide distribution in southern Africa and its relative abundance as a species make it well suited to continuous cropping for game meat production (Hoffman, 2000a; Bourgarel, des Clers, Roques-Rogery, Matabilila, & Banda 2002). The meat production potential of indigenous African ungulate species is something that has been recognized for some time (Ledger, 1963; Ledger, Sachs & Smiths, 1967; Fairall, 1984; Hoffman 2000b; Van Zyl & Ferreira, 2002). Berry (1986) showed that game meat production was the most profitable strategy for a game farm (when compared to live sales, trophy hunting and recreational hunting) in terms of return per kilogram of biomass. Meat production is playing an increasingly important role in the financial viability of game farms.

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Von la Chevallerie (1970) noted that carcass weights can give a good indication of the meat production potential of an animal when data on the carcass conformation and composition is available. According to Van Zyl & Ferreira (2002) there is little uniformity in the methods used to describe carcass composition of game in order to enable comparisons with domestic species such as sheep and cattle. The same criteria that apply to the meat production from domestic livestock are also applicable to game meat production (Skinner, 1984). These criteria include the yields, carcass chemical composition and aspects of production that affect the meat quality (Issanchou, 1996). Factors that are thought to influence the nutritional value of meat, such as age, sex and regional locality (Stevenson, Seman & Littlejohn, 1992), have not yet been intensively investigated for southern African ungulates (Hoffman, 2002).

The purpose of this study was to compare the physical and chemical carcass compositions of impala from two different regions and to determine the possible effects that age and sex may have on those compositions. A further purpose of this study was to establish a set of baseline data for impala as pertaining to the factors.

Materials and Methods

Impala were sampled from the Mara Research Station (Mara), and from the Musina Experimental Farm (Musina) in the Limpopo Province, South Africa. Mara is located 50 km west of Louis Trichardt, just south of the Soutpansberg mountain range (23° 05' S and 29° 25' E; 961 m.a.s.l.). The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988) and is 11 000 ha in extent. The vegetation found there includes the woody species *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and *Grewia* spp., while the grass species found include *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha.* The mean annual rainfall is 452mm, of which approximately 80% occurs from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January (Dekker, Kirkman & Du Plessis, 2001). The type of research conducted at Mara is primarily concerned with extensive cattle production. Impala occur naturally in the area and as they are in competition with the cattle for grazing, they are subject to yearly population reductions.

The Musina experimental farm is situated approximately 15km west of Musina and is bordered by the Limpopo river to the north (between 22° 12' and 22° 18' S and 29° 50' and 29° 57' E; 460 to 639 m.a.s.l). According to Acocks (1988) the farm is located within the northern block of the Mopani veld, where the mopani, *Colophospermum mopani* is the dominant tree species. The study took place in the 4 605 ha game fenced section of the farm. The mean annual rainfall is 366mm of which approximately 75% occurs from November to March. The mean maximum daily temperature varies from 25 °C in July to 34 °C in January (Dekker & van Wyk, 2002). Research conducted on this farm focuses on aspects of mixed cattle and game farming. Commercial hunting is also conducted on the farm during the hunting season.

At Mara, 40 impala comprised of 16 females and 24 males, were randomly cropped using .30 calibre rifles in a procedure similar to that described by Lewis, Pinchin & Kestin (1997). The animals were cropped during an organised game culling operation. The 28 impala from Musina, comprising 13 females and 15 males, were animals that were commercially hunted during the day by South African and European hunters. All the animals were bled in the veld after which they were transported to the processing facility.

The animals were exsanguinated with knifes directly following death and the initial weights of the dead animals were recorded afterwards. The carcasses were then slaughtered according to standard South African and Zimbabwean practices (Hoffman, 2000a). Weights of the body components were measured according to a method similar to the one described by Van Zyl & Ferreira (2002). The gastro-intestinal tract (GIT) was washed and weighed in order to obtain its empty weight. The whole empty body weight (including head, hooves, skin and viscera) of the animal was determined by subtracting the weight of the stomach contents from the initial weight of the live animal.

It is generally known that impala tend to be seasonal breeders with a restricted mating season in autumn (July to August) and a lambing season from November to December (Fairall, 1985; Skinner & Smithers, 1990). The ages of the animals were determined by examination of the tooth eruption and wear (Spinage, 1971) and then estimating the year of birth based on their seasonal breeding habits. In the case of the males, the length and shape of the horns were used as an additional means of pinpointing the age. The

animals from both regions are distributed between five age groups that range from eight months to 54+ months.

Physical measurements of the carcasses were taken after slaughter using a steel slide-rule and carcass circumferences were measured 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. Depth of the carcass was measured from the spine to the sternum just posterior to the forelegs. Breadth of the carcass was measured between the widest points of the rib cage just posterior to the forelegs. The neck circumference was measured at the base of the neck. The chest circumference was measured around the chest just posterior to the forelegs. Buttock circumference was measured at three places: A, at the top of the leg at the juncture with the abdomen; B, around the thigh just anterior to the knee; C, around the heel of the leg just anterior to the ankle. Two leg length measurements were taken, A, from the top of the inner thigh to the patella and B, from the same point at the top of the inner thigh to the hock.

After cooling ($\approx$ 36 hours to achieve 4°C) a sample of the *M. longissimus dorsi et lumborum* was cut from the carcass between the 1st and 4th lumbar vertebrae of each animal. Sub-cutaneous fat was trimmed from the samples and they were then minced three times through a 2mm sieve in order to ensure homogeneity. Samples were then analysed for moisture, crude protein, and ash, according to the AOAC (1997) method. The lipid content was determined by the solvent extraction method similar to that described by Lee, Travino & Chaiyawat (1996).

Analyses of variance were performed on all the variables measured using the General Linear Model (GLM) procedure of SAS (1989). The difference between the sexes and regions were, where appropriate, tested by means of the null hypothesis (H_0), with $H_0:\mu=\mu_0$ and the alternative hypothesis (H_a) being $H_a:\mu\neq\mu_0$. Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for sex and region. Where necessary, empty body weight of the animal was used as a co-variant to cater for the affects of age on certain parameters.

Results and discussion

Animals cropped at Mara were all felled with high neck or head shots and the particular cropping method employed worked very well. The number of missed shots (± 14%) during the operation was similar to the numbers reported by Lewis *et al.* (1997) and is within expected cropping limits. The animals from Musina were hunted by various commercial hunters, and were all shot in the chest behind the shoulder. While little or no meat damage (< 3.5%) occurred with the Mara animals, it was noticed that substantial amounts of meat were discarded from the Musina animals as a result of the placing of the shot (Von la Chevallerie & Van Zyl, 1971).

Due to the nature of the cropping methodology, there was an unequal age distribution of the sampled animals (Figure 1). Therefore age effects between groups were only tested on groups where there were more than five animals. The general morphological measurements of the impala for Musina and Mara are given in Table 1.
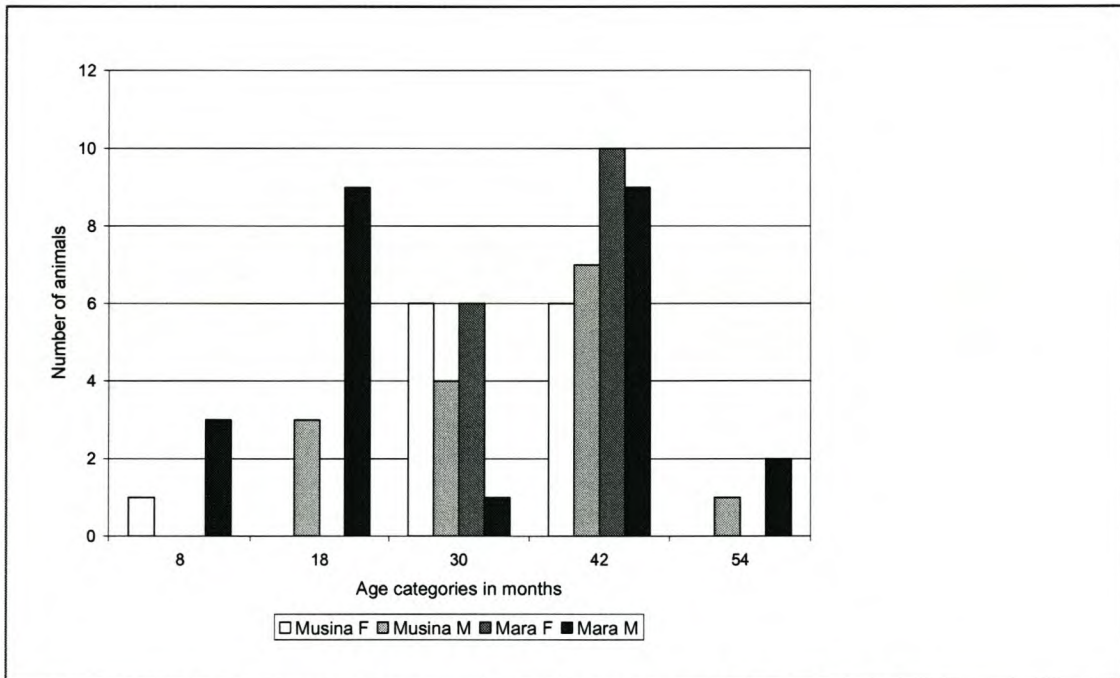
Figure 1: Age group distribution of the male (M) and female (F) animals from Mara and Musina

