IMPROVING THE MEAT QUALITY OF BLESBOK (*DAMALISCUS DORCAS PHILLIPSI*) AND SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) THROUGH ENHANCEMENT WITH INORGANIC SALTS

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 university for a degree.

Signature:…….

Date:……..

Abstract

This research had a dual purpose, firstly to study five muscles (*M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus*) of the blesbok (*Damaliscus dorcas phillipsi*) and springbok (*Antidorcas marsupialis*) in terms of the physical and chemical meat quality characteristics, and secondly, to investigate the effects of inorganic salt enhancement on the physical, chemical and sensory meat quality characteristics.

The muscles differed significantly for the investigated characteristics, with the exception of a* value, chroma, and ash percentage, which did not differ in either blesbok or springbok. Furthermore, no muscle differences were found in fat percentage in blesbok or protein percentage in springbok meat. Muscle differences were found in the stearic acid (C18:0) composition, the percentage saturated fatty acids (SF) and the polyunsaturated: saturated fatty acid ratio (P:S) of the blesbok. Only linoleic acid (C18:2) as a percentage of the total fatty acids differed significantly amongst the springbok muscles.

The shear force values were found to be significantly lower in the enhanced samples (blesbok: 25.16 vs. 43.75 N/1.27cm; and springbok: 23.96 vs. 34.89 N/1.27cm), which means that the enhanced muscles were more tender.

The enhanced muscles of both species were found to have lower values for all investigated colour characteristics. Moisture values were found to be higher in all the enhanced muscles (blesbok: 76.53% vs. 74.38%; and springbok: 75.34% vs. 73.37%). The lower fat and protein contents of the enhanced muscles can possibly be ascribed to a diluent effect caused by the water added as part of the inorganic salt injection (blesbok: fat, 1.86% vs. 2.22%, protein, 19.61% vs. 21.67%; and springbok: fat, 1.84% vs. 2.14%, protein, 21.23% vs. 23.26%). Major changes in the mineral contents were expected between the two treatments and in both species the enhanced muscles had higher phosphorus, potassium, sodium and copper values, but lower magnesium, iron and zinc levels than the untreated muscles.

Analytical sensory analyses were performed on the *M. biceps femoris* and *M. longissimus et lumborum* samples of both species. Tenderness and juiciness were significantly higher in the enhanced muscles. Although salty taste was significantly higher in the enhanced muscles due to the addition of the inorganic salt solution, it remained acceptable.

Analytical and consumer sensory analyses were performed on blesbok and springbok *M. longissimus et lumborum* samples prepared in a stock mixture. The outcome of the analytical sensory analysis was similar to the analytical results reported above. The consumer sensory

analysis showed that consumers preferred the enhanced blesbok and springbok muscles, with a significant improvement in consumers' likeness of enhanced vs. untreated meat.

This study provides important insights into the muscle differences of two of the most common game species currently utilised in South African meat production. It confirms that both species can be marketed as a low fat organic red meat source well capable of filling the modern consumer's nutritional and health needs. It also shows that enhancing game meat with an inorganic salt solution might be a very useful processing tool to use to further game meat acceptability in terms of tenderness and juiciness as game meat is often experienced as being dry and less tender because of its lower fat content and the use of incorrect preparation techniques.

Opsomming

Hierdie navorsing het ‘n tweeledige doel, eerstens om die vyf spiere (*M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* en *M. supraspinatus*) van die blesbok (*Damaliscus dorcas phillipsi*) en die springbok (*Antidorcas marsupialis*) in terme van die fisiese en chemiese eienskappe van vleiskwaliteit te bestudeer, en tweedens, om die effek van ‘n anorganiese sout oplossing op die fisiese, chemiese en sensories kwaliteitseienskappe te ondersoek.

Die spiere het betekenisvol verskil vir die meeste van die kwaliteitseienskappe, met die uitsondering van die a* waarde, chroma en as-persentasie, waarvoor daar geen verskille by die blesbok of die springbok was nie. Verder is daar ook geen spierverskille in die vet persentasie in blesbok of in die persentasie proteïene in springbokvleis gevind nie. Spier verskille is gevind in die stearіensuur (C18:0) samestelling, die persentasie versadigde vetsure (SF) en die poli-onversadigde: versadigde vetsuur ratio (P:S) van die blesbok. Slegs linoleïensuur (C18:2) as persentasie van die totale vetsure het betekenisvol verskil tussen die springbok spiere.

Die skeurkrag waardes was betekenisvol laer in die behandelde monsters (blesbok: 25.16 vs. 43.75 N/1.27cm; en springbok: 23.96 vs. 34.89 N/1.27cm), wat beteken dat die behandelde spiere sagter was.

Die behandelde spiere van beide spesies het laer waardes getoon vir alle kleur eienskappe wat ondersoek is. Vog waardes was hoër in al die behandelde spiere (blesbok: 76.53% vs. 74.38%; en springbok: 75.34% vs. 73.37%). Die laer vet en proteïen inhoud in die behandelde spiere kan waarskynlik verklaar word deur die verdunningseffek wat veroorsaak is deur die water wat bygevoeg is as deel van die anorganiese sout-inspuiting (blesbok: vet, 1.86% vs. 2.22%, proteïen, 19.61% vs. 21.67%; en springbok: vet, 1.84% vs. 2.14%, proteïen, 21.23% vs. 23.26%). Groot veranderinge is verwag in die mineraal inhoud van die twee behandelinge en in beide spesies het die behandelde spiere hoër fosfor, kalium, natrium en koper waardes en laer magnesium, yster en sink waardes as die onbehandelde spiere getoon.

Analitiese sensoriese analises is op die *M. biceps femoris* en *M. longissimus et lumborum* monsters van beide spesies uitgevoer. Sagtheid en sappigheid was betekenisvol hoër in die behandelde spiere. Alhoewel souterige smaak betekenisvol hoër was in die behandelde spiere as gevolg van die byvoeging van die anorganiese sout oplossing, was dit steeds aanvaarbaar.

Analitiese en verbruiker sensoriese analises is uitgevoer op blesbok en springbok *M. longissimus et lumborum* monsters wat in ‘n aftreksel voorberei is. Die uitkoms van die analitiese sensoriese analise was soortgelyk aan die bogenoemde gerapporteerde analitiese resultate. Die verbruikers sensoriese analise het getoon dat verbruikers die behandelde blesbok en springbok spiere verkies, met ‘n betekenisvolle verbetering in die hoeveelheid waarvan verbruikers van die behandelde, eerder as die onbehandelde vleis, gehou het.

Hierdie studie lewer belangrike insigte in die spierverskille van twee van die mees algemene wild species wat op die oomblik in Suid-Afrikaanse vleisproduksie benut word. Dit bevestig dat beide blesbok and springbok bemark kan word as ‘n bron van lae vet, organiese rooivleis wat uiters geskik is om aan die moderne verbruiker se voedings- en gesondheidsbehoeftes te voldoen. Dit wys ook dat die behandeling van wildsvleis met ‘n anorganiese sout oplossing moontlik ’n baie bruikbare prosesseringsmetode is om die aanvaarbaarheid van wildsvleis in terme van sagtheid en sappigheid te verbeter, aangesien wildsvleis dikwels as droog en minder sag ondervind word as gevolg van die laer vet inhoud en foutiewe voorbereidingstegnieke.

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Notes

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

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

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Chapter 1

Introduction

Over the last few decades people's impression of meat has changed dramatically – from traditionally being seen as an overall healthy nutritious food, it has become negatively associated with health risks. Red meat in particular has been associated with a high fat and cholesterol content (Schönfeldt, 1993; Higgs, 2000).

As people became more health conscious (especially since the 1980's), consumers started demanding knowledge of the nutritional composition of everything that passed their lips. Fat, particularly animal fat, as well as high cholesterol-foods (again linked to meat) had to be reduced or avoided where possible. Consumers have become much more informed about food components that could be harmful (e.g. saturated fatty acids) and those components that are beneficial (e.g. polyunsaturated fatty acids and anti-oxidants) to their health.

Reports such as those by the Committee on Medical Aspects of Food and Nutrition (COMA, 1984) and the World Cancer Research Fund (WCRF, as reported by Higgs, 2000) only broke down red meat's image as a healthy nutrient-rich food source further. The COMA report of 1984, which dealt with coronary heart disease, pointed out that meat is a major source of saturated fatty acids and since then a lot of the controversy surrounding the fat content of meat has (incorrectly) dealt with its saturated fat content. Higgs (2000) reported that it is generally assumed that all the fat in meat is saturated, but since the meat industry has been succeeding in producing meat with a lower fat content, the fatty acid composition of meat has gradually shifted and the percentage saturated fat is now lower than in the past. Pork and beef contains less than 50% saturated fat, while lamb and poultry contains 51% and 30% saturated fat respectively.

During 1997 and 1998 meat's association with cancer was blown out of proportion by the WCRF (as cited by Higgs, 2000) and COMA (1984) reports, which both dealt with diet and cancer and were published at the same time. The WCRF (as cited by Higgs, 2000) report was extremely negative towards meat and recommended that no more than 80g of red meat should be consumed per day. This recommendation could not be scientifically substantiated and a similar recommendation by COMA (1984) was revised.

A demand for low kilojoule-, low cholesterol products, has been created by growing health concerns. People are more than ever concerned about cardiovascular disease and high cholesterol. According to Elliot (1993) decreasing the intake of saturated fatty acids leads to lower blood serum cholesterol levels, which in turn diminish the risk of developing cardiovascular disease.

The demand for "healthier" food has created the perfect marketing niche for game meat. Game meat has a much lower fat content than red meat from domesticated species and can therefore be seen as being the "healthier" red meat option. Kritzinger (2002) noted that because game meat can be an attractive alternative to health conscious red meat consumers, a wonderful opportunity has arisen to aggressively market game meat and cause it to advance in the industry. Hudson (1999) observed that the ideal niche for game meat utilization was created by consumer demand for lean muscle with less fat and suggested that game meat should be promoted on the basis of its low fat content and natural image. Along the same lines, Stevenson, Seman and Littlejohn (1992) came to the conclusion that game meat should be promoted as a top-quality gourmet food item specifically because of its nutritional profile and that it should be targeted at health conscious consumers.

Since South African consumers consider fat content the most important quality when they buy meat, this is clearly the best way to market and promote game meat since it has a lower fat content than lamb, beef or pork (Hoffman, Muller, Schutte and Crafford, 2004). Elliot (1993) also showed that venison had less fat than roast skin-on chicken and was only moderately fatter than skinless roast chicken. Hoffman, Muller, Schutte, Calitz and Crafford (2005) found that 52.6% of 300 South African respondents would buy game meat more often if they had more information on the health benefits and cooking methods of game meat.

In 1984 Swatland reported that consumers were looking for alternative sources of red meat. Even though the meat industry was one of the oldest and most important industries in the world, people were concerned about the risks associated with, in particular, beef consumption. During the last few decades consumers yet again had to deal with safety and quality concerns surrounding meat and meat products with several outbreaks of foot-and-mouth disease as well as *Bovine Spongiform Encephalopathy* (BSE) scares (Swatland, 1984; MacRae, O'Reilly and Morgan, 2005). Another big concern to consumers is the use of hormones and other growth promoters, especially in feedlots.

Pauw (1993), as well as Hoffman and Bigalke (1999), noted that game meat could be seen as an organic product. The animals are not in intensive farming systems and are usually left to forage in the veld without any additional feeding. They are free of chemical fertilisers and growth hormones. This links well with the increasing concern about the environment and animal welfare that Steenkamp (1997) found expressed by consumers. He found that consumers had more interest in free-range and organic products, as well as natural production methods, because of this concern.

The gross income of the South African game industry was calculated to be around R843 million in 2000 (Eloff, 2002). However, prices of live sales of game animals are decreasing and game farmers need to look into alternative utilisation of game (Berry, 1986; Hearne,

Lamberson and Goodman, 1996). One of the possible alternatives is the production of game meat, which can be quite lucrative since there is a trend towards natural food utilisation worldwide. Berry (1986) found venison production to be the most profitable of the four most common ways of wild animal utilisation (which were trophy hunting, non-trophy recreational hunting, live animal sales and venison production) when an index was developed based on the numbers of animals involved. In 1982 Conroy and Gaigher reported that game meat could fetch high prices as it is considered a luxury product. Talbot, Payne, Ledger, Verdcourt and Talbot (1965) found that wildlife management and utilisation as a natural resource in Africa were becoming increasingly important because of their value to the tourist industry, but that their meat production potential only received marginal consideration.