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Table 1: Carcass measurements (LS Mean ± SE) of the separate age groups of the male (M) and female (F) animals from Mara (Mar) and Musina (Mus)

| Parameter | Area | Sex | Age groups in months | | | | |
			8	18	30	42	54
Initial weight[1] (kg)	Mus	F	26.00 ± 0.00	*	$35.00 \pm 3.52^{a}_{c}$	$42.08 \pm 2.06^{b}_{c}$	*
	Mus	M	*	33.00 ± 3.50	46.38 ± 0.39	$58.28 \pm 3.74_{e}$	58.00 ± 0.00
	Mar	F	*	*	$43.85 \pm 2.69^{a}_{d}$	$46.89 \pm 0.64^{b}_{d}$	*
	Mar	M	33.16 ± 0.35	48.32 ± 5.18^{a}	55.50 ± 0.00	$61.75 \pm 3.13^{b}_{e}$	65.80 ± 7.91
Empty body weight[2] (kg)	Mus	F	20.56 ± 0.00	*	$28.77 \pm 3.21^{a}_{c}$	$35.35 \pm 1.68^{b}_{c}$	*
	Mus	M	*	26.76 ± 3.55	39.69 ± 5.14	$51.58 \pm 4.06_{d}$	49.51 ± 0.00
	Mar	F	*	*	$37.76 \pm 2.33^{a}_{d}$	$40.74 \pm 1.80^{b}_{e}$	*
	Mar	M	29.87 ± 0.88	41.87 ± 4.42^{a}	48.12 ± 0.00	$54.14 \pm 2.58^{b}_{d}$	58.95 ± 8.81
Carcass weight[3] (kg)	Mus	F	15.00 ± 0.00	*	$20.25 \pm 2.04^{a}_{c}$	$24.75 \pm 2.04^{b}_{c}$	*
	Mus	M	*	18.83 ± 2.36	25.62 ± 4.64	$35.21 \pm 3.78_{d}$	32.50 ± 0.00
	Mar	F	*	*	$27.66 \pm 1.54^{a}_{d}$	$29.22 \pm 1.64^{b}_{e}$	*
	Mar	M	21.08 ± 0.81	29.36 ± 3.29^{a}	33.84 ± 0.00	$37.83 \pm 2.32^{b}_{d}$	43.33 ± 7.95
Dressout percentage	Mus	F	57.69 ± 0.00	*	$58.07 \pm 5.32_{c}$	$58.77 \pm 3.29_{c}$	*
	Mus	M	*	56.99 ± 1.19	55.03 ± 2.48	60.28 ± 3.17	56.03 ± 0.00
	Mar	F	*	*	$63.16 \pm 2.62_{d}$	$62.33 \pm 2.83_{d}$	*
	Mar	M	63.51 ± 2.17	60.75 ± 1.40	60.97 ± 0.00	61.27 ± 2.42	65.60 ± 4.19
Carcass length (cm)	Mus	F	76.29 ± 0.00	*	78.39 ± 2.61^{a}	$84.12 \pm 2.13^{b}_{c}$	*
	Mus	M	*	81.81 ± 0.55	83.71 ± 3.58	$89.41 \pm 3.31_{d}$	85.55 ± 0.00
	Mar	F	*	*	80.51 ± 3.40	$82.66 \pm 3.12_{c}$	*
	Mar	M	68.90 ± 2.00	79.50 ± 3.48^{a}	87.88 ± 0.00	$86.29 \pm 1.55^{b}_{d}$	94.99 ± 0.26
Chest breadth (cm)	Mus	F	23.23 ± 0.00	*	25.37 ± 1.14	$26.28 \pm 1.89_{d}$	*
	Mus	M	*	27.14 ± 3.23	24.53 ± 1.63	$26.99 \pm 2.52_{d}$	25.42 ± 0.00
	Mar	F	*	*	24.97 ± 0.60	$25.69 \pm 1.16_{c}$	*
	Mar	M	22.70 ± 0.26	25.84 ± 1.25^{a}	26.12 ± 0.00	$28.53 \pm 1.75^{b}_{d}$	27.60 ± 3.38

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Parameter	Area	Sex	Age groups in months				
			8	18	30	42	54
Chest depth (cm)	Mus	F	29.15 ± 0.00	*	26.92 ± 1.27^a_c	28.91 ± 0.24^b_c	*
	Mus	M	*	29.54 ± 1.48	30.44 ± 2.09	$32.60 \pm 3.35_{de}$	32.99 ± 0.00
	Mar	F	*	*	$31.55 \pm 3.92_d$	$30.46 \pm 1.51_e$	*
	Mar	M	27.03 ± 0.02	30.81 ± 1.02^a	33.13 ± 0.00	33.66 ± 1.86^b_d	35.80 ± 0.60
Back length (cm)	Mus	F	60.61 ± 0.00	*	68.39 ± 2.51	$69.22 \pm 4.43_c$	*
	Mus	M	*	68.36 ± 4.64	67.74 ± 5.67	$71.63 \pm 4.42_d$	69.31 ± 0.00
	Mar	F	*	*	69.16 ± 2.39	$69.43 \pm 2.01_c$	*
	Mar	M	59.06 ± 1.05	67.75 ± 5.03^a	71.41 ± 0.00	73.99 ± 2.98^b_d	76.26 ± 0.91
Chest circumference (cm)	Mus	F	79.20 ± 0.00	*	80.46 ± 1.71^a_c	84.30 ± 1.80^b_c	*
	Mus	M	*	85.16 ± 2.34	86.02 ± 6.81	$94.01 \pm 2.49_d$	91.90 ± 0.00
	Mar	F	*	*	$85.58 \pm 2.91_d$	$85.32 \pm 6.46_c$	*
	Mar	M	75.80 ± 2.87	84.90 ± 2.40^a	88.80 ± 0.00	94.66 ± 2.29^b_d	94.6 ± 1.41
Neck diameter (cm)	Mus	F	33.60 ± 0.00	*	29.67 ± 2.33^a_c	33.91 ± 3.28^b_c	*
	Mus	M	*	37.28 ± 2.15	42.62 ± 9.62	$51.59 \pm 11.59_d$	52.70 ± 0.00
	Mar	F	*	*	$39.88 \pm 1.51_d$	$41.19 \pm 3.15_e$	*
	Mar	M	36.23 ± 3.44	39.17 ± 2.21^a	49.70 ± 0.00	51.81 ± 8.83^b_d	60.95 ± 9.26
Buttock measurements (a)	Mus	F	51.40 ± 0.00	*	52.43 ± 1.65^a_c	56.91 ± 2.34^b_c	*
	Mus	M	*	56.43 ± 1.26	60.32 ± 6.59	$59.47 \pm 2.72_d$	58.10 ± 0.00
	Mar	F	*	*	$59.91 \pm 2.11_d$	$59.14 \pm 1.63_d$	*
	Mar	M	52.36 ± 1.50	57.60 ± 2.45^a	56.50 ± 0.00	60.93 ± 2.83^b	63.6 ± 6.08
(b)	Mus	F	28.80 ± 0.00	*	29.51 ± 1.45	30.90 ± 2.26	*
	Mus	M	*	30.10 ± 2.76	30.35 ± 2.86	32.08 ± 3.18	29.40 ± 0.00
	Mar	F	*	*	30.96 ± 3.94	33.56 ± 3.62	*
	Mar	M	30.83 ± 3.11	32.42 ± 2.47	34.50 ± 0.00	32.74 ± 3.66	33.10 ± 1.98

Parameter	Area	Sex	Age groups in months				
			8	18	30	42	54
(c)	Mus	F	18.7 ± 0.00	*	19.34 ± 1.29	20.39 ± 1.04	*
	Mus	M	*	19.40 ± 1.15	19.15 ± 0.74	21.04 ± 1.32	20.10 ± 0.00
	Mar	F	*	*	19.45 ± 0.88	19.76 ± 0.95	*
	Mar	M	19.93 ± 0.94	19.93 ± 1.16	21.80 ± 0.00	21.05 ± 1.86	22.25 ± 2.33
Leg	Mus	F	25.70 ± 0.00	*	29.27 ± 0.73	31.18 ± 2.45	*
measure-	Mus	M	*	30.90 ± 3.39	25.72 ± 2.25	29.15 ± 1.40	24.45 ± 0.00
ments (a)	Mar	F	*	*	30.70 ± 2.42	29.11 ± 1.35	*
	Mar	M	27.20 ± 1.93	28.73 ± 2.45	29.51 ± 0.00	30.38 ± 2.21	33.75 ± 2.68
(b)	Mus	F	37.30 ± 0.00	*	38.71 ± 1.34	$40.64 \pm 1.15_c$	*
	Mus	M	*	40.33 ± 0.61	40.23 ± 3.56	$41.91 \pm 2.39_{cd}$	36.31 ± 0.00
	Mar	F	*	*	42.26 ± 1.46	$43.31 \pm 2.11_{de}$	*
	Mar	M	39.86 ± 1.26	42.92 ± 1.48^a	44.11 ± 0.00	45.26 ± 1.89^b_e	42.44 ± 0.86

[ab] Means in the same row with different superscripts differ significantly (P < 0.05).

[cd] Means in the same column and parameter with different subscripts differ significantly (P<0.05).

[1] Weight of the animal without blood prior to slaughter.

[2] Weight of the gastro intestinal contents subtracted from the initial weight.

[3] Weight of the dressed carcass with the skin, hooves and head off.

The LS Mean weight of the mature animals (42-54 months) from Mara (males, 62.5kg; females, 48.9kg) was higher (P<0.05) than that of the same age group from Musina (males, 59.3kg; females, 41.9kg). The weights of the Musina animals were similar to those reported by Hoffman (2000b) for animals cropped in central Zimbabwe and by Howells & Hanks (1975) for animals cropped in Hwange National Park (western Zimbabwe). They are higher than the weights reported by Hitchins (1966) for animals in the Kruger National Park and Hlululwe Game Reserve (males, 49.2kg; females, 38.3kg). The weights of the Mara animals were higher than any reported for other areas in previous studies (Hitchins, 1966; Hoffman, 2000b; Howells & Hanks, 1975; Van Zyl & Ferreira, 2002; Von la Chevallerie, 1970). This is likely as a result of the fact that Mara is prime impala habitat situated in the Arid Sweet Bushveld (Acocks, 1988) and the

abundant grazing is of very high quality. As a result of the improved nutriment, more energy is available for growth and development and this is most likely to be the main contributor to the larger size and overall better condition of the Mara animals.

The effect of age on the initial weight (live weight) of the impala is shown in Figure 2. The males from both regions were found to be significantly heavier (P<0.05) than the females in the age groups that could be compared (Table 1). The male and female weights of the Mara animals were heavier (P<0.05) than those of the male and female weights from Musina for the compared age groups respectively. The weights of the 42-month-old females from both regions were significantly (P<0.05) heavier than those of the 30 month-old animals. The weights of the 42 month-old males at Mara were also significantly heavier (P<0.05) than 18 month-old males. Although the other age groups have too few animals to be statistically comparable, the represented weights together with the statistical differences between the compared weight groups point to definite age induced increases in the initial weight, carcass weight and empty body weight.
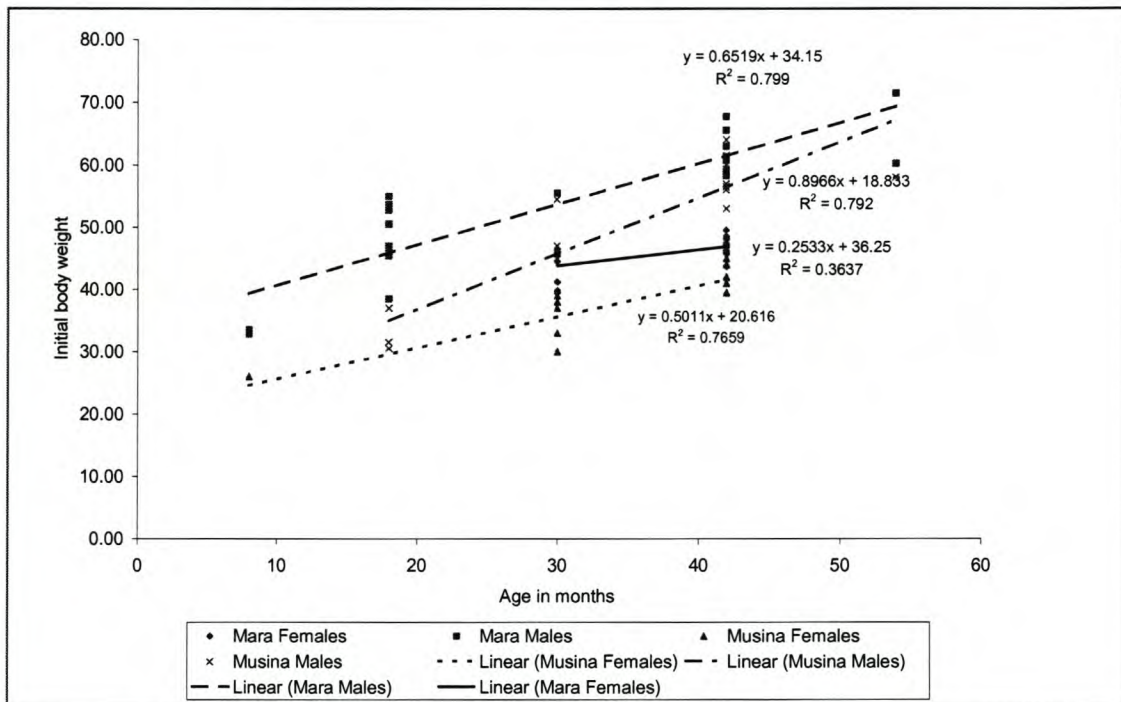
Figure 2: The linear relationships between the age of the male and female animals and the initial (live) body weights from Mara and Musina

When compared to domesticated species such as sheep and goats, impala have higher dressing percentages (Van Zyl & Ferreira, 2002). According to Von la Chevallerie (1970)

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wild ungulates are able to achieve similar or higher dressing percentages without carrying the same proportion of body fat as domestic species. Previous researchers have reported variations in the dressing percentages of game based on whether the expression of the carcass yield is expressed in terms of the inclusion or exclusion of gut fill and blood (Ledger, 1963; Ledger, Sachs & Smith, 1967; Von la Chevallerie, 1970; Skinner, 1984; Van Zyl & Ferreira, 2002). Hoffman (2000b) also noted that domestic animals are usually fasted for 24 hours prior to slaughter and so their dressing percentages reflect results based on less gut fill.

In the present study, initial weight was determined on animals that were bled in the veld but had full gut contents. The animals from both regions were slaughtered according to the same method. The mean carcass weights for the age groups compared differed significantly ($P<0.05$) between males and females. Within the regions they were also found to increase significantly ($P<0.05$) with age. The males from both regions were found to have similar carcass weights whilst the mean 42-month-old female carcass weights differed significantly ($P<0.05$) between the regions (Table 1). The R^2 value for the regression line depicting the Mara female's carcass weights (Figure 2) is low as a result of the fact that those females were only sampled from two age groups. It is likely that if there were better age group representation in the sampling, the R^2 value for that regression line would be improved.

The organ weights from this study are shown in Table 1 to provide a better understanding of the proportional distribution of the body of the impala. Whilst the organs of game animals are usually considered to be of little or no value, they could be of significant economic importance if marketed correctly (Barnett, 2000). They are therefore an important consideration in a base line study such as this. Game carcasses are usually sold with the skin still on to prevent excessive moisture loss. This becomes an important consideration in terms of cost when the skin makes up as much as 15% of the carcass weight.

When the mean dressed weights were expressed as a percentage of initial body weight no significant differences were found between the sexes within the regions ($P>0.05$). This is in accordance with the findings of Hoffman (2000b). It could be expected that the sexual dimorphism of impala would result in differing dressing percentages between

males and females. The fact that the dressing percentages between the sexes within the regions are similar may be attributed to the greater amounts of subcutaneous fat, intramuscular fat and fattier *capsula adiposa's* of the female animals in particular. In addition to this the head of the male animals makes up a larger proportion of the offal than the female heads due to the presence of horns. The mean weights of the viscera are also generally heavier in the male animals, thus compensating for the effects of their thicker necks and heavier forequarters as proportions of the carcass.

An interesting difference was that the dressing percentages of the impala differed significantly (P<0.05) between the two regions for the age groups compared. Mara experienced extremely good rainy seasons for two years prior to this study, which manifested in unusually good grazing for two consecutive seasons. This resulted in the impala at Mara being in extremely good physical condition and when the animals were slaughtered they had an unusually visible layer of subcutaneous fat. This, together with the general tendency of the Mara animals to be physically larger in stature than the Musina animals (Table 1) is the likely cause for the regional difference in the dressing percentages. The 42 month-old males were found to have significantly thicker necks than the females (P<0.05) of the same age, and the thickness increased with age (Table 1). Musina males also showed significantly (P<0.05) larger chest depths than the females. The chests of the males at Mara were wider (P<0.05) than those of the females. The 42 month-old female animals have shorter back lengths (P<0.05) than the males of the same age.

The mean proportional distribution (as a percentage of empty body weight) of body components for the impala from both regions are presented in Table 2. The head, hooves, skin and viscera of the Musina animals were found to be generally higher as a proportion of the empty body weight than those for the Mara animals. These relatively higher proportions thus further explain the dressing percentage differences between the regions.

The proportional representation of the heads of the males was significantly (P<0.05) greater than that of the females at Mara. This is as a result of the horns (female impala do not have horns). There was a tendency for an increase in sexual dimorphism with

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age. This is supported by previous studies (Blumenschine & Caro, 1986; Hitchins, 1966; Hoffman, 2000b; Ledger *et al.,* 1967).

Table 2: Proportional distribution of the body components (LSMean ± SE) of male and female impala from Mara and Musina (expressed as a percentage using empty body weight as a co-variant)

Variable	Musina		Mara	
	Females (n=13)	Males (n=15)	Females (n=16)	Males (n=24)
Initial weight	120.86 ± 2.83^a	116.20 ± 5.33^b	115.53 ± 3.25^b	114.05 ± 2.57^b
Carcass	70.57 ± 5.43	67.25 ± 3.57	72.31 ± 1.95	70.34 ± 2.09
Head	8.83 ± 1.93^a	9.09 ± 2.13^a	5.44 ± 0.51^b	7.24 ± 0.81^c
Hooves	4.34 ± 0.81^a	3.48 ± 1.07^b	3.06 ± 0.22^c	3.14 ± 0.40^{cb}
Heart	1.07 ± 0.25	0.93 ± 0.19	0.95 ± 0.14	0.89 ± 0.14
Lungs	2.97 ± 0.97^a	2.27 ± 1.11^{ab}	1.34 ± 0.32^b	1.38 ± 0.27^b
Liver	2.82 ± 0.50^a	2.41 ± 0.70^a	1.71 ± 0.26^b	1.70 ± 0.25^b
Kidneys	0.73 ± 0.88^{ab}	0.45 ± 0.13^a	0.38 ± 0.24^{ba}	0.33 ± 0.05^b
GIT[1] empty	8.82 ± 2.38^a	7.53 ± 1.91^a	7.11 ± 0.88^b	6.16 ± 1.14^c
Skin	6.52 ± 1.44^a	6.12 ± 1.63^a	4.86 ± 0.57^b	5.55 ± 0.73^c

[1] Gastro-intestinal tract
[abc] Means in the same row with different superscripts differ significantly (P<0.05)

There is not a great deal of data available on the chemical carcass composition of wild ungulate species. This fact makes it difficult to draw comparisons between the species in terms of the chemical compositions of their meat. In this investigation, no significant differences as a result of age could be found and so the data were pooled for further analysis. The mean percentages of protein, fat, ash and moisture from both the regions in this study are reported in Table 3 and are similar to those found by Hoffman (2000b) for impala cropped in central Zimbabwe. Van Zyl & Ferreira (2002) reported higher lipid (2.7%) and ash values (4.5%) with lower protein values (19.5%), in their study conducted on impala, this is likely because the analyses in their study were carried out on complete three-rib-cuts which includes bone. It should also be noted that the animals used in that study were sampled near Bredasdorp in the Western Cape which is outside of the natural range of impala and could therefore also result in some variation. Variations in

the proximate compositions of impala muscle could be the result of regional differences in climate, vegetation and topography. This is evident in the fact that the Musina animals showed a significantly higher (P<0.05) percentage of crude protein in their *M. longissimus dorsi et lumborum* than the Mara animals. This higher level may also be the result of nutritional differences between the two regions.