A major advantage that wild animals have over domesticated meat animals is their ability to survive in relatively dry areas without being fed and watered. Several authors have commented on wild game animals' adaptation and ability to survive in harsh environments (Talbot *et al.*, 1965; Fairall, 1985; Onyango, Izumimoto and Kutima, 1998; Barnett, 2000). According to Hearne *et al.* (1996) many cattle farmers are changing over to game farming which could lead to more meat utilisation since farmers have to focus on the optimum sustained use of these animal resources. More meat production can lead to more export opportunities, but in order for that to happen, the exact nutritional composition of the meat from the different game species must be known. Hoffman (2000) has stated that meat produced from wild ungulates must be put to the same criteria as that applied to meat from domestic species. These criteria include yield, physical and chemical properties and sensory characteristics.

It has been confirmed by numerous authors that game meat contains less fat than any other red meat type (Talbot *et al.*, 1965; Von la Chevallerie, 1972; Elliot, 1993; Schönfeldt, 1993; Hoffman, 2000) and was found by Von la Chevallerie (1972) to be below 2.5%, while Schönfeldt (1993) and Hoffman (2000) both reported game meat fat levels of between 2 and 3%. Hoffman (2000) also reported game meat to be lower in saturated fatty acids and higher in polyunsaturated fatty acids than beef. This supports the findings of Schönfeldt (1993). An intermediate moisture content was found for game meat by both Von la Chevallerie (1972), at 75.5%, and Elliot (1993), at 56.8%. Onyango *et al.* (1998) found that moisture, ash and protein values of beef and game meat were similar to that of other red meat. Van Zyl and Ferreira (2004) reported the protein value of game meat to be between 22 and 24%, which is much higher than that of domesticated meat species (Sayed, Frans and Schönfeldt, 1999).

The physical properties of game meat were found to be very similar to that of domesticated meat species. Hoffman and Bigalke (1999) reported that carcass yields of wild ungulates are usually in the range of 56 to 66% of the live weight and this was also found by several other authors (Talbot *et al.*, 1965; Van Zyl, Von la Chevallerie and Skinner, 1969; Conroy and

Gaigher, 1982). These dressing percentages of wild ungulate species are only slightly higher than the 50 to 55% reported for sheep (Pauw, 1993) and is similar to those found for cattle (Van Zyl *et al.*, 1969).

There has been little sensory research on game meat and there is almost nothing to be found in the literature on the sensory aspects of game meat. Forss, Manley, Platt and Moore (1979) reported that all venison types that they were examining tended to be dry and Jansen van Rensburg (1997) also reported that springbok meat was found to be rather dry. Hoffman (2001) confirmed that South African game meat is often seen as dry and suggested that it could be because the meat is derived from stressed animals. Several authors commented on the use of the right cropping and slaughtering procedures to ensure that animals experience the least amount of stress and that the highest quality meat can be produced (MacDougal, Shaw, Nute and Rhodes, 1979; Conroy and Gaigher, 1982; Elliot, 1993; Smit, 2004).

According to Conroy and Gaigher (1982) springbok, eland, blesbok, impala and kudu are the most common game species farmed with in South Africa. Jansen van Rensburg (1997) found that springbok was ranked as the favourite species to farm with by South African game farmers. Presently, springbok is the most extensively cropped game species in South Africa (Jansen van Rensburg, 1997; Hoffman, 2000). Hoffman *et al*. (2005) found that most respondents to their questionnaires have eaten springbok and kudu before and these two species, along with gemsbok, were found to be regularly available in supermarkets, butcheries and restaurants.

Game meat image has suffered because of several misconceptions of which the idea that game meat is less tender and juicy, is probably the most harmful. These particular misconceptions have resulted from ignorance, as improper handling and preparation can negatively influence the eating quality of game meat (Webb, 2001). Informing consumers about proper preparation methods is one way of dealing with it, but another less conventional way of dealing with the problem of tenderness and juiciness may be to enhance the meat with an inorganic salt solution. Several authors have commented on the effect certain inorganic salts have on meat tenderness (Wheeler, Koohmaraie and Shackelford, 1997; Dhanda, Taylor and Murray, 2003; Lawrence, Dikeman, Hunt, Kastner and Johnson, 2003; Robbins, Jensen, Ryan, Homco-Ryan, McKeith and Brewer, 2003) and juiciness (Smith, Simmons, McKeith, Betchel and Brady, 1984; Robbins *et al*., 2003).

With increased tenderness, game meat will acquire an even more positive image as the better red meat alternative. In 1963 Mitchell reported that consumers considered tenderness to be the most important eating quality characteristic in meat acceptance. This is still true today: Bickerstaffe, Bekhit, Robertson, Roberts and Geesink (2001) reported that tenderness was identified as the most important meat quality characteristic considered by consumers and at

supermarkets, meat tenderness is the deciding factor determining whether or not consumers become repeat buyers of a certain meat product.

References

Barnett, R. (2000). Food for thought: the utilization of wild meat in eastern and southern Africa. *TRAFFIC east/southern Africa*, Nairobi, Kenya.

Berry, M.P.S. (1986). A comparison of different wildlife production enterprises in the northern Cape Province, SA. *South African Journal of Wildlife Research* 16, 124-128.

Bickerstaffe, R., Bekhit, A.E.D., Robertson, L.J., Roberts, N. & Geesink, G.H. (2001). Impact of introducing specifications on the tenderness of retail meat. *Meat Science* 59, 303-315.

Committee on Medical Aspects of Food Policy (1984). 'Diet and Cardiovascular Disease.' *Report on Health and social subjects*, Department of Health and Social Security, No. 28, HMSO, London.

Conroy, A.M. & Gaigher, I.G. (1982). Venison, Aquaculture and ostrich meat production: Action 2003. *South African Journal of Animal Science* 2, 219-233.

Dhanda, J.S., Taylor, D.G. & Murray, P.J. (2003). Part 2. Carcass composition and fatty acid profiles of adipose tissue of male goats: effects of genotype and live weight at slaughter. *Small Ruminant Research* 50, 67-74.

Elliot, J. (1993). Farmed Venison, the new meat comes of age. *Nutrition and Food Science* 4, 26-29.

Eloff, T. (2002). The economic realities of the game meat industry in South Africa. In: H. Ebedes, B. Reilly, W. van Hoven, and B. Penzhorn (Eds.) *Sustainable utilisation – Conservation in practice*. Pp. 78-86.

Fairall, N. (1985). Manipulation of age and sex ratios to optimise production from impala (*Aepyceros melampus*) populations. *SA Journal of Wildlife Research* 15, 85-88.

Forss, D.A., Manley, T.R., Platt, M.P. & Moore, V.J. (1979). Palatability of venison from farmed and feral red deer. *Journal of the Science of Food and Agriculture* 30, 932-935.

Hearne, J., Lamberson, R. & Goodman, P. (1996). Optimising the off take of large herbivores from a multi-species community. *Ecological Modelling* 92, 225-233.

Higgs, J.D. (2000). The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science and Technology* 11, 85-95.

Hoffman, L.C. (2001). The effect of different culling methodologies on the physical meat quality attributes of various game species. In: H. Ebedes, B. Reilly, W. van Hoven, & B. Penzhorn, (Eds.) *Sustainable utilisation - conservation in practice*.

Hoffman, L.C. (2000). The yield and carcass chemical composition of impala (*Aepyceros melampus*), a southern African antelope species. *Journal of the Science of Food and Agriculture* 80, 752-756.

Hoffman, L.C. & Bigalke, R.C. (1999). Utilizing wild ungulates from southern Africa for meat production: Potential research requirements for the new millennium. *Congress of the Wildlife Management Association of SA* (pp. 1-14). George, South Africa.

Hoffman, L.C., Muller, M., Schutte, De W., Calitz, F.J. & Crafford, K. (2005). Consumer expectations, perceptions and purchasing of South African game meat. *South African Journal of Wildlife Research* 35, 33-42.

Hoffman, L.C., Muller, M., Schutte, De W. & Crafford, K. (2004). Retail of South African game meat: current trade and marketing trends. *South African Journal of Wildlife Research* 34, 123-134.

Hudson, R.J. (1999). Wildlife production: trends and issues. New Zealand diversified livestock. URL http://www.deer.rr.ualberta.ca/library/wcapkora/WCAPfinal.html

Jansen van Rensburg, D.M. (1997). The physical, chemical and sensory quality characteristics of Springbok (*Antidorcas marsupialis marsupialis*) meat. D. Tech. (Food and Nutrition). Department of Food and Nutrition. Technikon Pretoria, Pretoria.

Kritzinger, B. (2002). Meat quality parameters of the Impala (*Aepyceros melampus*). M.Sc. Agric (Animal Science) thesis. Department of Animal Science. University of Stellenbosch, Stellenbosch.

Lawrence, T.E., Dikeman, M.E., Hunt, M.C., Kastner, C.L. & Johnson, D.E. (2003). Effects of calcium salts on beef *longissimus* quality. *Meat Science* 64, 299-308.

MacDougall, D.B., Shaw, B.G., Nute, G.R. & Rhodes, D.N. (1979). Effect of pre-slaughter handling on the quality and microbiology of venison from farmed young red deer. *Journal of the Science of Food and Agriculture* 30, 1160-1167.

MacRae, J., O'Reilly, L. & Morgan, P. (2005). Desirable characteristics of animal products from a human health perspective. *Livestock Production Science*, 94, 95-103.

Mitchell, J.D. (1963). Problems relating to uniform meat tenderness in a commercial operation. In: *Proceedings meat tenderness symposium* (pp. 243-253). Campbell Soup Company, Camden.

Onyango, C.A., Izumimoto, M. & Kutima, P.M. (1998). Comparison of some physical and chemical properties of selected game meats. *Meat Science* 49, 117-125.

Pauw, J. (1993). The development of venison marketing. In: *Forum: The venison industry. Research requirements and possibilities* (pp. 3-5). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Robbins, K., Jensen, J., Ryan, K.J., Homco-Ryan, C., McKeith, F.K. & Brewer, M.S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Science* 65, 721-729.

Sayed, N., Frans, Y. & Schönfeldt, H.C. (1999). *Composition of South African foods*. Medical Research Council. Parow.

Schönfeldt, H. (1993). Nutritional content of venison. In: *Forum: The venison industry. Research requirements and possibilities* (pp. 51-60). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Smit, K. (2004). Meat quality characteristics of blesbok (*Damaliscus dorcas phillipsi*) and red hartebeest (*Alcelaphus buselaphus caama*) meat. M. Consumer Sc. (Food) thesis. Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Smith, L.A., Simmons, S.L., McKeith, F.K., Betchel, P.J. and Brady, P.L. (1984). Effects of sodium tripolyphosphate on physical and sensory properties of beef and pork roasts. *Journal of Food Science* 49, 1636-1637.

Steenkamp, J. E. M. (1997). Dynamics in consumer behaviour with respect to agricultural and food products. In: B. Wierenga, A. van Tilburg, K. Grunert, J.E.M. Steenkamp, & M. Wedel (Eds.). *Agricultural marketing and consumer behaviour in a changing world* (pp. 143-188). Boston: Kluwer academic publishers.

Stevenson, J.M., Seman, D.L. & Littlejohn, R.P. (1992). Seasonal variation in venison quality of mature, farmed red deer stags in New Zealand. *Journal of Animal Science* 70, 1389-1396.

Swatland, H.J. (1984). *Structure and development of meat animals*. Ontario Agricultural College, University of Guelph, Englewood Cliffs, NY: Prentice Hall.

Talbot, L.M., Payne, W.J.A., Ledger, H.P., Verdcourt, L.D. & Talbot, M.H. (1965). *The meat production potential of wild animals in Africa. A review of biological knowledge. Technical Communication No. 16*. Commonwealth Agricultural Bureaux, Farnham.

Van Zyl, L. & Ferreira, A.V. (2004). Physical and chemical carcass composition of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*). *Small Ruminant Research* 53, 103-109.

Van Zyl, J.H.M., Von la Chevallerie, M. & Skinner, J.D. (1969). A note on the dressing percentage in the springbok (*Antidorcas marsupialis*) and impala (*Aepyceros melampus*). *Proceedings of the South African Society for Animal Production* 8, 199-200.