Kay *et al.* (1981) reported the following chemical composition values for farmed red deer (*Cervus elaphus*) in Scotland: 21.8% crude protein, 1.2% fat, 1.1% ash and 75% moisture. Babiker & Yousif (1990) reported very similar values for camel meat. Other than the marginally lower protein contents in red deer and camel, the proximate chemical composition values are very similar to the findings of the present study. When compared to the chemical carcass compositions of a domestic species such as the sheep, it is clear that impala have higher protein (22-24% versus 18-19% in sheep), higher moisture (71-74% versus 58-65% in sheep), lower fat (1.2-3.2% versus 7-11% in sheep), and lower ash content (1.2-2.0% versus 2-3% in sheep) (Kabbali, Johnson, Johnson, Goodrich & Allen, 1992; Kirton & Barton, 1962; Kock, Ryssen & Davies, 1995; Rowe, Macedo, Visentainer, Souza, & Matsushita, 1999).

Table 3: The chemical composition of the *M. longissimus dorsi et lumborum* of male and female impala at Musina and Mara (LSMeans ± SE)

Variable	Musina		Mara	
	Females (n=13)	Males (n=15)	Females (n=16)	Males (n=24)
Crude Protein (%)	24.87 ± 0.89^a	24.89 ± 1.19^a	23.85 ± 0.92^b	23.77 ± 0.80^b
Lipid (%)	1.98 ± 0.64^a	1.43 ± 0.51^b	1.88 ± 0.73^a	1.37 ± 0.24^b
Ash (%)	1.22 ± 0.13	1.23 ± 0.33	1.17 ± 0.17	1.19 ± 0.09
Moisture (%)	72.50 ± 1.59	72.51 ± 1.05	71.92 ± 3.83	73.08 ± 1.79

[ab] Means in the same row with different superscripts differ significantly (P < 0.05).

The low fat percentages found in animals from both regions in this study are supported by the findings of Ledger *et al.* (1967) for 18 other wild ungulate species. These low fat percentages are an indication of the leanness of game meat (Van Zyl & Ferreira, 2002) and are part of it's appeal as a desirable product for health conscious consumers. One female animal at Musina was found to have an intramuscular lipid content in excess of

7%. It was suspected that the reason for this was that the particular female had not lambed the previous season and had maintained her fat deposits. The lipid value for this particular animal was thus left out of the statistical analysis. There were significant (P<0.05) differences in the fat contents between sexes for both regions (Table 3) with the females from both regions showing higher lipid contents than the males. These results are supported by the findings of Ledger *et al.* (1967), Von la Chevallerie & Van Zyl (1971), Brooks (1978), and Hoffman (2000b). A possible explanation for the lower lipid content in males is that during the breeding season or rut the male animals loose body fat and condition because of the heightened physical activity associated with courtship behaviour. Rams also spend less time foraging for food during this period (Hoffman, 2000b). This observation is substantiated by work done by Dunham & Murray (1982) and Van Rooyen (1993). According to Stevenson, Seman & Littlejohn (1992) commercially farmed stags also tend to reduce food intake during the rut period even when they are not actively breeding.

Conclusions

The results of this study show that the carcass weight and dressing percentage of the impala (expressed as a percentage of body weight) are similar to previous estimations of these physical components. The main effects that are brought about by age of the animal, are increases in dimensions of certain carcass components such as the neck and chest. These increases in size are brought about firstly by the growth of the animal, and secondly by the progressive development of the sexual dimorphism. Older males have thicker necks and larger forequarters. Age had no effect on the chemical carcass composition in this study.

Regional differences were shown to occur both in terms of the average physical size of the animals, as well as in their chemical carcass composition. Higher crude protein was found in the Musina group.

Female animals were shown to have a greater fat content in their muscle, which is in accordance with previous studies. The organ percentages as a proportion of the empty body weight were found to be generally higher in the females and may explain why they do not have a better mean dressing percentage when compared to the male animals.

The offal makes up a significant portion of the animal and therefore it should be utilised to its fullest extent to maximise profitability.

Acknowledgements

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CHAPTER 4

THE EFFECTS OF REGION AND SEX ON THE FATTY ACID, AMINO ACID, MINERAL, MYOGLOBIN AND COLLAGEN CONTENTS OF IMPALA (*AEPYCEROS MELAMPUS*) MEAT

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Abstract

The effects of sex and region on the fatty acid profile, mineral contents, collagen and myoglobin contents of impala (*Aepyceros melampus*) meat were investigated in this study. The study was conducted in the Limpopo Province of South Africa where impala were sampled from two separate regions. Female animals at Mara showed higher levels ($P<0.05$) of saturated (SFA), and mono-unsaturated fatty acids (MUFA) in their tissues than the male animals. The females at Musina also showed a tendency ($P<0.10$) towards higher levels than the males. Males from both regions showed higher levels ($P<0.05$) of poly-unsaturated fat (PUFA) than the females. Myristic, palmitic and stearic acid made up the greatest proportion of the SFA component for the males and females from both regions. Oleic acid represented the largest component of the MUFA, with the Mara animals showing higher levels than the Musina animals. α-linoleic, γ-linoleic, and linolenic acid made up the largest proportions of the poly-unsaturated component for both of the regions. The male animals at Mara had lower ($P<0.05$) myoglobin contents than the females for that region. Region had no effect on the myoglobin content of the meat. No significant sex or regional differences were found in the hydroxyproline and collagen contents of the meat ($P>0.05$). Regional differences ($P<0.05$) were found in the amounts of phosphorous and calcium present in the meat. The male animals at Mara were found to have higher levels of zinc than the females.

Keywords: Fatty acid profile; mineral content; myoglobin content; collagen content; hydroxyproline; game meat

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Introduction

In spite of recent economic recessions and frequent droughts, game farming is growing in popularity in southern Africa and many cattle farms are being game-fenced to accommodate game (Ebedes, 2002). Game farming is a relatively new agricultural industry that has now become well established in South Africa. According to Eloff (2002), the estimated gross income from the game industry in 2000 was R843m. In a study undertaken by Van Der Waal & Dekker (2000) it was reported that game ranches cover 26% of the surface area of the Limpopo Province alone. This is equivalent to approximately 3.6m ha and is more than the combined surface area of the National and Provincial parks in the province.

The browsing habits of the impala make it well suited to the South African bushveld because of its ability to utilize both the tree and shrub components (Fairall, 1983). They are widely distributed in southern Africa and are able to survive in a variety of habitats (Skinner & Smithers, 1990). Together with this wide distribution and their relative abundance as a species, impala are well suited to sustained yearly cropping regimes (Bourgarel, des Clers, Roques-Rogery, Matabilila, & Banda, 2002; Hoffman, 2000a). Impala also have a rapid reproductive rate which makes them an ideal species with which to establish a game population on a farm in a short space of time (Fairall, 1984). These factors have led to the impala being the most popular game species sold at game auctions during the last six years (Eloff, 2002).

The culling of game on a farm becomes an essential practice in order to avoid over-population and the associated environmental damage that can be caused by overgrazing (Conroy, 2002). There have been a number of studies conducted on African ungulate species and their potential for meat production and it is now widely acknowledged (Ledger, 1963; Ledger, Sachs & Smiths, 1967; Fairall, 1984; Hoffman 2000b; Van Zyl & Ferreira, 2002). Berry (1986) showed that game meat production was the most profitable strategy for a game farm (when compared to live sales, trophy hunting and recreational hunting) in terms of return per kilogram of biomass. Meat production is playing an increasingly important role in the financial viability of game farms.

There is a preference amongst modern consumers for healthier foods. Game meat has the potential to be effectively marketed as a natural or organic product because of the way in which it is extensively farmed under natural conditions. Game meat is perceived as being darker than the meats of domestic animals (Hoffman 2000a) and many believe this to be the result of game meat's susceptibility to the DFD condition. It is likely that an increased level of myoglobin due to high levels of physical activity in game animals could be the cause of the darker colour of game meat (Vestergaard, Oksbjerg & Henckel, 2000; Diaz et al., 2002). The lower fat content of game meat (Hoffman, 2000b; Van Zyl & Ferreira, 2002) is of tremendous potential value to the health conscious consumer. It is widely accepted that fat intake beyond one's dietary requirements is a risk that leads to hypertension and concomitant heart disease, strokes, diabetes and obesity. Consumers have become increasingly aware of the fat contents of foods as a result of this. The quality of the fat itself is an important determinant in the appearance, palatability, nutritive value, processing characteristics and shelflife of meat and so is also an important factor in the meat quality (Casey, Van Niekerk & Spreeth, 1988; Webb, Bosman & Casey, 1994).

Saturated fats tend to solidify when they cool and so increase the hardness of fat. This affects the palatability of fat in the meat and therefore also the consumer acceptability. On the other hand, unsaturated fats oxidize easily and can cause rancidity, which negatively affects the shelf life (Casey & Van Niekerk, 1985; Webb et al., 1994). It is widely accepted that plasma cholesterol levels are influenced by the fatty acid composition of the diet. High levels of long-chain SFA in a diet increase plasma cholesterol levels whereas high levels of mono-unsaturated fat and poly-unsaturated fats do not (Grundy & Denke, 1990; Rowe, Macedo, Visentainer, Souza & Matsushita, 1999).

Game animals, and impala in particular, show very low levels of sub-cutaneous and intramuscular fat when compared to domestic species (Hoffman, 2000b). This is one of the reasons that game meat has potential to be marketed as a health product. With the growing game industry in South Africa and the increasing utilisation of game animals for meat production, it has become necessary to quantify all aspects of their meat quality. As yet there is very little information available in this regard for game species. Therefore the purpose of this study was to determine the possible effects of sex and region on the

fatty acid and mineral profiles of impala as well as the quantification of the levels of myoglobin and collagen in their meat.

Materials and methods

Impala were sampled from the Mara Research Station (Mara), and from the Musina Experimental Farm (Musina) in the Limpopo province, South Africa. Mara is located 50 km west of Louis Trichardt, just south of the Soutpansberg mountain range (23° 05' S and 29° 25' E; 961 m.a.s.l.). The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988) and is 11 000 ha in extent. The vegetation found there includes the woody species *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca and Grewia* spp., while the grass species found include *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha.* The mean annual rainfall is 452mm, of which approximately 80% occurs from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January (Dekker, Kirkman & Du Plessis, 2001). The type of research conducted at Mara is primarily concerned with extensive cattle production. Impala occur naturally in the area and as they are in competition with the cattle for grazing, they are subject to yearly population reductions.

The Musina experimental farm is situated approximately 15km west of Musina and is bordered by the Limpopo river to the north (between 22° 12' and 22° 18' S and 29° 50' and 29° 57' E; 460 to 639 m.a.s.l). According to Acocks (1988) the farm is located within the northern block of the Mopani veld, where the mopani, *Colophospermum mopani* is the dominant tree species. The study took place in the 4 605 ha game fenced section of the farm. The mean annual rainfall is 366mm of which approximately 75% occurs from November to March. The mean maximum daily temperature varies from 25 °C in July to 34 °C in January (Dekker & van Wyk, 2002). Research conducted on this farm focuses on aspects of mixed cattle and game farming. Commercial hunting is also conducted on the farm during the hunting season.

At Mara, 40 impala comprised 16 females and 24 males, were randomly harvested in a procedure similar to that described by Lewis, Pinchin & Kestin (1997). These animals were cropped as part of an annual organised game culling operation to contain population numbers. The 28 impala from Musina, comprised of 13 females and 15

males, were animals that were commercially hunted during the day by South African and European hunters. All of the animals fell into one of the following age groups: 8, 18, 30, 42 and 54+ months. The ages were determined by comparing tooth eruption and wear with the weight of the animal. With male animals the development of the horns was also used to judge the age (Spinage, 1971). The harvesting operation of both groups of animals took place during the winter months and coincided with the rutting period. The animals were exsanguinated with knifes directly following death and the initial weights of the dead animals were recorded afterwards. The carcasses were then dressed according to standard South African and Zimbabwean practices (Hoffman, 2000a). The carcasses were hung by their Achilles tendons in a cooler set at 4°C.

After cooling (± 36 hours to achieve 4°C) a sample of the *M. longissimus dorsi et lumborum* (LD) was cut from the right-hand side of the hanging carcass between the 1st and 4th lumbar vertebrae of each animal. Any visible sub-cutaneous fat was trimmed from the sample. The meat samples were minced through a 2mm sieve three times in order to ensure homogeneity. The lipids in the meat sample were then analysed for their fatty acid composition.

Fatty acid methyl esters (FAME) were prepared according to the method of Morrison & Smith (1964). The FAME were analysed with a GC (Varian Model 3300), equipped with flame ionisation detection and two 30 m fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&W Scientific Folsom, CA). Gas flow rates were: hydrogen, 25 ml/min; air, 250 ml/min; and nitrogen, (carrier gas) 5-8 ml/min. Temperature programming was linear at 4°C/min; initial temperature, 160°C; final temperature, 220°C held for 10 min; injector temperature, 240°C; and detector temperature, 250°C. The FAME were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian Minnesota).

Sixteen impala from Mara were used for the amino acid analysis. Amino acids were determined on dried, fat free samples of meat by ion-exchange chromatography of the acid-hydrolysed protein. Samples were hydrolysed (AOAC, 1997) with 6 M HCl in a sealed tube under nitrogen for 22 hours in an oil bath at 110 °C. Amino acids were separated using the Waters Chromatography System with a Breeze HPLC 1525 and autosampler and injector 717.

The mineral contents of the meat samples were determined according to method IIa of Watson (1994). Element concentrations were measured on an ICP-AES (Inductive Coupled Plasma Atomic Emission Spectrophotometer; Liberty Series AA Varian). Collagen and myoglobin contents were determined according to the methods described by Kolar (1991) and Boccard *et al.* (1981) respectively.

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1989). No significant age differences could be found and so the data were pooled for further analysis. The difference between the sexes and regions were, where appropriate, tested by means of the null hypothesis (H_0), with $H_0:\mu=\mu_0$ and the alternative hypothesis (H_a) being $H_a:\mu\neq\mu_0$. Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% (P<0.05) for sex and region.

Results and discussion

Most modern consumers are interested in alternatives to conventional meat products (Feron, 1995). Game meat has great potential as a health food commodity because of the presence of n–3 and n–6 fatty acids that contribute to its nutritional quality (Rule, Broughton, Shellito & Maiorano, 2002). The presence of these fatty acids in the diets of laboratory animals is associated with many health benefits to the animals and it has been shown that n–3 fatty acids reduce serum tri-acylglycerols in humans (Harris, 1997).

The data in Table 1 represent the fatty acid profiles of the animals from the two regions. It can be seen that myristic (C14:0), palmitic (C16:0) and stearic (C18:0) acid are the major constituents of the saturated fatty acid (SFA) component for both Mara and Musina. The SFA component makes up the biggest proportion of the fatty acid profile with poly-unsaturated fat acids (PUFA) and mono-unsaturated fatty acids (MUFA) making up the second and third largest proportions respectively. This larger proportion of SFA can be attributed to the hydrogenation of dietary fat by micro-organisms in the rumen (Sales, 1995). The females at Mara showed significantly higher (P<0.05) levels of palmitic acid than the males. The females at Musina also showed relatively higher levels than the males although the difference was not significant. The females at Mara also had a higher (P<0.05) total amount of SFA than the males. The intramuscular fat content of the female animals was found to be significantly higher (P<0.05) than that of the males

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for both Mara (Females: 1.88 ± 0.73; Males: 1.37 ± 0.24) and Musina (Females: 1.95 ± 0.64; Males: 1.43 ± 0.51) (Kritzinger, Hoffman & Ferreira, 2002a). The females tend to have higher levels of body fat than the males and their fat is only usually required during the gestative period (Howells & Hanks, 1975). Males have lower levels of intramuscular fat and therefore have fewer triglycerides. As a result of this there are less SFA, more phospholipids and increased PUFA.

The effect of diet on the fatty acid profile of ruminant animals is not as pronounced as it is with monogastrics because of the low lipid content of their diets and the hydrogenation of any dietary lipids in the rumen (Wood & Enser, 1997; Nurnberg, Wegner & Ender, 1998). Despite these hydrogenating effects of the rumen microbes, diet can modify the fatty acid profile of the meat. Research has focussed on manipulating the essential fatty acids, such as α-linolenic acid (C18:3n3) which is known to have beneficial effects on human health (Rule *et al.*, 2002). In a review by Bas & Morand-Fehr (2000) that examined the factors that influence fatty acid composition in lambs, it was reported that grass based diets increased the levels of myristic, stearic and α-linolenic acids. Results reported in a study conducted by Rowe *et al.* (1999) indicate that the fatty acid profile of lambs fattened on pastures have higher levels of saturated long chain fatty acids (stearic and arachidic acid, C20:0) and PUFA (linoleic, α-linolenic, and arachidonic acid, C20:4n6) than animals fed in a feedlot system. These results are consistent with the present investigation where the Mara animals (that are predominantly grazers, with *Panicum maximum* as the dominant grass species) had higher concentrations of stearic and γ-linolenic acid (C18:3n6), and significantly higher levels (P<0.05) of α-linolenic acid than the Musina animals that are predominantly browsers (where *Colophospermum mopani* is the dominant tree species). Fairall (1983) noted that the proportion of browse in the diet of impala varied annually from 13% in December to 82% in June in the Kruger National Park where *Colophospermum mopani* is also the dominant species.

Oleic acid (C18:1n9) makes up the largest proportion of the MUFA in both regions and for both of the sexes. The males from Musina showed a significantly lower (P<0.05) proportion of MUFA than both the males and females from Mara. They also have the highest proportion of PUFA. The Musina group had significantly less eicosanoic acid (C20:1n9) than the Mara group which is probably also caused by nutritional differences between the two areas.