Von la Chevallerie, M. (1972). Meat quality of seven wild ungulate species. *South African Journal of Animal Science* 2, 101-103.

Webb, R. (2001). It's all in the game. *Diabetes Forecast* 54, 30-33.

Wheeler, T.L., Koohmaraie, M. & Shackelford, S.D. (1997). Effect of post-mortem injection time and postinjection ageing time on the calcium-activated tenderisation process in beef. *Journal of Animal Science* 75, 2652-2660.

Chapter 2

Literature review

1. Game meat image

Unfortunately the image of game meat has suffered greatly because of ignorance. While consumers are left ill-informed about other aspects such as sensory qualities and preparation methods, the cause of game meat is not helped at all (Webb, 2001; Hoffman, Muller, Schutte and Crafford 2004; Bronkhorst, 2005). This ignorance on the handling and preparation of game has mainly caused game meat to have a fairly negative connotation regarding eating quality. Because consumers are unsure of how to prepare game meat, they often end up with "tough, dry and chewy meat" according to Webb (2001), since that is what game meat is reduced to by incorrect preparation and cooking techniques. Of all the participants of their survey, Hoffman, Crafford, Muller and Schutte (2003) stated that European tourists visiting South Africa had the most knowledge about the health benefits and sensory properties of game meat.

While working on nyala (*Tragelaphus angasii*), Jansen van Rensburg (2001) listed three factors that contribute to consumers' dislike in venison: improper preparation and cooking procedures can result in tough and dry meat and generally results in a bad eating experience; incorrect handling and care during harvesting can, among other things, result in a strong "gamey" flavour, which is not preferred by most consumers; and most consumers are apprehensive about trying new or unfamiliar things, especially food products, and game meat is not quite as common as beef, pork or chicken and therefore some consumers may harbour a preconceived dislike of game meat without ever trying it. Something that closely relates to this last point is the emotional connotation many consumers have with game meat (or any meat, for that matter). McCarthy, de Boer, O'Reilly and Cotter (2003) reported that consumer concern with animal welfare and environmental issues were found to be responsible for a reduction in the consumption of red meat in Ireland and the rest of Europe. Participating consumers associated conventional farming practices with environmental damage, as well as maltreatment of animals. This confirmed the findings of Issanchou (1996) that consumers would lower their meat consumption, or even entirely stop eating meat, when their concerns about animal welfare are not placated by perceived improvement in animal treatment and meat production systems.

In a survey on game meat (Hoffman *et al*., 2003), tourists to South Africa were asked their opinions on game meat. All 60 participants had eaten game before and 90% liked the taste of game meat, while 2% stated that they would eat game in South Africa because it is meat typical to Africa. Most tourists (87%) stated that they would eat game meat again. Some

respondents (3%) claimed that they would not eat game again, as they were afraid some wildlife species might become extinct. Warthog (13%), springbok (12%) and kudu (10%) were the most popular South African game species consumed by most tourists. In the survey performed on South African consumers (Hoffman *et al*., 2003), 73% of the meat-eating group had eaten game meat, and the game species most frequently consumed were springbok and kudu. This survey found that local consumers thought game meat too expensive and 76% of consumers were not willing to pay more for game meat than for other meat types.

When tourists were asked to comment on the possible health benefits they thought game meat held, 80% stated that game meat definitely has health benefits, including being low in fat (32%), cholesterol (32%) and kilojoules (32%). The fact that game meat was not at all associated with BSE was also mentioned (Hoffman *et al*., 2003). When local consumers were asked to comment on positive and negative attributes of game meat, the top three positive characteristics were healthfulness (25%), leanness (23%) and taste (14%), while the top three negative characteristics were price (19%), taste (18%) and lack of availability (12%). When respondents were questioned on the possible health benefits of game meat, 48% thought that game meat will benefit health, and low fat (83%) and cholesterol (7%) content were listed as the top beneficial attributes (Hoffman, Muller, Schutte, Calitz and Crafford, 2005).

Bronkhorst (2005) stated that local (South African) consumers were not acquainted well enough with the use of game meat as part of their weekly menu. He blamed the ignorance of consumers with regard to game meat and the fact that there is no controlling or governing body that controls the game meat industry, therefore, game meat quality is perceived as being unreliable.

In addition to the health benefits, game meat can be considered an “untainted” meat source since it contains no added antibiotics, growth hormones or other chemicals regularly used in conventional farming systems. The following principles were compiled from the work of Lampkin and Padel (1994) and Madge (1995) as part of the basis of organic agriculture: farming methods should co-exist with natural systems; there should be minimal damage to the environment; mineral fertilisers should be avoided; agro-chemical pesticides are prohibited; and attention should be given to the impact of farming on the environment and the conservation of wildlife and natural habitats. Free-range game farming, as mostly found throughout South Africa, can therefore be considered as organic agriculture and thus, game meat is an organic product (Pauw, 1993; Hoffman and Bigalke, 1999; Webb, 2001; Jansen van Rensburg, 2001). Nowadays organic food products are in high demand by consumers and therefore marketing game meat as an organic product may positively influence game meat consumption.

2. Game meat as a 'healthier' red meat

Schönfeldt (1993) noted that red meat consumption in South Africa and in other countries has been steadily declining in favour of white meat and other non-meat protein sources. People are becoming more concerned about the quality and safety of their food and consumers' growing health concerns have led them to demand low kilojoule, low cholesterol products (Dransfield, 2001). Higgs (2000) reported that red meat has gotten a bad reputation health-wise even though it was traditionally seen as an essential part of a balanced diet. This shift in consumers' perception of the role that meat plays in their health has been attributed to the negative image of meat because of its fat content and composition. Many factors have led to this negative image of red meat: formal reports such as those from COMA (1984) and the WCRF (as cited by Higgs, 2000) that incorrectly appointed red meat as the main culprit leading up to various adverse health conditions; foot-and-mouth-disease outbreaks among meat animals in various countries; BSE scares; and concerns about hormone-use as growth stimulators (Swatland, 1984; Higgs, 2000).

2.1. Fat content

According to nutritional guidelines, dietary fat should provide 15-30% of the total calorie-intake and saturated fats should not exceed 10% of the caloric intake (Chizzolini, Zanardi, Dorigoni and Ghidini, 1999). Melanson, Gootman, Myrdal, Kline and Rippe (2003) reported that many people believe red meat (especially beef) to be unsuited for a balanced, weight-loss diet since red meat is associated with obesity because of its total dietary fat and saturated fat content. Because obesity has been linked with dietary fat intake, it has long been suggested that red meat intake be decreased or eliminated from the diet.

Due to all the inconsistent recommendations surrounding red meat consumption in weight-loss programmes and diets designed to minimise the risk of cardiovascular disease, Melanson *et al.* (2003) tested the effects of red meat versus white meat as the protein source in a hypocaloric diet. A 12-week hypocaloric diet with either lean beef or chicken as primary protein source was followed and it was found that there was significant weight loss in both groups, with results between groups being similar. The total body fat percentages as well as the total and low-density lipoprotein (LDL) cholesterol were significantly reduced within both lean beef- and chicken consumption groups and there were no differences between groups. They found that the major fatty acid found in beef, stearic acid, did not have the same hypercholesterolemic effects that other saturated fatty acids have shown and it has been postulated that other meat components, such as conjugated linoleic acid (CLA) and arginine might be beneficial for cardiovascular health. Higgs (2000) also reported that CLA is only found in useful amounts in meat (particularly from ruminants) and dairy products. Conjugated linoleic acid is a mixture of geometric and positional isomers of linoleic acid in meat and 76-93% of it is in the form of cis-9, trans-11-octadienoic acid.

The lipid hypothesis focussed attention on the dietary fat contributed by meat and reports such as the COMA report on coronary heart disease (COMA, 1984) also pointed at meat as the main source of saturated fatty acids. Epidemiologically, regular red meat consumption became linked to increased cardiovascular disease risk, a stigma that still sticks to red meat (Higgs, 2000; Melanson *et al.*, 2003). Higgs (2000) stated that the reports by the WCRF (as cited by Higgs, 2000) and COMA (1984) implicated meat in the development of various cancers, especially colorectal cancer, and many people believe red meat to be associated with cancer (Melanson *et al.*, 2003). Chizzolini *et al.* (1999) also reported that there appear to be relationships between a high fat intake, particularly saturated fat, and an increased risk of cancers such as colon and breast cancer. However, there is no sufficient scientific evidence to link meat directly with human cancers (Higgs, 2000).

The average fat content of most game species has been recorded to be less than 3% (Von la Chevallerie, 1972; Kroon, Van Rensburg and Hofmeyr, 1972; Schönfeldt, 1993; Pauw, 1993; Hoffman, 2000) and is therefore much lower than meat from domesticated species (Table 1). Although Van Zyl and Ferreira (2004) reported fat percentages as high as 4.6% for whole blesbok carcasses, it is still much lower than red meat from domesticated meat animals. From the values in Table 1 it is clear that both springbok and blesbok contain the lowest amount of fat (1.7%) from all species evaluated.

Table 1 Nutritional value of seven game species compared to that of domesticated meat species.

Species	Moisture (g/100g)	Protein content of carcass (g/100g)	Fat content of buttocks (g/100g)
Springbok	74.7[1]	23.7[3]	1.7[1]
Eland	75.8[1]	-	2.4[1]
Impala	75.7[1]	22.5[3]	1.4[1]
Blesbok	75.5[1]	23.5[3]	1.7[1]
Gemsbok	75.9[1]	-	1.9[1]
Hartebeest	76.3[1]	-	2.0[1]
Black Wildebeest	77.0[1]	-	2.3[1]
Mutton	60.7[2]	13.9[2]	21.6[2]
Ostrich	76.3[2]	21.1[2]	3.1[2]
Pork	55.0[2]	13.9[2]	17.6[2]
Beef	65.4[2]	19.2[2]	14.2[2]

([1]Von la Chevallerie, 1972; [2]Sayed, Frans and Schönfeldt 1999; [3]Van Zyl and Ferreira, 2004)

As can be seen from the work of McCane and Widdowson (1991, as cited by Elliot, 1993), the fat content of venison is much lower than that of other red meat and it is even lower than skin-on roast chicken (Table 2). The fact that skinless roast chicken, commonly assumed to be

the meat with the lowest fat content, contains only 1g/100g less fat than venison shows that venison can compete with so-called low-fat meat types such as chicken.

Table 2 Nutritional information on cooked meat from several meat species.

	Fat (g/100g)	Protein (g/100g)	Energy (kcal)	Water (g/100g)
Venison (haunch roast)	6.4	35.0	198	56.8
Beef (topside roast)	12.0	26.6	214	60.2
Lamb (leg roast)	17.9	26.1	266	55.3
Pork (leg roast)	26.9	19.8	286	51.9
Chicken (roast, skin-on)	14.0	22.6	216	61.9
Chicken (roast, meat only)	5.4	24.8	148	68.4

(From McCane and Widdowson, 1991, as referenced by Elliot, 1993)

When the fat content from venison is compared with that of the game species commonly found in South Africa (Tables 1 and 2), it is remarkable how much lower South African game meat (from all game species evaluated) is in fat content. This alone should merit further investigation into the marketing of South African game meat.

Since it has been shown by several authors (Higgs, 2000; Melanson *et al.*, 2003) that lean meat has a positive influence on health, game meat could be considered as the healthier red meat and a definite threat to white meat (specifically chicken) as the overall healthiest meat available.

2.2. Cholesterol content

Chizzolini *et al.* (1999) reported that most nutritional guidelines advised that cholesterol-intake should not exceed 300mg per day. Serum cholesterol has been associated with chronic heart disease for quite some time, although it has recently been shown that dietary cholesterol had only little effect on serum and low-density lipoprotein (LDL) cholesterol levels. Higgs (2000) stated that consumers associate meat with cholesterol, no matter what the scientific evidence shows, and that cholesterol content is just another black spot on the image of meat. Cholesterol is an essential constituent of animal cells and therefore dietary cholesterol is stringently linked with foods of animal origin.

Nelson, Schmidt and Kelley (1995) confirmed that blood LDL cholesterol levels appeared to be unaffected by the fat calories (either saturated or unsaturated) in the diet. These authors suggested that the changes in blood cholesterol levels could actually be ascribed to the ratio of fatty acids in the diet. Chizzolini *et al.* (1999) reported that cholesterol content differences between breeds, sexes or feeding regimes are small compared to the differences that have been noticed between muscle types. Lower cholesterol content was found in predominantly

white muscle (e.g. *M. longissimus lumborum* in pigs) compared to predominantly red muscle (e.g. *M. semispinalis capitits* in pigs). Oxidative muscles contain more phospholipids and the higher the phospholipid contents of the muscle, the higher its cholesterol content. Muscle total cholesterol content varied between 61.0 mg/100g and 63.5 mg/100g, while adipose total cholesterol levels were between 113 mg/100g and 121 mg/100 g (Hoelscher, Savell, Harris, Cross and Rhee, 1987; Chizzolini *et al.*, 1999). This shows that lean meat intake would have an almost negligible effect on cholesterol levels and might even positively influence lipid biochemistry by lowering saturated and increasing polyunsaturated fatty acids because the polyunsaturated fatty acids are part of the structural components of membranes and their absolute values cannot change (Chizzolini *et al.*, 1999). Higgs (2000) also found that the inclusion of beef fat increased blood cholesterol levels, but that lean beef as part of a low fat, low saturated fat diet reduced plasma cholesterol and LDL-cholesterol levels similarly to equal amounts of fish and chicken.

Elliot (1993) found venison to have a cholesterol content that was half that of lamb and beef, in both wet fat and lean tissue.

2.3. Fatty acid composition

As reported, the fatty acid composition of meat, particularly the ratio of polyunsaturated fatty acids to saturated fatty acids, is more important for health reasons than the total fat content (Nelson *et al.*, 1995; Chizzolini *et al.*, 1999; Higgs, 2000). Schönfeldt (1993) mentioned that a dietary decrease of saturated fatty acids, especially myristic and palmitic acids, is associated with lower blood serum cholesterol, which ultimately leads to a decrease in the risk of cardiovascular disease. Thus, it is imperative to know the fatty acid composition of meat from different species so that an informed choice regarding the best protein source can be made. Several authors (Schönfeldt, 1993; Viljoen, 1999; Hoffman, 2000) have commented on the high levels of polyunsaturated fatty acids in game meat – higher polyunsaturated fatty acid levels and lower saturated fat contents than beef – as part of its claim as a 'healthier' red meat (Table 3).

Springbok meat contains a high percentage of arachidonic acid (C20:4) – this poly-unsaturated fatty acid has the ability to lower serum cholesterol (Viljoen, 1999). Springbok also has lower palmetoleic acid (C16:1) levels. Palmetoleic acid has cholesterol increasing properties.

As stated by Elliot (1993): "For those wishing to eat meat, nothing could be better than to consider the merits of venison." People used to eating red meat often find it difficult to keep to a diet of fish and chicken when they are advised to follow a low-fat, low-cholesterol diet.

Table 3 Fatty acid content of several game species compared to some domesticated species.

Fatty acid (%)	Springbok	Blesbok	Black Wildebeest	Mountain reedbuck	Red Hartebeest	Beef	Lamb	Pork
Myristic (14:0)	-	-	-	-	-	2.660 ± 0.540[4]	3.30 ± 1.07[4]	1.330 ± 2.20[4]
Palmitic (16:0)	13.931 ± 1.20[1]	16.44 ± 3.50[2]	0.69[3]	16.12[3]	18.27 ± 4.25[2]	25.000 ± 1.770[4]	22.2 ± 1.56[4]	23.200 ± 1.46[4]
Palmetoleic (16:1)	0.067 ± 0.03[1]	0[2]	6.16[3]	0.18[3]	0[2]	4.540 ± 0.810[4]	2.20 ± 0.26[4]	2.710 ± 0.45[4]
Arachidonic (20:4)	9.304 ± 0.73[1]	10.96 ± 3.40[2]	0.06[3]	7.72[3]	7.01 ± 2.92[2]	0.630 ± 0.210[4]	0.64 ± 0.23[4]	2.210 ± 0.73[4]
Linoleic (18:2n-6)	21.615 ± 1.33[1]	18.89 ± 4.48[2]	8.85[3]	20.45[3]	14.55 ± 5.94[2]	2.420 ± 0.630[4]	2.70 ± 0.86[4]	14.200 ± 4.09[4]
α-Linolenic (18:3n-3)	3.371 ± 0.29[1]	3.72 ± 1.28[2]	7.11[3]	4.57[3]	4.06 ± 1.74[2]	0.700 ± 0.180[4]	1.37 ± 0.48[4]	0.950 ± 0.33[4]
SFA	41.108 ± 2.11[1]	-	42.58[3]	38.47[3]	-	-	-	-
MUFA	20.994 ± 2.10[1]	-	14.28[3]	17.27[3]	-	-	-	-
PUFA	36.342 ± 3.37[1]	-	43.14[3]	44.15[3]	-	-	-	-
P:S	1.141 ± 0.13[1]	1.00 ± 0.39[2]	1.09[3]		0.75 ± 0.46[2]	-	-	-
n-6:n-3	3.278 ± 0.12[1]	3.62 ± 0.75[2]	2.82[3]		2.75 ± 0.36[2]	-	-	-

([1] Kroucamp, 2004; [2] Smit, 2004; [3]Van Schalkwyk, 2004; [4]Enser, Hallett, Hewett, Fursey, Wood and Harrington, 1998)

Elliot (1993) has shown that venison compares favourably with chicken in fat content, has the highest protein and lowest energy content of all the meats evaluated, has a low cholesterol count that is about half the value of the cholesterol content found in beef and lamb, and has a very high polyunsaturated fatty acid to saturated fatty acid ratio.

The health benefits of game meat remain largely unknown to most consumers. Of the total group of respondents polled by Hoffman *et al*. (2005) 47.7% thought that game meat might have health benefits and 83.2% of these consumers thought game meat to be low in fat, while 7% thought it had a low cholesterol content. Their research also indicated that 52.6% of all the respondents would buy game meat more often if they were given more information on its health benefits.

3. Game species

In lists compiled of the most common and most favoured game species to farm with in South Africa, springbok ranks first, while blesbok seems to be in the top four (Conroy and Gaigher, 1982; Jansen van Rensburg, 1997). Hoffman and Bigalke (1999) and Jansen van Rensburg (1997) found springbok to be the most frequently cropped species in South Africa. In a study that included game meat consumption of South African consumers, Hoffman *et al*. (2005) found that most consumers had eaten springbok meat on a previous occasion and that springbok was one of three game meat species regularly available in supermarkets, butcheries and restaurants.

3.1. Blesbok (Damaliscus dorcas phillipsi)

The blesbok is a large antelope and is very similar to the bontebok (Hanks, 1983). Smithers (1983) recorded blesbok live weight as 61kg for females and 70kg for males, which falls in the range of 58-86kg reported by Kroon *et al*. (1972) and is similar to the live weights reported by other authors (Huntley, 1971; Conroy and Gaigher, 1982; Smit, 2004). Carcass yield reported for blesbok lies in the range of 49-55% (Huntley, 1971; Conroy and Gaigher, 1982; Van Zyl and Ferreira, 2004).

3.2. Springbok (Antidorcas marsupialis)

The springbok is a medium-sized antelope (Hanks, 1983) and compared to six other wild game species, springbok meat performed the best in the quality tests conducted by Von la Chevallerie (1972). Springbok live weights was found to be around 37kg for females and 41kg for males (Smithers, 1983), with a total live weight range of 27-37kg (Conroy and Gaigher, 1982; Van Zyl and Ferreira, 2004). The carcass yield for springbok is shown to be around 56-58% (Van Zyl, von la Chevallerie and Skinner, 1969; Conroy and Gaigher, 1982; Van Zyl and Ferreira, 2004).

4. Species differences in meat composition

4.1. Proximate composition

There are very definite differences in the proximate composition of game species vs. other ruminant (domesticated) species (Table 4). For example, Jansen van Rensburg (2001) reported nyala (*Tragelaphus angasii*) meat contained 10% more protein than beef, while having significantly lower cholesterol levels, kilojoules and fat contents.

Table 4 Differences in the proximate meat composition of game, sheep and beef.

Characteristic	Game meat (%)	Sheep (%)	Beef loin (%)
Protein	22.1 – 24.2[1]	14.5 – 18.5[2]	19.4 ± 0.4[3]
Moisture	58.4 – 65.0[1]	52.0 – 58.0[2]	77.5 ± 0.4[3]
Ash	6.1 – 7.5[1]	4.0 – 4.9[2]	1.1 ± 0.05[3]
Fat	1.3 – 9.0[1]	17.0 – 25.0[2]	0.4 ± 0.06[3]

([1]Van Zyl and Ferreira, 2004; [2]Kirton and Barton, 1962; [3]Onyango, Izumimoto and Kutima, 1998)

4.2. Fat and fatty acids

Several authors have reported the much lower fat content of game meat compared to domesticated meat species (Schönfeldt, 1993; Jansen van Rensburg, 2001; Van Zyl and Ferreira, 2004). Dhanda, Taylor and Murray (2003) did, however, note that goat meat is also low in fat and high in protein when compared to sheep (at similar ages), but there were also marked differences between goat genotypes. While the fat content of game meat is usually described as being in the range of 1.0-9.0%, Enser, Hallett, Hewett, Fursey, Wood and Harrington, (1997a) reported much higher fat contents for beef (15.6%), lamb (30.2%) and pork (21.1%).

Pig fat is less firm (hard) than the fat tissue of ruminants because its fatty acid profile contains more unsaturated fatty acids, while ruminant fat contains more saturated fatty acids (Wood *et al*., 2004). While studying the fatty acid composition of ruminants (beef and lamb) and pigs, Wood *et al*. (2004) observed the n-6:n-3 ratio to be less (thus, more favourable) in ruminants, because of its lower amount of C18:2 than in pork and its higher levels of n-3 polyunsaturated fatty acids, especially C18:3. The n-6:n-3 values of loin muscle were reported by Enser, Hallett, Hewett, Fursey and Wood (1996) to be much lower in beef (2.1) and lamb (1.3) than in pork (7.2), which shows that in this regard ruminant meat complies better to the recommended value of 4.0 or less stipulated by the UK Department of Health (1994). Pork has a higher polyunsaturated to saturated fatty acid (P:S) ratio, mainly because of the higher

levels of C18:2 – this was suggested to be the result of the cereal-based diet pigs are fed. These findings also confirmed the findings of Enser *et al*. (1996).

Enser, Hallett, Hewett, Fursey, Wood and Harrington (1997b) also suggested that ruminants had a lower P:S ratio because dietary unsaturated fatty acids are hydrogenated in the rumen, whereas pigs deposit unsaturated fatty acids virtually unchanged. According to the UK Department of Health (1994) the P:S ratio of beef and lamb is considered as unfavourably low, as the recommendation is 0.45 or higher for the whole diet. The P:S ratio for beef (0.11) and lamb (0.15) were found to be much less than that of pork (0.58) (Enser *et al*., 1996). Conjugated linoleic acids (CLA) are produced naturally by ruminants and may be beneficial in human health (Enser, 2001).

4.3. Cholesterol content

The cholesterol content of various meat species differ tremendously (Table 5) and depending on the tissue type (lean muscle vs. fat), the amount of cholesterol actually consumed may also differ greatly. In animals, cholesterol is an integral part of cell membranes and therefore the cholesterol content of meat cannot be lowered too much without compromising cell membrane integrity.

Table 5 Fat and Cholesterol content in meat and fat of several meat species.

Species	Fat (%)	Cholesterol (mg/100g^{-1})
Beef (muscle) [1]	1.90	60.00
Veal (muscle) [1]	0.81	70.00
Pork (muscle) [1]	1.86	65.00
Mutton (fillet) [1]	3.41	70.00
Chicken (average) [1]	5.60	81.00
Chicken (breast without skin, average) [2]	0.70	43.40
Turkey (average) [1]	15.00	74.00
Turkey (breast without skin, average) [2]	1.00	44.00
Lamb (intermuscular fat) [1]	68.30	75.00
Beef (intermuscular fat) [1]	70.90	99.00
Pork (intermuscular fat) [1]	76.70	93.00
Black wildebeest (muscle, male) [3]	0.97	46.05
Blesbok (muscle, male) [4]	0.76	51.38

([1] Chizzolini *et al*., 1999; [2]Honikel and Arneth, 1996; [3]Van Schalkwyk, 2004; [4]Smit, 2004)

As shown above, both black wildebeest and blesbok contain lower cholesterol levels than any of the traditional red meat species and show lower cholesterol levels than chicken and turkey. However, once skinless chicken and turkey breasts are considered, the cholesterol levels of these two species are lower than the two game meat species shown. This shows that game

meat can compete favourably with meat from other species where cholesterol content is considered.