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Table 1: Fatty acid profile (Mean ± SE) of the male and female impala from Mara and Musina

Fatty acid (%)	Mara		Musina	
	Females (n = 16)	Males (n = 24)	Females (n = 13)	Males (n = 15)
C14:0	0.39 ± 0.41	0.32 ± 0.77	0.30 ± 0.36	0.58 ± 0.96
C16:0	20.72 ± 4.27^a	15.04 ± 5.55^b	22.47 ± 3.71^a	19.83 ± 3.43^a
C18:0	22.07 ± 2.16	22.25 ± 3.86	21.94 ± 4.35	20.35 ± 2.92
C20:0	0.11 ± 0.04	0.14 ± 0.08	0.13 ± 0.06	0.10 ± 0.06
C22:0	0.09 ± 0.06^a	0.16 ± 0.12^b	0.16 ± 0.10^{ca}	0.19 ± 0.12^{cb}
C24:0	0.15 ± 0.07	0.19 ± 0.09	0.14 ± 0.07	0.19 ± 0.10
SFA	43.55 ± 4.96^a	38.11 ± 5.27^b	45.13 ± 7.16^a	41.26 ± 5.87^a
C16:1n7	0.61 ± 0.46	0.57 ± 0.33	0.67 ± 0.33	0.66 ± 0.20
C18:1n9	21.81 ± 5.81^a	19.34 ± 4.80^a	19.06 ± 3.72^{ba}	15.98 ± 4.77^b
C20:1n9	0.13 ± 0.23^a	0.10 ± 0.04^a	0.07 ± 0.02^b	0.07 ± 0.04^b
C24:1n9	0.11 ± 0.15	0.14 ± 0.08	0.09 ± 0.07	0.10 ± 0.11
MUFA	22.66 ± 6.08^a	20.15 ± 5.02^a	19.89 ± 3.72^{ba}	16.80 ± 4.87^b
C18:2n6	16.16 ± 4.69^a	19.67 ± 3.62^b	18.34 ± 5.22^a	22.74 ± 5.74^b
C18:3n6	0.20 ± 0.19	0.14 ± 0.03	0.13 ± 0.05	0.13 ± 0.04
C18:3n3	4.36 ± 1.39^a	5.09 ± 1.11^a	4.01 ± 1.41^{ba}	3.95 ± 0.70^b
C20:2n6	0.15 ± 0.06	0.18 ± 0.04	0.13 ± 0.04	0.15 ± 0.06
C20:3n6	0.69 ± 0.26	0.86 ± 0.23	0.75 ± 0.33	0.96 ± 0.28
C20:4n6	6.12 ± 2.00^a	7.87 ± 1.67^b	5.87 ± 2.47^a	7.79 ± 2.69^b
C20:3n3	0.06 ± 0.04	0.09 ± 0.05	0.06 ± 0.04	0.06 ± 0.05
C20:5n3	2.76 ± 1.37	3.44 ± 0.84	2.41 ± 1.02	2.78 ± 1.20
C22:2n6	0.08 ± 0.07^a	0.14 ± 0.07^b	0.08 ± 0.06^a	0.14 ± 0.12^b
C22:4n6	0.41 ± 0.55	0.43 ± 0.42	0.22 ± 0.08	0.24 ± 0.17
C22:5n3	2.02 ± 0.87	2.82 ± 0.78	2.29 ± 0.90	2.43 ± 1.17
C22:6n3	0.77 ± 0.36	1.00 ± 0.64	0.69 ± 0.34	0.56 ± 0.45
PUFA	33.79 ± 10.06^a	41.74 ± 7.02^b	34.98 ± 10.22^a	41.94 ± 10.31^b

[abc] Means in the same row with different superscripts differ significantly (P<0.05)

The males from both regions had significantly (P<0.05) higher amounts of linoleic acid (C18:2n6) than the females, this was also the case with arachidonic acid and erucic acid (C22:2n6). As mentioned previously, the males from both regions were found to have significantly less intramuscular fat than the females.

The influence of fatty acid composition of dietary fat on the plasma cholesterol concentration of humans is widely accepted. Cholesterol levels are increased by high dietary levels of long-chain SFA compared with high levels of MUFA and PUFA (Grundy & Denke, 1990). Not all SFA have the same effects because lauric (C12:0), myristic, and palmitic acids increase plasma cholesterol levels but stearic acid has no effect (Grundy & Denke, 1990; Sundram, Hayes, Siru, 1994). According to Rhee (1992) the desirable fatty acids are all the UFA and stearic acid. Impala muscle has low levels of myristic and palmitic acids and relatively high levels of stearic acid, MUFA and PUFA. The total amount of Desirable Fatty Acids (DFA) amounted to approximately 82% of the total fatty acids for males, and 79% of the total for females. It could therefore be considered a health food commodity because of its potential to lower plasma cholesterol levels (Hoffman, Ferreira & Sheridan, 2002).

The amino acid composition of the LD is given in Table 2. No significant differences were found between sexes or between the age groups and therefore the data were pooled. According to Sales (1995), amino acid profiles do not vary greatly between species. The amino acid composition of meat protein remains fairly constant for most species regardless of the type of cut (Schweigert, 1987). When compared to the amino acid profile of the duiker (*Sylvicapra grimmia*) (Table 2), it can be seen that the amino acid composition of the LD of impala is very similar to that of the duiker. The essential amino acids with the highest concentration in the LD of impala are lysine (26.09 g/kg) and leucine (26.14 g/kg). These values are considerably higher than those given by the USDA (2001a, 2001b) for goat and sheep meat (lysine: goat = 15.3; sheep = 14.9; leucine: goat = 17.2; sheep = 13.1)

Table 2: Amino acid composition (g/kg muscle) (Mean ± SE) of the *M. longissimus dorsi et lumborum* of impala (n = 16) and common duiker (n = 10)[#]

Amino acids	Impala	Duiker[#]
	Essential	
Arginine	14.94 ± 0.89	16.70 ± 1.39
Histidine	16.81 ± 1.29	6.70 ± 0.21
Isoleucine	11.63 ± 0.90	11.60 ± 0.14
Leucine	26.14 ± 1.89	22.10 ± 0.29
Lysine	26.09 ± 1.58	24.70 ± 0.52
Methionine	7.94 ± 0.55	6.60 ± 0.09
Phenylalanine	10.14 ± 0.69	10.20 ± 0.13
Threonine	17.72 ± 1.13	10.80 ± 0.16
Valine	14.70 ± 0.95	13.80 ± 0.15
	Non-essential	
Alanine	34.66 ± 2.35	15.30 ± 0.13
Aspartic acid	32.61 ± 1.85	*
Cystine	2.33 ± 0.59	*
Glutamine	45.48 ± 2.93	*
Glysine	24.18 ± 2.27	*
Proline	14.71 ± 1.21	*
Serine	17.21 ± 1.89	8.50 ± 0.14
Tyrosine	8.19 ± 0.49	8.70 ± 0.14

[#] Hoffman *et al.* (2002).

Table 3 represents the results for the mineral, myoglobin, and collagen content analyses of the impala meat. The animals at Mara showed significantly higher levels of phosphorous in their tissue than the Musina animals (P<0.05). This may be the result of a phosphorous deficiency on the Musina farm and could be corrected by providing phosphorous/salt licks at various points on the farm if the deficiency were resulting in clinical symptoms. It is fairly common practice for commercial farmers in that region to put out mineral blocks for their cattle. Phosphorous and potassium occurred in relatively high quantities compared to calcium and magnesium. When compared to values for the mineral content of beef (Sales, 1995), impala meat (Table 3) was found to be higher in

potassium (beef = 3500 mg/kg), phosphorous (beef = 1800 mg/kg) and calcium (beef = 70 mg/kg), but sodium was higher in beef (610 mg/kg). The mineral values for common duiker meat (Hoffman *et al.*, 2002) were similar to the values for impala except for potassium (2805 mg/kg) and phosphorous (4767 mg/kg), which were lower in the duiker. The animals at Mara showed significantly lower levels of calcium in their tissues than the Musina animals. This could be as a result of higher calcium levels in the water and feed on the Musina farm. Once again, a calcium deficiency could be corrected with a calcium/salt lick. The Musina animals showed relatively higher levels of iron in their tissue than the Mara group although the difference was not significant.

Table 3: Myoglobin, hydroxyproline, collagen and mineral contents (Mean ± SE) of the *M. longissimus dorsi et lumborum* of male and female impala from Mara and Musina.

Minerals/ (mg/kg muscle)	Mara		Musina	
	Females (n = 16)	Males (n = 24)	Females (n = 13)	Males (n = 15)
Phosphorus	7500.50 ± 179.00[a]	7479.21 ± 125.31[a]	6339.15 ± 154.14[b]	6421.45 ± 178.21[b]
Potassium	7454.45 ± 181.23	7399.85 ± 90.24	7208.16 ± 179.48	7425.82 ± 161.64
Calcium	125.05 ± 10.50[a]	119.45 ± 10.24[a]	316.32 ± 20.28[b]	327.41 ± 29.45[b]
Magnesium	915.35 ± 20.21	925.35 ± 10.25	945.23 ± 35.11	931.78 ± 45.24
Sodium	587.19 ± 149.44	643.75 ± 89.86	598.38 ± 120.15	602.33 ± 110.42
Zinc	64.49 ± 15.13[a]	82.20 ± 14.48[b]	68.09 ± 10.88[ca]	70.99 ± 18.29[cb]
Iron	101.87 ± 27.33	112.22 ± 21.58	117.35 ± 23.78	120.83 ± 42.19
Myoglobin	7499.99 ± 368.21	7345.18 ± 750.14	7254.65 ± 199.24	7249.35 ± 168.87
Hydroxyproline	68.20 ± 15.98	72.64 ± 13.87	70.84 ± 30.32	70.50 ± 10.15
Collagen	5520.23 ± 113.65	5634.52 ± 103.85	5595.74 ± 224.12	5548.56 ± 111.87

[abc] Means in the same row with different superscripts differ significantly (P<0.05)

The colour of meat is influenced by the myoglobin content of the meat and this myoglobin content varies between different species (Gatellier, Hamelin, Durand & Renerre, 2001; Kranen *et al.*, 1999; Warris, Brown, Adams & Lowe, 1990) The myoglobin contents of the meat samples from the *M. longissimus dorsi* were not significantly affected by region. The myoglobin contents of the impala from both regions

were higher than the values reported for beef (5800.00 mg/g) and chicken (2530.00 mg/g) by Gatellier *et al.* (2001) and Kranen *et al.* (1999) respectively. This would explain why game meat is darker in colour when compared to beef or chicken (Hoffman, 2000a). Systematic exercise can lead to an increase in the amount of myoglobin that is present in muscle to heighten its oxygen carrying capacity (Diaz *et al.,* 2002; Lawrie, 1998; Vestergaard *et al.,* 2000;). Wild ungulates tend to be more active than domestic herds and this causes the proliferation of the myoglobin content, which is contributory to the darkness of game meat. The males at Mara showed slightly lower levels of myoglobin than the females from Mara and the males from Musina. The females showed relatively similar myoglobin values from both regions. The DFD (Dark Firm and Dry) condition is also a potential factor in the darker colour of game meat. In a study conducted by Hoffman (2000a), one of the sample animals was found to have exceptionally dark meat (L* = 24.55; a* = 9.13; b* = 4.88) and it was said to be the result of the animal having been wounded just prior to death causing tremendous ante-mortem stress. The mean colorimetric values for the other animals in that study (L* = 28.99; a* = 11.30; b* = 7.54) and were similar to the values reported by Kritzinger, Hoffman & Ferreira (2002b) (L* = 30.30; a* = 12.80; b* = 9.15) were considerably lighter than those of the wounded animal, however, they still showed game meat to be darker than the meat of domestic species such as pork and beef.