4.4. Myoglobin

Meat colour differs amongst species mostly because of the difference in myoglobin content (Young and West, 2001). Species or breeds that underwent intensive selection over the years, such as most commercial pig and chicken breeds, usually have paler meat. When selecting for an increased muscle protein quantity, myoglobin content is not increased similarly to protein, which leads to a lesser overall myoglobin concentration in these breeds.

South African game animals roam freely and have to forage for food, since they do not receive supplementary food and generally have to fend for themselves, unlike domesticated meat animals which are normally kept in pens or feedlots. Game animals, thus have higher amounts of myoglobin in their muscles because of the exercise involved in foraging, since the myoglobin quantity is also influenced by muscle activity and exercise (Hoffman, 2001; Young and West, 2001).

5. Muscle differences

5.1. Individual muscles

The *M. longissimus thoracis et lumborum* (also known as the *M. longissimus et lumborum* or *M. longissimus dorsi*) is considered to be a ribcage (thoracic region) and a loin (lumbar region) muscle, because of its length, and provides the round of meat in chops and steaks cut from the posterior rib and loin (Swatland, 1994). It is a compound muscle formed by subunits, each of which stretches over several vertebrae and helps with the flexibility of the vertebral column. Because of its compound nature and its length, the *M. longissimus et lumborum* shows qualities usually associated with either ribcage or loin muscles and therefore its characteristics may differ widely throughout the muscle. The muscle increases in width towards the posterior part of the ribcage, but through the loin the cross-sectional area remains unvarying. The muscle fibre bundles are angled towards the vertebral column. Swatland (1994) describes muscles from the ribcage as having intermediate levels of tenderness, while loin muscles are tender with a desirable taste.

The *M. supraspinatus* is a shoulder muscle found dorsally to the spine (Swatland, 1994). It has an intermediate level of tenderness and generally needs to be cooked completely to make it tender.

The *M. biceps femoris,* as well as the *M. semitendinosus*, is located in the hind limb (Swatland, 1994). These muscles are quite large and are considered to be moderately tender. While the *M. biceps femoris* appears to be made up of two parts divided by a deep

cleft, it is actually a single muscle even though the smaller segment is often paler in colour. It can be found on the lateral side, while the *M. semitendinosus* can be found on the posterior side of the hind limb. Paul (1963) described the *M. biceps femoris* as having a mealy texture after cooking, which can be related to pronounced granulation of the collagen structure of the muscle fibres because of cooking.

5.2. Muscle tenderness

The different muscles have different levels of tenderness and Shackelford, Wheeler and Koohmaraie (1995) found the *M. longissimus dorsi* to rank higher than *M. semitendinosus* and *M. supraspinatus* (ranked equally), which in turn ranked higher than *biceps femoris* in overall tenderness. Olsson, Hertzman and Tornberg (1994) also found *M. biceps femoris* to have a lower overall tenderness score than *M. semitendinosus*, while Shorthose and Harris (1990) reported no significant differences between the tenderness of these two muscles. The latter authors found that *M. semitendinosus* and *M. longissimus dorsi* tenderness was similar in cattle at 10 months of age, but when muscles from cattle older than 24 months were compared the *M. semitendinosus* muscle was much less tender ($P<0.01$). In the Shackelford *et al*. (1995) study, Warner-Bratzler shear force values did not detect any differences between the muscles (Table 6).

Table 6 Mean values found in overall tenderness and Warner-Bratzler shear force values for different beef muscles (SD = Standard deviation).

	Overall tenderness (8 point scale) (1=extremely tough; 8= extremely tender)				Warner-Bratzler shear force (kg)			
Muscles	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Biceps femoris	5.0	0.6	3.2	6.1	4.3	0.8	3.2	6.0
Longissimus dorsi	6.5	0.8	5.1	7.4	4.1	1.1	2.7	6.7
Semitendinosus	5.7	0.4	4.8	6.4	4.1	0.7	3.3	5.8
Supraspinatus	5.6	0.6	4.6	6.8	4.3	0.9	3.0	5.8

(Shackelford *et al*., 1995)

Shackelford *et al*. (1995) found that the myofibrillar component of tenderness, or ease of fragmentation, described more of the variation in overall tenderness than the amount of connective tissue could and that ease of fragmentation followed the same trend as overall tenderness in the different muscles. The shear force of the *M. longissimus dorsi* could not be highly related to the shear force of other muscles (Shackelford *et al*., 1995).

While studying the course of rigor mortis, ageing and tenderness in beef *M. semimembranosus* and *M. longissimus dorsi*, Olsson *et al*. (1994) found that shear force values of *M. longissimus dorsi* are low after only two days (at 7 and 10 ºC) and that there is a greater reduction in shear force values of *M. longissimus dorsi* than in *M. semimembranosus*

between days two and 15 (at 14 ºC). This led them to believe that the ageing process is more active in *M. longissimus dorsi* than *M. semimembranosus*, which means that *M. longissimus dorsi* is more tender after ageing.

M. rectus femoris and *M. semitendinosus* were rated as having the highest sensory tenderness of five sheep muscles examined by Jeremiah, Smith and Carpenter (1971).

Cover, Ritchey and Hostetler (1962c) reported *M. biceps femoris* fragmented more easily than *M. longissimus dorsi* at 80 and 100ºC. It was also reported that there was less adhesion between the muscle fibres of *M. biceps femoris* than that of *M. longissimus dorsi*. The trend of muscle fibres to become more easily fragmented and to adhere less to each other with increased internal temperature is a tendency towards tendering with heat.

5.3. Connective tissue and muscle tenderness

Connective tissue plays a part in tenderness, but because factors such as gender, age, species and breed can greatly influence the connective tissue content of meat as well as the solubility of the collagen component, the exact impact of connective tissue on muscle tenderness cannot really be generalised, but has to be ascertained for each specific sample. Jeremiah, Dugan, Aalhus and Gibson (2003b) found that the most tender muscles (e.g. *M. triceps brachii* and *M. ilio-psoas*) contained very low (<30µmol/g) levels of insoluble hydroxyproline.

5.4. Fatty acid differences between muscles

Muscle types differ in fatty acid content – red oxidative muscles have a higher concentration of phospholipids than white muscles. Enser *et al*. (1998) chalks fatty acid differences between muscles up to their differences in phospholipid concentration and levels of intramuscular fat.

Lengyel, Husvèth, Polgar, Szabo and Magyar (2003) found the *M. longissimus* of bulls contained lower levels of polyunsaturated fatty acids than *M. semitendinosus*, although the concentrations of saturated and mono-unsaturated fatty acids were much higher in the *M. longissimus dorsi*. These findings show that muscles that consist predominantly of red oxidative fibres (e.g. *M. semitendinosus*) have higher levels of polyunsaturated fatty acids than muscles low in red oxidative fibres (e.g. *M. longissimus dorsi*).

5.5. Cholesterol differences between muscles

In beef *M. longissimus dorsi* the majority (60-80%) of total cholesterol is located in the membrane component and 20-40% in the cytoplasmic component (Hoelscher *et al*., 1987). The reverse was found in the subcutaneous fat, with the majority (88-92%) of total cholesterol found in the cytoplasm and 8-12% in the membrane component.

5.6. Muscle colour

Young and West (2001) states that colour differences between muscles are because of myoglobin and iron differences. The differences in myoglobin concentration between muscles often relate to the function of the muscle, which translates into muscles used in a repetitive action (e.g. diaphragm used for breathing) containing higher myoglobin concentrations and thus appearing redder than muscles used less often.

Muscles using glycolysis as an energy mechanism contain low levels of myoglobin as opposed to muscles using oxidative metabolism, which contain high levels of myoglobin. Muscles rich in myoglobin also contain more mitochondria and cytochromes because of oxidative metabolism (Young and West, 2001). Wheeler, Koohmaraie and Shackelford (1997) found *M. longissimus dorsi* to have the greatest colour stability during display than other beef muscles. Young and West (2001) reported muscles with low colour stability contained high metmyoglobin-reductase activity, with high oxygen-consumption rates.

5.7. The effect of age on muscles

With increased age and increased weight, tissue proportions in the animal's body changes, with muscle and bone proportions decreasing as fat proportions increases. Most muscles are affected by age with regard to its different characteristics. In general muscles become tougher with age. This increased toughness is related to the connective tissue strength and that is why Shorthose and Harris (1990) found beef *M. biceps femoris*, which have high connective tissue strength, trebled in toughness with increased age. In direct opposition to that, the tenderness of the *M. psoas major* was found to be virtually unchanged by increased age.

Total intramuscular lipid content and fatty acid composition are also affected by slaughter age (Lengyel *et al*., 2003). These authors found that with increased age the proportions of saturated and mono-unsaturated fatty acids in the total lipid content increased, while polyunsaturated fatty acids decreased for all muscles analysed. The *M. semitendinosus* had lower total lipid content at all slaughtering ages than the *M. longissimus dorsi* and *M. psoas major*. The *M. longissimus dorsi* showed higher intramuscular lipid content at slaughter ages of 14 and 19 months than at 7 months. All muscles had significantly higher levels of saturated fatty acids at 14 and 19 months than at a slaughter age of 7 months of age and the percentage polyunsaturated fatty acids decreased markedly between 7 and 14 months of age. The polyunsaturated fatty acids mostly affected were linoleic (C18:2n-6) and arachidonic (C20:4n-6), which decreased (Lengyel *et al*., 2003).

5.8. Muscle shortening

M. longissimus dorsi has a higher level of cold shortening than *M. semimembranosus*, because it has more oxidative fibres (Olsson *et al.,* 1994). On the other hand, the *M.*

semitendinosus reaches constant shortening earlier than *M. semimembranosus* or *M. biceps femoris* even though its shortening process starts later than the latter two muscles (Hertzman, Olsson and Tornberg, 1993). This happens because the *M. semitendinosus* contains the most white (rapid) fibres and predominantly white muscles have a longer delay phase than muscles containing more red fibres.

5.9. Juiciness and marbling fat

M. biceps femoris and *M. rectus femoris* were rated juiciest, *M. semimembranosus* received intermediate ratings and *M. semitendinosus* and *M. vastus lateralis* were rated least juicy when these five sheep muscles were investigated (Jeremiah *et al*., 1971). Sheep *M. semitendinosus* showed significantly more and *M. rectus femoris* had significantly less marbling than *M. biceps femoris* and *M. vastus lateralis* (Jeremiah *et al*., 1971). Marbling fat acts as lubrication during chewing and causes initial juiciness to be experienced, whereas the moisture left in meat after cooking is responsible for the awareness of prolonged juiciness (Warriss, 2000).

6. **Physical properties of meat**

6.1. Colour

Meat colour is one of the most important factors that consumers consider when purchasing meat. Consumers consider colour to be a particularly important indicator of meat quality and use colour as a cue for freshness (Jeremiah, Smith and Carpenter, 1972; Stevenson, Seman, Weatherall and Littlejohn, 1989; Wheeler, Koohmaraie and Shackelford, 1996a; Young and West, 2001; Mancini and Hunt, 2005). According to Issanchou (1996) consumers tend to favour normally coloured meat, rather than meat that is either too dark or too pale. Carpenter, Cornforth and Whittier (2001) established that there was a close relationship between colour preference and a consumer's decision to purchase beef and that consumers preferred bright red beef instead of purple or brown. The colour of meat is, unfortunately, influenced by a variety of factors, which can range from ante mortem stress to the type of myoglobin molecule primarily present in the cut of meat (Issanchou, 1996; Honikel, 1998; Lawrie, 1998).

6.1.1. Myoglobin

The redness of the meat of land mammals is chiefly caused by the pigment myoglobin, which is chemically very similar to haemoglobin (blood protein) and also contains iron bound in porphyrin (Young and West, 2001; Mancini and Hunt, 2005). The water-soluble myoglobin structure contains eight alpha helices, which are linked by short non-helical sections. Additionally, it contains a haeme ring with an iron atom in the centre – this iron atom can form six bonds: four with pyrrole nitrogens, one in co-ordination with the proximal histidine-93 and the 6^{th} site can reversibly bind with ligands (Mancini and Hunt, 2005). It is true that there is also haemoglobin present in muscle, but compared to the myoglobin content, it is fairly minimal. The primary function of myoglobin is to bind oxygen (O_2) temporarily in between

haemoglobin-bound O_2 in the blood and chemically reduced O_2 produced as water (H_2O) by mitochondrial respiration in the cells. Mancini and Hunt (2005) also mentioned that cytochrome C may play a minor role in beef, lamb, pork and poultry colour.

Lawrie (1998) observed that surface-appearance of meat is subject to the quantity of myoglobin, as well as the type of myoglobin, present in the meat, the chemical state of the myoglobin and also the chemical and physical state of other meat components.

Myoglobin concentration in the muscle generally depends on the activity level of the muscle, with highly active muscles generally containing more myoglobin (Honikel, 1998; Lawrie, 1998; Young and West, 2001). This generalisation carries over into other areas such as species, breed, age, type of muscle and training. Muscles such as the *M. longissimus dorsi* is less intensively used than the diaphragm, which is a highly active muscle, therefore, the diaphragm contains more myoglobin than the *M. longissimus dorsi*. Animals that are kept in relative confinement (i.e. a stall or pen) have less myoglobin than pasture-kept or free-range animals. Thus, game animals, which are generally free roaming, often have darker meat than their domesticated counterparts, since game animals have to forage for food and therefore exercise more, while domesticated animals are usually fed and exercise fairly little. Diet can also influence pigmentation, with diets low in iron causing lower myoglobin levels in the meat.

Oxymyoglobin is the most important chemical form of myoglobin in fresh, uncooked meat. Oxymyoglobin is formed by oxygenating myoglobin and occurs only on the surface of meat (Lawrie, 1998). The thickness of the oxymyoglobin layer (and thus, the depth to which O_2 penetrates the meat) may depend on several factors, such as the temperature, O_2 partial pressure and pH of the meat (Mancini and Hunt, 2005). This pigment is extremely important when taking consumer demands and perceptions into consideration as it represents the bright red colour that consumers want their meat to be (Lawrie, 1998). Cytochrome enzymes remain capable of O_2 utilization for quite some time post-mortem. O_2 diffuses into the meat for some distance from the exposed surfaces until a balance is reached between diffusion-rates and uptake by cytochrome enzymes.

The purplish-red colour associated with vacuum packaged meat or that occurs just after meat has been cut, is the result of deoxymyoglobin (Mancini and Hunt, 2005). When no ligand is bound to the 6^{th} binding site of the haeme ring and when the haeme iron is in the ferrous (Fe^{2+}) form, deoxymyoglobin occurs.

According to Lawrie (1998) brown pigmentation is a desirable attribute in cooked meat. Pigment conversion is affected by temperature in the following ways: beef cooked to an internal temperature of 60ºC has a bright red interior, internal temperatures of 60-70ºC

causes a pink interior and internal temperatures of 70-80ºC causes a greyish brown colour. Maillard-type reactions and caramelisation of carbohydrates also contribute to the brown colour of cooked meat.

There are a few undesirable colour-occurrences when dealing with meat, but metmyoglobin-formation is the most common of these. When about 60% of myoglobin appears in the metmyoglobin form, its brown colour is quite noticeable (Lawrie, 1998). Carpenter *et al.* (2001) found that, once metmyoglobin reaches 30-40% of the total amount of pigments on the surface of fresh beef, consumers will make a no-purchase decision. Metmyoglobin can be produced from myoglobin or oxymyoglobin and can be accelerated by, for example, low pH, heat, salts, lipid oxidation, microbial load and O_2-consumption rates. Low temperatures tend to delay metmyoglobin formation. Furthermore, Mancini and Hunt (2005) noted that metmyoglobin forming beneath the surface, can also influence meat appearance since it gradually thickens and moves to the surface of the meat.

6.1.2. Colour stability

Colour stability is very important, especially in retail display, and can be influenced by several factors, but is most often linked to oxidation. Sanchez-Escalante, Djenane, Torrescano, Beltran and Roncales (2001) observed that with time (thus, storage) metmyoglobin forms because of the oxidation of oxymyoglobin. This oxidation of oxymyoglobin to metmyoglobin has been described by several authors, including Lawrie (1998) and Wood *et al.* (2004). As previously mentioned, metmyoglobin has an unattractive brown colour which consumers usually discriminate against. Metmyoglobin reduction is important to ensure colour stability, which is why many studies research the effects of antioxidant addition to meat (Sanchez-Escalante *et al.,* 2001; Mancini and Hunt, 2005).

Different antioxidants have been tried and tested to varying degrees of success. So, for example, Sanchez-Escalante *et al.* (2001) found rosemary powder (1 000 ppm) extremely effective in inhibiting oxymyoglobin oxidation when used alone or in conjunction with ascorbic acid (500 ppm) in beef patties. When rosemary was used in conjunction with ascorbic acid, the relative metmyoglobin to total myoglobin ratio was significantly lower than in the untreated samples (Sanchez-Escalante *et al.*, 2001). After 20 days of storage, the treated samples reached and maintained critical, but still acceptable, metmyoglobin levels (30-40%). Rosemary alone could only cause beef patties to maintain non-critical metmyoglobin levels for up to eight days of storage, when 40% metmyoglobin was exceeded (still significantly lower than control samples), while ascorbic acid alone inhibited metmyoglobin formation effectively.

Samples treated with both rosemary and ascorbic acid displayed a* values that were significantly higher than control samples throughout the whole storage period investigated (Sanchez-Escalante *et al.*, 2001). During the first 12 days of storage, rosemary and ascorbic

acid also caused treated samples to attain significantly higher a* values when used alone and ascorbic acid had an additive effect on a* values when used in conjunction with the antioxidants taurine and carnosine. Ascorbic acid can act either as an antioxidant or as a pro-oxidant, depending on the presence of metal ions, the tocopherol content and the concentration in which ascorbic acid is added to the meat (Sanchez-Escalante *et al.*, 2001).

Mancini, Hunt, Kim and Lawrence (2004, as cited by Mancini and Hunt, 2005) reported that the regeneration of post-mortem NADH and metmyoglobin reduction involved lactate dehydrogenase, which caused the enhanced colour stability in a study on enhanced beef. It was suggested that the lactate dehydrogenase converted the lactate injected into post-mortem muscle to pyruvate and NADH. This additional pyruvate and NADH expanded the reducing equivalent pool of post-mortem muscle. This increased the metmyoglobin reducing activity and metmyoglobin was therefore chemically reduced, causing greater meat colour life.

Vitamin E has also been shown to delay colour oxidation (Wood *et al.*, 2004).

Diet can also influence colour stability, as has already been reported by Warren *et al.* (2002) through the difference between grass-fed and grain-fed cattle and the improved colour stability in grass-fed cattle. The bright red colour of oxymyoglobin in grass-fed beef, keeps longer in retail display than the colour of meat from grain-fed cattle (Warren *et al*., 2002). It was thought to be due to antioxidants in grass that caused vitamin E to be present in higher concentrations in grass-fed animals. Higher vitamin E-levels resulted in lower lipid oxidation and thus, better colour retention even though the grass-fed animals had higher levels of n-3 polyunsaturated fatty acids. The n-3 polyunsaturated fatty acids are more oxidisable than the n-6 polyunsaturated fatty acids, with the latter being higher in grain-fed animals (Warren *et al.*, 2002). Vatansever *et al*. (2000) reported decreased colour saturation in ruminants receiving a fish oil diet in which lipid oxidation was also the greatest.

Colour change (oxymyoglobin oxidation) usually precedes lipid oxidation (Wood *et al.*, 2004).

6.1.3. Colour measurement

Although meat colour can be measured both as a sensory attribute and as a physical attribute, it is most commonly measured objectively with a reflectance colorimeter as part of the physical analyses of meat. Measuring colour with an instrument is generally accepted as more objective and reproducible at different times and locations than using human taste panellists who can produce results that differ extensively (Young and West, 2001). These instrumental measurements are based on a three-dimensional 'colour space'.

Stevenson *et al.* (1989) noted the CIEL*a*b* (CIELAB) colour scale (Commission International De l'Eclairage, 1976) as appropriate for meat colour measurement. This was

confirmed by Honikel (1998) and this author explained the different measurement properties often used (Table 7) as well as the aspects of meat colour measured by them.

Table 7 Description of main measurement properties most commonly used in CIEL*a*b* colour measurement of meat.

Measurement property	Measurement taken	Scales / values used
L*	Lightness	0 = black 100 = white
a*	Redness and greenness (red-green value)	
b*	Yellowness and blueness (yellow-blue value)	
Hue angle (º)	Defines the colour	Calculated as $\tan^{-1}$ (b*/a*) Is determined by rotation about the a* and b* axes.
Chroma	Colour intensity	Calculated as $\sqrt{(a^{*2} + b^{*2})}$

(Honikel, 1998)

Stevenson *et al.* (1989) further explained that hue angle is increased as b* rotates towards a*. When a* and b* values are high, it results in higher saturation (higher chroma values) and the muscle will appear brighter. According to Onyango *et al.* (1998) this meat will have higher appeal and desirability to consumers because of its greater colour purity. It was also found that three component equations, rather than a trained colour panel, could be used and that a significantly better relationship was produced if L*, a* and b* values or L*, hue and chroma values were used instead of only one or two of these variables (Stevenson *et al.*, 1989).

Young and West (2001) stated that, although the meat surface mainly reflects light in a diffuse way, a minor amount of spectral reflectance from the glossy surface of wet (fresh, uncooked) meat does occur. There is also some light reflected internally since a part of the incident light is transmitted below the surface because of the partial translucency of meat. Meat grading scales often refer to the paleness or darkness, or to the chroma of meat samples.

Young and West (2001) reported that a* values and hue angle are both good indicators of meat discolouration. These authors observed that the a* values fell and hue angles increased as discolouration progressed in beef during retail display. It was also noted that chroma (colour intensity) drops and meat is seen as dull.

6.1.4. Game meat colour

Several authors have reported game meat (or venison) as being darker in colour than red meat from other meat animals (Hoffman, 2001; Young and West, 2001). Hoffman (2001) stated that, in South Africa, game meat is often perceived as having a dark, unattractive red

colour, linked to DFD (dark, firm, dry) meat. This author gave the explanation for DFD meat in game animals as being due to stress when harvested and explained that the normal, slightly darker red colour of game meat is due to the extensive way in which game is reared. Game animals are more active than traditional meat animals and therefore have higher myoglobin levels in their muscles.

Venison has a high tendency to form a brown colour and generally has a higher level of myoglobin than domesticated meat animals, therefore also appearing darker (Young and West, 2001). While investigating the properties of meat from black wildebeest and mountain reedbuck, Van Schalkwyk (2004) reported a series of colour findings (Table 8) noting, among other things, that game meat has lower L* values than other meat species which partly causes game meat to be perceived as darker than, for example, beef. The colour measurements for blesbok, as found by Smit (2004), are also shown.

Table 8 Colour findings for blesbok, black wildebeest and mountain reedbuck.

Animal	L* value	a* value	b* value	Hue angle (°)	Chroma
Blesbok (male) [1]	30.53	12.54	8.46	33.98	15.26
Black wildebeest (male) [2]	35.98	14.85	9.24	30.21	17.64
Mountain reedbuck (male)[2]	31.13	11.89	8.16	36.5	14.52

([1]Smit, 2004; [2]Van Schalkwyk, 2004)

Of all the species investigated by Von la Chevallerie (1972), eland and gemsbok had the lightest colour and it was found that the colour of the other species varied from dark red-brown to pale-red.

6.1.5. Other factors affecting colour

The pH value of meat may influence meat colour and colour stability and is also a major influence in DFD meat formation. The influence of pH on meat and meat qualities, along with DFD meat, will be covered at a later stage.

Paul (1963) observed that heating caused changes in the colour and structure of collagen and that there was a link between these characteristics. As collagen structure changes from fibrous to granular, its colour changes from areas of red to areas stained yellow. Changes in pigment due to temperature, as reported by Lawrie (1998), have been addressed earlier.

If intra-muscular fat is present in large quantities, it can increase lightness even when the pigment content is increased (Fiems, De Campeneere, De Smet, Van de Voorde, Vanacker and Boucque, 2000).