The hydroxyproline and collagen contents of the meat were not significantly affected by region or sex (Table 1). The total collagen content values for impala were slightly higher than those reported by Wheeler, Shackelford & Koohmaraie (2000) for pork muscle (4100.00 mg/g) and similar to those reported by Kruggel & Field (1971) for beef (5360.00 mg/g).

Conclusions

It can clearly be seen that the composition of what the animals eat has a marked effect on the fatty acid profile. The animals with a more grass-based diet had increased levels of stearic and α-linolenic acid. The male animals were found to have higher PUFA than the females, but they showed lower levels of both MUFA and SFA within the regions. This is likely linked to the lower levels of intramuscular fat present in the male animals. Game meat has a high nutritional value and because of it's low fat contents and high levels of PUFA it is a desirable product from a health aspect. The amino acid content of

impala muscle is not affected by age of the animal and is similar to that of other ungulate species. Impala muscle shows high levels of essential amino acids when compared to goat and sheep meat.

Regional differences in the levels of phosphorous in the tissues of the impala were found. If a phosphorous deficiency in the Musina animals is clinically manifested, mineral blocks can be provided in order to alleviate the problem. Studies such as this are therefore important in pinpointing such regional mineral shortages. Impala meat has been shown to have higher mineral contents of certain minerals than beef, and fairly similar in mineral composition to duiker meat.

Acknowledgements

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CHAPTER 5

CHARACTERISATION OF FOUR IMPALA (AEPYCEROS MELAMPUS) SKELETAL MUSCLES

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Abstract

Impala (*Aepyceros melampus*) is a commercially important species in game farming in South Africa. Muscular enzyme activities and muscle fibre types may be important factors to consider in modern game farming systems as they may have significant economic implications in terms of the processing characteristics, shelf life of the meat, and may indirectly improve farm management to maximize meat quality. The purpose of this study therefore was to establish preliminary baseline biochemical data for the musculature of impala. Samples from the *M. semi-membranosus (SM)*, *M. deltoideus (D)*, *M. longissimus dorsi et lumborum (LD)*, and *M. psoas major (PS)*, were taken from 6 male impala carcasses. The samples were analysed for citrate synthase (CS) and phosphofructo-kinase activities, which are markers of oxidative and glycolytic metabolism, respectively. Myosin heavy chain (MHC) isoform distribution varied significantly between *D, SM* and *LD* ($P<0.05$). *D* expressed more MHC I, and less MHC IIa than the other 3 muscle groups. Positive correlations were found between age and MHC I in *D* ($r=0.93$; $P<0.05$) and CS and weight of the animal in *D* ($r=0.76$; $P<0.05$). The enzyme activities and MHC isoform distribution indicate that energy in the impala is produced to a large extent via oxidative pathways. To date, this is the first study to investigate muscular enzyme activities and MHC isoform distribution in impala.

Keywords: impala; citrate synthase; phosfofructokinase; meat quality; myosin heavy chain

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Introduction

There is a generally recognized trend away from conventional livestock production to game production in southern Africa (Van Der Waal & Dekker, 2000). The reasons for this, when compared to a traditional domestic stock farming operation, are that there is a perceived greater financial return from a game farming operation (Berry, 1986), it is aesthetically pleasing and ostensibly more environmentally friendly.

The impala is well suited to commercial game farming because of its fairly wide distribution and its rapid reproductive rate (Fairall, 1984). Because of these two factors impala have been the most popular game species sold at game auctions during the last six years (Eloff, 2002). Furthermore their browsing habits make them desirable to game farmers because they browse a wider variety of trees and shrubs than other species, thus efficiently utilising the available browse material (Fairall, 1983). The culling of game is an essential management strategy to curb over population on game farms and prevent environmental damage (Conroy, 2002). The impala's wide distribution in southern Africa and its relative abundance as a species make it well suited to continuous cropping for game meat production (Bourgarel, des Clers, Roques-Rogery, Matabilila & Banda, 2002; Hoffman, 2000).

With the growth in the game farming industry has come the commercial production of game meat. It has become important that all aspects of game meat quality be quantified in order to improve its quality and make it competitive with other meat types. While some research concerning the physicochemical aspects of impala meat has been carried out (Hoffman, 2000a, 2000b; Kritzinger, Hoffman & Ferreira, 2002; Van Zyl & Ferreira, 2002), as yet there is no data available concerning their muscle enzyme kinetics and muscle fibre types. According to Lawrie (1998) the texture and grain of meat is influenced to a large extent by the muscle fibre types and this in turn is affected by the function of the muscle within the body and it's level of activity.

Skeletal muscle is metabolically characterised by analysing enzyme activities representing different metabolic pathways and intramuscular substrates (Peter, Barnard, Edgerton, Gillespie & Stempel, 1972; Essen, Jansson, Henriksson, Taylor & Saltin, 1975). According to Essen-Gustavsson & Rehbinder (1985), the metabolic characteristics of the different fibre types show that type I fibres have a high oxidative,

but low glycolytic capacity. Type IIa and type IIx both have high glycolytic capacities and show large variations in oxidative capacities (Reichmann & Pette, 1982). Many of the skeletal muscle studies until now, have been performed on human muscle and that of domesticated animal species such as rats, mice, rabbits, dogs, pigs and horses. Very few studies of this kind have been carried out on non-domesticated species, and this is the first work conducted on impala muscle. The purpose of this study was to establish a set of preliminary baseline data for the myosin heavy chain isoform distribution of four impala muscles that are of commercial importance in terms of meat production. Furthermore, to establish baseline data for citrate synthase and phosphofructokinase activity in these muscles that can be used as a basis for further research into wild ungulate muscle enzyme dynamics.

Materials and methods

The cropping of impala herds took place at the Mara Research Station (23° 05' S and 29° 25' E; 961 m.a.s.l.) in the Limpopo Province, South Africa. The study area is located 50 km west of Louis Trichard, just south of the Soutpansberg mountain range. The Mara Research Station is situated in the Arid Sweet Bushveld (Acocks, 1988) and is 11 000 Ha in extent. The vegetation found there includes the woody species *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and *Grewia* spp. The grass species found include, *Eragrostis rigidior, Panicum maximum, Urochloa mosambicensis* and *Digitaria eriantha.* The mean annual rainfall is 452mm, of which approximately 80% occurs from November to March. The mean daily maximum temperature ranges from 22.6 °C in June to 30.4 °C in January (Dekker, Kirkman & Du Plessis, 2001). The type of work done there is primarily concerned with research into extensive cattle production. Impala occur naturally in the area and as they are in competition with the cattle for grazing, they are subject to yearly population reductions. The topography of the area is such that there are no mountains or large hills.

The cropping of impala took place as part of an annual population control measure of the endemic impala herds at the Mara Research Station. Six male impala were used for this study and the sampling took place between the months of May and July. Their body weights ranged between 35-65kg and their ages ranged from 30 to 54 months. The animals were killed by a single shot to the upper neck or head region, and no undue stress or struggling of the animals was observed prior to death. Samples were taken

from the *M. longissimus dorsi et lumborum* (LD), *M. Deltoideus* (D), *M. psoas* (PS) and *M. semimembranosus* (SM) within ½ an hour of the death of the animal. These samples were immediately frozen in liquid nitrogen and transported to the laboratory facilities where they were stored at −80 °C until the analyses took place.

Prior to analysis, the samples were freeze dried over a 48-hour period and weighed. A hundred mM (pH 7.40) chilled phosphate buffer was added to the samples at a ratio of 1:90 and this suspension was then homogenised by hand and sonicated with an ultrasound disintegrator.

Phosphofructokinase (PFK) activity and Citrate Synthase (CS) activity were analysed using the methods described by Ling *et al.* (1965) and Srere (1969) respectively. The relative myosin heavy chain isoform composition was analysed using the Sodium Dodecylsulfate Poly-Acryamide Gel Electrophoresis (SDS-PAGE) method described by Talmadge & Roy (1993), with added mercaptoethanol in the upper running buffer.

All variables were statistically analysed using the GLM procedure of the software package Statistical Analysis System (SAS, 1989). The differences between the muscles were tested by means of the null hypothesis (H_0), with $H_0:\mu=\mu_0$ and the alternative hypothesis (H_a) being $H_a:\mu\neq\mu_0$. Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$). Where applicable correlations between the variables were tested using the same software (SAS, 1989).

Results and Discussion

CS is one of the key enzymes in the citric acid cycle pathway and therefore was analysed as a marker for citric acid cycle activity. PFK was analysed as a marker of glycolytic activity. CS activity ranged between 100-238µmol/min/g (Table 1) of dry weight and a positive correlation was found between CS activity and the weight of the animal in the D ($r = 0.764$; $P < 0.05$). This is probably because the larger animals are more mature males with a greater level of development of the secondary sexual characteristics (thicker shoulders and necks, Hoffman, 2000a). Part of the reason for this muscle development is that the D is one of the main muscles used in the forequarters of the animal during fighting. Fighting involves crouching on the forelegs and clashing horns

with the opponent. Larger males engage in fighting during the rut period to establish dominance hierarchies (Fairall, 1984) and the level of activity in the D is increased, requiring greater glycolytic capacity for improved short term activity. The relatively high CS activity in the D further points to the dual functionality of the muscle in terms of it's oxidative capacity and it's endurance capability for longer term exertions. The LD showed a slightly higher CS activity than the other three muscles possibly because of the long term endurance function in the running and walking actions of the animals. PFK activity ranged between 123 and 374μmol/min/g of dry weight. The PS and LD showed relatively higher PFK activity than the SM and D. This is probably because the function of the LD and the PS muscles are primarily orientated around the maintenance of posture and equilibrium, which are functions that require longer term endurance type capacity.

Table 1. Myosin heavy chain isoform composition (LSmeans ± SE) and levels of CS and PFK activity (LSmeans ± SE) in four muscles of impala (n = 6)

	Type	M. Psoas (PS)	M. Longissimus dorsi et lumborum (LD)	M. Deltoideus (D)	M. Semi-membranosus (SM)
Enzyme activities (μmol/g)	PFK	374 ± 181	350 ± 179	175 ± 179	123 ± 129
	CS	114 ± 30	238 ± 162	119 ± 21	100 ± 23
Myosin heavy chain isoforms (%)	I	19.5 ± 7.30	7.1 ± 12.26	32.4 ± 16.20	10.4 ± 16.6
	IIa	80.6 ± 7.30	92.9 ± 12.26	54.8 ± 22.32	89.6 ± 16.6
	IIx	0.0 ± 0.0	0.0 ± 0.0	12.9 ± 19.93	0.0 ± 0.0

Myosin is the most abundant of the myofibrillar proteins (Lawrie, 1998) and is made up of two main types of sub-unit, light meromyosin and heavy meromyosin. The heavy meromyosin or myosin heavy chain (MHC) can further be divided into type I, type IIa and type IIx fibres, amongst others. The MHC contains all the ATPase and the actin-combining properties of myosin and is situated on the periphery of the myosin filaments (Lawrie, 1998). The proportion of these MHC isoforms in relation to each other is determined to a large extent by the function (either oxidative, glycolytic or a mixture of the two) of the muscle. The percentage of the Type IIa fibres was high in all four of the

muscles studied (55 – 93%). The D was the only muscle of the four that contained any Type IIx fibres (Table 1). This is in keeping with the glycolyitic nature of it's functioning. The LD showed the highest amount of Type IIa, once again in agreement with it's endurance type oxidative function within the body. Positive correlations were found in the D between the weight of the animal (r=0.93; P<0.05) and the amount of Type I fibre as well as between the age of the animal and the amount of Type I fibre (r=0.79; P<0.05). This is likely because as the animal grows older and becomes heavier the amount of territorial and courtship behaviour increases, requiring increased development in the muscles associated with such behaviour. A positive correlation was also found between the PFK activity and Type I fibre in the *LD*. The more oxidative type I fibres present, the greater the amounts of PFK.

The D is one of the muscles used extensively by impala rams for intense short-term activity during courtship behavior in the rut period (fighting). The remaining three muscles sampled are primarily associated with longer-term endurance type activity such as maintenance of posture and equilibrium, and running and walking. This difference is reflected by the presence of MHC IIx in the D and their absence in the other three muscles.

In most humans and animals studied, types I and IIa fibres are highly oxidative. The high levels of these oxidative fibres in impala muscle show a remarkable oxidative capacity. The enzyme activities also show a large oxidative capacity with the citrate synthase activity being similar to that seen in racehorses, greyhounds and elite human athletes (Essen-Gustavsson, & Rehbinder, 1985). Muscles that show this kind of high oxidative capacity often have little or no type IIx fibres, as can be seen in this study.

It is generally believed that the oxidative types I and IIa are more fatigue resistant and are recruited during steady and continuous types of activity. Whereas the glycolytic type IIx fibres that are found in the *D* are rapidly fatigable and largely involved in maximal efforts, such as fighting during the rut period. In a flight response all fibre types would be used to provide explosive high speed in the short term and high endurance in the long term for prolonged effort. There is evidence that the relative susceptibility of animals to develop the DFD condition is positively correlated with the number of slow, oxidative fibres (types I and IIa) in their muscles (Zerouala & Stickland, 1991). It is widely held that

game animals are highly susceptible to the DFD condition and it could be as a result of the previously mentioned fact.

A low oxidative capacity indicates a low level of activity or involvement in locomotion. Different locomotor patterns may involve various muscles. In the pig, the LD has been shown not to react to a program of treadmill training (Essen, Lindholm & Persson, 1980; Essen-Gustavsson & Lindholm, 1983) indicating that this muscle is not very active in this type of locomotion. However, in greyhounds and reindeer, the LD has a high oxidative capacity, which is in keeping with the findings of this study. Galloping, with the heavy involvement of the back, as in the case of the greyhound, reindeer and impala, forces this muscle to develop a higher oxidative capacity (Karlström, 1995).

Conclusions

Different muscles around the body of an animal have differing metabolic enzyme activities. This can be seen from the results of this study. The metabolic enzyme activity could be of great importance in determining impala meat shelf life, and susceptibility to microbial growth and it is therefore necessary to further investigate this aspect of the meat quality.

Myosin heavy chain isoform composition of the muscle could help in quantifying differences in the texture and grain of impala muscle that influence its palatability. Understanding the MHC composition can lead to better understanding of the occurance of DFD and other stress related conditions in meat. Lawrie (1998) stated that systematic exercise could cause the thickening and diversification of muscle fibres. With this in mind, management practices of farmed impala could be implemented to influence the ratios of MHC isoform composition in order to improve meat quality parameters pertaining to texture, toughness, susceptibility to DFD and grain of the meat.

Further research is required in this field and should be conducted on specific factors that may influence enzyme activity in different muscles, such as age, sex and nutritional status of the animal.

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GENERAL CONCLUSIONS

The increase in the world population and the concurrent decrease in the per capita supply of high quality protein has intensified the search for new sources of food protein, particularly in the developing countries (Onyango, Izumimoto & Kutima, 1998). Africa's environment cannot economically support increased numbers of domestic animals (Cole, 1990). Game farming is a system that is an important strategy in alleviating Africa's problem of desertification while being able to produce high quality protein (Talbot, Payne, Ledger, Verdcourt & Talbot, 1965; Cole, 1990).

Indigenous animals are well adapted to the available food, excessive temperatures and limited water in Africa (Cole, 1990). They have lower nutritional requirements and are more resistant to diseases and parasites. They exhibit higher yield of meat per unit area and yield greater financial return from both meat and hide production (Hopcraft, 1980).

Cropping of impala is an essential management strategy in order to control the effects of game populations on relatively limited tracts of land (Bourgarel, Des Clers, Roques-Rogery, Matabilila & Banda, 2002; Conroy, 2002; Hoffman, 2000a). From a meat production aspect it is imperitive to utilise a cropping strategy that minimises the amount of stress that animals are subjected to post mortem, thereby improving their meat quality.

The night cropping technique when compared to the day cropping technique was shown to produce a higher initial pH (6.67 ± 0.11), a slower rate of pH decline and a relatively low final pH (5.39 ± 0.08). These factors are favourable for improved meat quality and are manifested in significantly less drip loss (P<0.05) and significantly lower Warner Bratzler shear force values (which is an indication of improved tenderness). There were no significant differences in the colour of the meat between the two groups, however excessive ante-mortem stress is presumed to cause DFD. Evidence to this effect is provided by a single animal in a study conducted by Hoffman (2000a) that was shown to have extremely dark meat and almost no drip loss after having been accidentally wounded and severely stressed for ten minutes prior to death.

Apart from the improved meat quality, the night cropping method facilitates greater accuracy of shooting, thereby reducing the chances of wounding. It allows careful selection of the animals to be cropped in order to manipulate age and sex structures within the population with an eye to increased productivity (Fairall, 1985).

A review of the literature revealed that the initial body weights of the mature animals from Musina (Males: 59.3kg; Females: 41.9kg) are in accordance with previous findings. The weights of the animals from Mara are slightly heavier than those reported in previous studies (Hitchins, 1966; Von la Chevallerie, 1970; Howells & Hanks, 1975; Hoffman, 2000b; Van Zyl & Ferreira, 2002).

Increasing age brings about increases in body size as well as sexual dimorphism. Older males have thicker necks and forequarters than the younger animals. Age did not have any significant effects on the chemical carcass composition in this study. Regional differences were shown to occur in both the average physical size of the animals and their chemical carcass compositions. The Musina animals showed higher crude protein levels. The female animals from both regions were found to have higher levels of intramuscular fat than the males.

Game meat has very good nutritional value because of it's low fat content and it's high levels of PUFA in relation to SFA and MUFA. The fatty acid profile of the animals varied between the two regions as a result of the differences in vegetation. These findings are supported by Rowe, Macedo, Visentainer, Souza, & Matsushita (1999) and Bas & Morand-Fehr (2000). Male animals were shown to have lower levels of MUFA and SFA ($P>0.05$) than the females and this is linked to the fact that males have lower levels of intramuscular fat.

Impala meat was shown to have an amino acid composition similar to the duiker. Amino acid compositions do not vary widely between different species (Sales, 1995), but impala meat was shown to have higher levels of certain essential amino acids than reported for sheep and goats by the USDA (2001a, 2001b). The mineral profile of the meat was found to be different between the two regions, showing less phosphorous in the Musina animals than in the Mara animals. This could be as a result of differences in the amounts of phosphorous available in the grazing between the two areas.

Muscle characterisation is an area of great potential in terms of quantifying the effects of metabolic enzyme activities and muscle fibre types on meat quality. All of the four muscles that were tested showed high oxidative capacity as well as glycolytic capacity. The *M.deltiodeus* was the only muscle that had any MHC IIx fibres, indicating a high glycolytic as well as oxidative capacity. The MHC isoform composition of the other muscles was restricted to MHC IIa and I. Further research into the possible effects of age, sex and nutritional status of the animal needs to be carried out.

The potential to utilse game meat for commercial production is now widely acknowledged. As can be seen from the results of this study, with an efficient cropping methodology and efficient farm management impala are a species capable of producing good quality meat.

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