Packaging can also exert an influence on meat colour, particularly when different gasses are used in modified atmosphere packaging as shown by Carpenter *et al.* (2001). Beef packaged in 0.5% CO_2 was described as red, beef packaged in 100% N_2 as purple and beef packaged in 1.0% O_2 as brown by sensory panellists. Beef packaged in CO_2 showed the highest a* values and was therefore seen as the most red, while beef packaged in O_2 had the highest b* values (thus more yellow) and was seen as brown. Beef packaged in N_2 had lower a* values, but similar b* values and the meat seemed purple.

6.2. Water holding capacity

Water holding capacity (WHC) has a very important function in meat quality. Together with meat pH, it influences important aspects of meat eating quality, such as tenderness and juiciness, and also directly influences physical properties such as cooking loss and drip loss (Honikel, 1998; Lawrie, 1998; Immonen, Ruusenen and Puolanne, 2000; Thomas, Gondoza, Hoffman, Oosthuizen and Naudè, 2004).

Huff-Lonergan and Lonergan (2005) reported that about 75% of lean muscle is water and that this water is held by the structure of the muscle and muscle cells. Lawrie (1998) stated that WHC refers to the way moisture is present in muscle, which is mostly in the spaces between myosin (thick) and actin/tropomyosin (thin) filaments in the myofibrils. A maximum of 5% of the total water in muscle can bind directly to hydrophilic groups on proteins. Bound water cannot easily be moved to other compartments (Lawrie, 1998; Huff-Lonergan and Lonergan, 2005). Entrapped and free water are the two other water fractions, although free water is not often encountered in pre-rigor meat. Entrapped water is the water fraction mainly affected by rigor. Especially post-mortem pH fall affects the sarcoplasmic proteins, to which some of the WHC is due or attributed to – the faster the rate of pH fall, the worse the sarcoplasmic protein denaturation.

In normal muscle tissue post-mortem glycolysis will proceed to an ultimate pH that is close to the isoelectric point of meat, which is at pH 5.4-5.5 and is also the point at which WHC is at a minimum (Lawrie, 1998). This means that there will always be some loss of water after death. Thus, the higher the ultimate pH of muscle, the stronger water is bound in that muscle. This was confirmed by the work of Thomas *et al.* (2004). These authors found that drip loss percentage and pH followed opposite trends – as muscle pH values increased, drip loss percentage declined. Changes in the ion-protein relationship can cause an increased WHC as there is a net increase in change through K^+ -absorption and Ca^{2+}-release to enhance WHC, particularly in comminuted meats, when salts of weak acids, specifically phosphates and polyphosphates, are added to meat (Lawrie, 1998).

Offer and Trinick (1983) explained WHC as increased water up-take by myofibrils in strong salt solutions. This occurs when the lattice of thick and thin filaments expand when the

increasingly negatively charged components repel one another and when those forces determining the arrangement of the filaments at the Z- and M-lines and between myosin heads and actin filaments, are disrupted.

Bouton, Harris and Shorthose (1971) showed that WHC was significantly ($P<0.001$) correlated with pH in both whole and minced samples ($r = 0.80$ and $r = 0.88$, respectively). Again, this strengthens the fact that anything that affects pH, and specifically the rate of pH fall, will affect WHC, which in turn can affect other quality aspects of meat.

Appearance may also be influenced. Lawrie (1998) reported that meat with a high WHC might appear to have a dry surface.

6.3. Cooking loss

Cooking loss is the moisture lost from muscle during cooking and may act as a measure of WHC, along with drip loss. Cooking loss can mostly be attributed to structural changes occurring in the muscle because of the denaturing of various proteins at varying temperatures (37-75ºC). Shrinkage of the myofibrils occurs when the filament lattice expands and this results in water loss during cooking (Honikel, 1998). Some of the structural changes that occur are cell membrane destruction, shrinkage of muscle fibres, and aggregation of sarcoplasmic proteins and shrinkage of the connective tissue. Although all of these changes contribute to cooking loss, changes in connective tissue are of particular interest.

In the work of Marsh, Ringkob, Russell, Swartz and Pagel (1987) a linear relationship was shown between cooking losses and pH. At 65ºC there was a linear decrease in cooking loss as pH increased in raw or cooked meat over the pH range of 5.6-7.0. However, at 90ºC there was little change in cooking loss until pH 5.9 in raw, and 6.2 in cooked meat, which saw a linear decrease in cooking loss with increased pH.

Animal age had almost no effect on cooking loss in samples from seven out of eight beef age groups (Shorthose and Harris, 1990). Contradictory findings were reported by Jeremiah *et al.* (1971) who showed significant ($P<0.05$) correlations between chronological age and measures of tenderness and cooking loss. The way in which carcasses were hung caused differences in cooking loss, as was shown by the work of Shorthose and Harris (1990) when it was found that carcasses hung via the sarcosciatic ligament (so-called tenderstretched) showed significantly ($P<0.001$) lower cooking losses than carcasses hung (conventionally) from the Achilles tendon (29.2% vs. 30.6%).

Jeremiah, Dugan, Aalhus and Gibson (2003a) observed that muscles differed extensively when cooking loss was considered. The cuts containing more fat showed lower cooking

losses and cuts that contained more insoluble and total hydroxyproline sustained greater total cooking losses because of its higher connective tissue content.

Cooking loss is associated with tenderness and Briskey (1963) found muscles with a low cooking loss to be very tender, while muscles with a high cooking loss lacked tenderness. Silva, Patarata and Martins (1999) showed a significant ($P<0.05$) relationship between tenderness and cooking loss. A similar trend was found by Thomas *et al.* (2004), i.e. increased tenderness was found in meat with decreased cooking loss. These latter authors thought it possible that this was due to a diluting effect of the bound water. That is to say, in a fixed area, when more water is bound, a smaller amount of muscle fibres will be found. Thomas *et al.* (2004) observed that cooking loss and drip loss showed opposite tendencies – i.e. percentage cooking loss increased, while drip loss percentage decreased as shear force values increased.

6.4. Tenderness and meat tenderisation

To the consumer, tenderness is the most important quality characteristic of meat (Whipple, Koohmaraie, Dikeman, Crouse, Hunt and Klemm, 1990; Dransfield, Zamora and Bayle, 1998; Lawrie, 1998; Pietrasik and Shand, 2004). Toughness in meat is seen as a serious quality defect and Mitchell (1963) found this to be a common problem in lamb.

Deatherage (1963) described tenderness as "a quality representing the summation of properties of the various protein structures of skeletal muscle." Tenderness can be described as a function of the solid (or water-insoluble) structures of muscles and that tenderness could be directly related to the protein structure of muscle and the denaturation, coagulation and hydrolysis of these proteins. Miller *et al*. (1995) related the cause of tenderness to four main factors: muscle shortening (state of actomyosin complex); ageing (action of enzymes over longer periods of time); contents of connective tissue; and marbling; although tenderness is actually a very complex matter that cannot be explained thoroughly in such simplistic terms.

6.4.1. Consumers and meat tenderness

Consumers want their meat to be tender and flavourful (Husaini, Deatherage, Kunkle and Draudt, 1950) and have very specific preferences and ideas about ideal tenderness, juiciness and flavour (the three most important eating qualities of meat). As previously mentioned, several authors have found that consumers are chiefly concerned with meat tenderness (Lawrie, 1998; Gerelt, Ikeuchi and Suzuki, 2000; Pietrasik and Shand, 2004). They will find any meat that does not comply with their demands on tenderness as unsatisfactory, notwithstanding the satisfaction of all other aspects of quality and enjoyment.

Dransfield *et al.* (1998) reported that steak acceptability increased if steaks were more tender and other authors also declared that tenderness after consumption, is the meat quality

characteristic that will lead consumers to decide about the overall acceptability of the product (Miller *et al*., 1995; Gerelt *et al*., 2000). In a study conducted by Miller *et al*. (1995), consumers had to rate steaks in terms of tenderness and overall acceptability. The steaks found acceptable were ranked between 3 (moderately tough) and 4 (slightly tough) on an 8-point scale, which translated to Warner-Bratzler shear force values of 4.6-5.0 kg.

6.4.2. Tenderness measurement

Tenderness (or the sensation of tenderness) is an intricate meat property and it is very difficult to take all aspects of tenderness into account when measuring it. The perception of tenderness is construed by various processes and sensations (Pearson, 1963). The physical process of chewing alone involves cutting, grinding, tearing, shearing and squeezing. The impression of tenderness collected by sensors in the mouth, tongue, teeth and lips, as well as other aspects of meat quality such as texture influence the perception of tenderness.

Tenderness may be measured either by a trained sensory panel as part of the sensorial analyses, or by instruments as part of the physical analyses of meat. Warner-Bratzler shear force values are most commonly used for objective tenderness evaluation (Pearson, 1963; Bouton and Harris, 1972; Lawrie, 1998; Shackelford, Wheeler and Koohmaraie, 1999), although there are a few other instrumental methods also frequently used such as the Instron Universal Testing Machine (with a Warner-Bratzler attachment) and the MIRINZ tenderometer (Bouton and Harris, 1972). The way in which meat cores are obtained for shear force measurement may influence the outcome. Wheeler, Shackelford and Koohmaraie (1996b) described meat cores obtained perpendicular to the steak surface as much less repeatable and reported that such cores caused lower mean shear force values to be measured. On the other hand, meat cores obtained parallel to muscle fibres delivered much better results. These authors also found that shear force repeatability increased as more sample cores were tested, but found that more than five cores per sample did not improve repeatability significantly. AMSA (1995) advises to obtain meat cores from chilled (2-5 ºC) meat rather than meat at room temperature (24-28 ºC) because it is then easier to ensure that all cores have a uniform diameter.

Bickerstaffe, Bekhit, Robertson, Roberts and Geesink (2001) noted that shear force, as measured by a MIRINZ tenderometer, accurately reflected eating assessment of tenderness by consumers. These authors created instrumental tenderness categories, which were linked to consumer tenderness perceptions.

6.4.3. Game meat tenderness

Consumers generally have the idea that game meat is tougher and drier than red meat from other red meat species, but Von la Chevallerie (1972) found that Warner-Bratzler shear force values did not correspond with the perception of game meat as being tougher. Hoffman

(2001) reported that impala shear force values were similar to shear force values observed in pigs, which shows that meat tenderness of at least some game species is similar to pork tenderness. When examining the Warner-Bratzler shear force values of seven game species (Table 9), Von la Chevallerie (1972) found springbok to be the most tender of all the examined species.

Table 9 Shear force values of seven game species

Species	Shear force value (g/cm^2)
Blesbok	2 323
Eland	3 366
Gemsbok	4 088
Hartebeest	2 907
Impala	2 751
Springbok	1 181
Wildebeest	1 805

(Von la Chevallerie, 1972)

Elliot (1993) accounted for the idea that game meat (or venison) is generally tough, originating from incorrect, or improper, harvesting and slaughtering procedures. Especially wild venison quality suffered as a result of this and it led to wild venison being associated with an unpleasant taste.

Although it has been well established that there is a correlation between pH and meat tenderness, Wiklund, Barnier, Smulders, Lundström and Malmfors (1997) found no significant correlations between the two characteristics in reindeer meat.

6.4.4. Connective tissue

Cover, Ritchey and Hostetler (1962a) identified the two structural components involved in meat tenderness as muscle fibres and connective tissue. Connective tissue content and composition can influence tenderness. Collagen is the main protein of connective tissue and Bailey and Light (1989) reported it as the “one major protein common to all connective tissues in all higher animals”. Collagen constitutes 25-30% of total protein in mammals.

Jeremiah (1978, as cited by Jeremiah et al, 2003b) identified the two factors that influence the ultimate tenderness of muscle most, as a myofibrillar component (ultra structure of myofibrillar proteins) and a stromal component (content, composition and structure of connective tissue proteins). Olsson *et al.* (1994) stated that ‘background toughness’ refers to the quality and maturity of connective tissue in meat.

Toughness caused by connective tissue is due to cross-linkages forming between collagen molecules over a prolonged period (Jeremiah *et al*., 2003a). Thus, older animals have more cross-linkages and produce tougher meat than younger animals. Solubility differs between cross-linked and non-cross-linked collagen – cross-linked collagen is less soluble than non-cross-linked collagen. Non-cross-linked collagen is therefore also known as soluble collagen (Hill, 1966). Berry, Smith and Carpenter (1974) found that an increased soluble collagen percentage, along with a lower amount of collagen, were associated with higher tenderness in beef. Light, Champion, Voyle and Bailey (1985) found higher heat-stable collagen cross-links in tougher muscles and declared collagen cross-links important to meat tenderness.

6.5. pH

Various meat quality characteristics, such as colour, tenderness and WHC are influenced by the pH value of the meat (Lawrie, 1998; Silva *et al.* 1999). In turn, the pH value is affected by many factors – such as ante-mortem stress.

The post-mortem pH of meat is determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis. The isoelectric point (pH 5.4-5.5) is the pH range where, in normal muscle, under normal conditions, the enzymes implementing glycogen-conversion to lactic acid are inactivated (Lawrie, 1998). Normal pH decline occurs because of post-mortem lactic acid accumulation (Immonen *et al*., 2000).

The final pH reached after glycolysis has ceased, is referred to as the ultimate pH (pHu). The pHu of individual muscles differ according to ante-mortem metabolic state, but settles in the region of about 5.4. Temperature has a definite effect on pHu. Usually when pHu is reached, temperatures are still relatively high. Olsson *et al*. (1994) found that pHu was affected by temperature and that the rate of glycolysis was reduced so much by very low temperatures that 'normal' pHu was not reached. In a similar study the results of Hertzman *et al*. (1993) included the following temperature and pH values of two beef muscles entering rigor at constant temperatures in the cold-shortening region: 1ºC, pH 6.6; 10ºC, pH 6.3; 15ºC, pH 6.2

Many sensory aspects of meat are influenced by its pHu. However, there is some controversy surrounding the relationship between pHu and tenderness. Some authors (Bouton, Carroll, Harris and Shorthose, 1973; Guignot, Touraille, Ouali and Renerre, 1994; Thomas *et al.*, 2004) have found a linear relationship between pHu and tenderness, while others (Jeremiah, Tong and Gibson, 1991) have found a curvilinear relationship, with minimum tenderness between pH 5.8 and 6.2.

Silva *et al.* (1999) found that beef tenderness increased linearly with increasing pHu (5.5 to 6.7), even after periods of ageing (1, 6 and 13 days). At a high pHu (>6.3) neutral proteases (i.e. calpains) are favoured, while cathepsin activity is favoured by a low pHu (<5.8).

Intermediate pHu values are not favourable to either calpain or cathepsin-activity, which results in the lowest degree of tenderisation. According to Yu and Lee (1986) this is the reason for the curvilinear relationship sometimes found between tenderness and pHu and this was confirmed by Jeremiah (1990, as cited by Van Schalkwyk, 2004).

Bouton *et al.* (1971) found peak toughness at pH 6 (Warner-Bratzler shear force only). While studying the effect of acidity and temperature on muscle structure, Wismer-Pedersen and Briskey (1961) found that temperatures up to 40ºC were not critical if pH values were higher than 6.2, but if the pH values were lower than 5.9, temperatures above 35ºC would alter muscle structure. By maintaining a specified pre-rigor temperature (from 0 to 30ºC) until the pH had reached 6.4 and by then keeping muscle at 15ºC (Dransfield, Wakefield and Parkman, 1992), neither tenderness, nor rate of tenderisation after rigor, was affected. After a pH value of 6.1 was reached, first-order tenderisation began and thereafter rate of tenderisation was severely affected by temperature. Tenderisation rate at 30ºC was 10 times higher than at 1ºC and was unaffected by pH varying from 6.1 to 5.5. Dransfield *et al*. (1992) found that aged meat was slightly tougher at higher temperatures than at the lower temperatures. The temperature and pH at the start of rigor mortis were deemed very important for tenderness in beef by Hannula and Puolanne (2004) who stated that *M. longissimus dorsi* pH values should fall to below 5.7 before or when muscle temperature reaches 7ºC.

Varnam and Sutherland (1995) reported that pHu had a negligible effect on juiciness.

It appears that flavour intensity and pHu show opposite trends – as muscle pHu increases, flavour intensity decreases and Lawrie (1998) explains that the access of substances to the palate is encumbered by the swollen myofibrillar structure.

MacDougal, Shaw, Nute and Rhodes (1979) reported that game meat with a high pHu is darker than game meat with a normal pHu. This is in agreement with dark, firm, dry (DFD) meat which is caused by limited post-mortem glycolysis and has a pH value higher than 5.8 (Lawrie, 1998). DFD meat is associated with better ultimate tenderness, but can be very susceptible to bacterial spoilage, which means a short shelf life, and has reduced flavour (Silva *et al.,* 1999; Hoffman, 2001). It also has very poor processing characteristics. DFD meat is also known as dark-cutting meat. This, according to Young and West (2001), is not only because of its colour, but also because surface blooming is poor because of its high O_2-consumption rate. The dark red colour is due to protein that is relatively undenatured, thus it is non-reflective and meat appears darker because of light-absorption and also no myoglobin is lost through drip due to its high WHC (Hoffman, 2001; Young and West, 2001).

DFD meat is usually caused by pre-slaughter stress. Stress causes the glycogen stores to become so depleted that not enough lactic acid can be formed for meat acidification to progress normally and that causes the pHu to remain high (Hoffman, 2001). This explains why DFD meat is a quality problem that often occurs in game meat. As Hoffman (2001) explains, when an animal is wounded and chased afterwards, it is a typical chronic stress situation, which causes DFD meat.

As previously mentioned, stress can have a huge influence on pHu. Virtually anything can act as a stressor – from transportation to diet restriction to genetic factors. If an animal is slaughtered before its glycogen reserves are replenished, this will act negatively on pH-decline and pHu. This, unfortunately, is a very big problem with game meat and that is why correct harvesting procedures must be followed. Because game animals are farmed in extensive systems, they are not familiar with people or vehicles and capture can be very stressful. Hoffman and Ferreira (2000) found harvesting game animals at night to be the least stressful and this is in accordance with the findings of several other authors (MacDougall *et al.*, 1979; Conroy and Gaigher, 1982).

When excessive post-mortem glycolysis occurs, it leads to pale, soft, exudative (PSE) meat (Lawrie, 1998), which is also caused by stress before slaughter and results in meat with a low pH and high temperature. Although PSE meat does affect game species, it is more often seen in warthogs and animals that have been experiencing acute (short-term, heavy) stress (Hoffman, 2001) and since neither springbok nor blesbok generally experience PSE meat during normal harvesting procedures, it shall not be discussed further.

6.6. Enzymatic tenderisation

Calpains are the most important group of cysteine peptidases when meat tenderisation is considered and are mainly controlled by calpastatin (their specific inhibitor), calcium ions and phospholipids. Several calpains are known, but µ-calpain and m-calpain are most commonly found (Sentandreu, Coulis and Ouali, 2002).

Although the precise action of calpains in the body could not be identified, treating myofibrils with calpains is the action best able to explain density decline of the Z-disks (Sentandreu *et al*., 2002). Using cathepsin B- and L-specific inhibitors had no effect on shear force or protein solubility, which caused Hopkins and Thompson (2001) to believe that calpains were the enzymes responsible. Koohmaraie (1996) found that µ-calpain is responsible for the proteolysis of key myofibrillar proteins and pointed to this as the underlying mechanism responsible for tenderisation during storage at low temperatures. After storage of 14 days at 4ºC, about 5-10% µ-calpain remains active in skeletal muscles. Dransfield (1994, as cited by Hannula and Puolanne, 2004) notes that calpain-activity immediately post mortem is pH- and temperature-dependent.

Cathepsins are defined as mammalian intracellular enzymes exhibiting proteinase activity, requiring sulfhydryl activators and varying largely between tissues and species (Landman, 1963). Sentandreu *et al*. (2002) describe cathepsins as lysosomal peptidases at an acidic pH. Most cathepsins are stable over a wide pH range, but it is generally accepted that they are only active in acidic environments (Sentandreu *et al*., 2002). The known cathepsins in muscle tissue include six cysteine peptidases (cathepsins B, L, H, S, F and K) and one aspartic peptidase (cathepsin D). Although there is much controversy on the role of cathepsins in tenderness, free cathepsin activity (cathepsin B, L and D) have been linked to meat tenderisation – from one day post mortem through the ageing process. Cathepsins have no or very little effect on actin and myosin, but were shown to degrade other structural and contractile proteins. Cathepsins were shown to play a role in ostrich tenderisation. Thomas *et al*. (2004) found cathepsin D to remain active throughout ageing at 4ºC. Cathepsins B, L and H showed little activity at first, but increased after the first few hours post-mortem and still showed activity after 12 days.

Cystatin is a group of cysteine peptidase inhibitors, inactive against other peptidases such as serine- or aspartyl peptidases (Sentandreu *et al*., 2002). All cystatins inhibit lysosomal peptidases such as cathepsins B, H and L and cystein peptidases such as papain, which is present in the latex of *Carica papaya* and affects the M-line and myosin filaments of the A-band, while disrupting and disorganising the actin filaments (Wada, Suzuki, Yaguti and Hasegawa, 2002; Azarkhan, El Moussaoui, van Wuytswinkel, Dehon and Looze, 2003).

7. Chemical properties of meat

7.1. Total moisture

The moisture content of meat is generally about 70-77% and decreases as the fat content of meat increases (Young, Frost, West and Braggins, 2001). It was also stated by Lawrie (1998) that, of all the components of meat, moisture constituted the biggest quantity by far. Moisture in muscle is mainly found in the spaces between the myosin and actin or tropomyosin filaments.

Crafford (2002) noted that the moisture content of game meat compared favourably with that of beef, while Von la Chevallerie (1972) observed average percentage moisture of 75.5% in game meat. The moisture content of several game species (Table 10) has been researched and reported by several authors (Von la Chevallerie, 1972; Onyango *et al.*, 1998; Van Zyl and Ferreira, 2004) and was generally found to be in the range of 74-77%. Onyango *et al*. (1998) found the moisture content (%) of three other game species (Kongoni loin, 73.4 ± 0.2; Oryx loin, 76.6 ± 0.8; Zebra loin, 75.2 ± 0.3) to also fall within this range.

Table 10 Moisture contents of several game species compared to that of several domesticated species.

Species	Moisture (%)	Moisture (%)	Moisture (%)	Moisture (%)
Black Wildebeest	77.0[1]	-	-	74.69(male)[5]
Blesbok	75.5[1]	75.5[3]	71.1 ± 1.1[4]	75.12(male)[6]
Eland	75.8[1]	74.8[3]	-	-
Gemsbok	75.9[1]	-	-	-
Hartebeest	76.3[1]	-	-	-
Impala	74.7[1]	75.7[3]	74.0 ± 0.8[4]	-
Mountain reedbuck	-	-	-	72.76(male)[5]
Springbok	74.7[1]	74.7[3]	75.3 ± 5.5[4]	74.24 ± 0.16[7]
Beef	65.4[2]			
Mutton	60.7[2]			
Ostrich	76.3[2]			
Pork	55.0[2]			

([1]Von la Chevallerie, 1972; [2]Sayed *et al*., 1999; [3]Skinner and Louw, 1996; [4]Van Zyl and Ferreira, 2004; [5]Van Schalkwyk, 2004; [6]Smit, 2004; [7]Kroucamp, 2004)

Game meat species are expected to have higher moisture contents than other domesticated species, because of their low intramuscular fat content and the inverse correlation between intramuscular fat and moisture content of meat Sales (1995).

Various authors have established that moisture plays an indirect role in tenderness and juiciness, both important eating quality characteristics (Lawrie, 1998; Jeremiah *et al.*, 2003b; Thomas *et al.*, 2004). Moisture content of meat is usually investigated under the guise of WHC and has thus been discussed in depth as WHC.

Moisture levels in meat can be increased by various methods. Pietrasik and Shand (2004) observed that 16 hours of tumbling increased the moisture percentage in non-tenderised meat. It was concluded by Baublits, Pohlman, Brown Jr. and Johnson (2005) that steaks injected with a solution containing NaCl and different phosphates at 18% pumped gain (of raw weight) showed higher moisture percentages and were generally rated as more tender and juicy. The same phenomenon was found for several other inorganic salt injections.

7.2. Total fat

Total fat can be defined as encompassing all fatty acid-containing substances (Young *et al.*, 2001). The substances mainly found in meat fats primarily include tri-, di- and mono-acylglycerols, but also include some phospholipids, cholesterol esters and free fatty acids. The fat contents of meat and meat products show great variation and can be influenced by

animal species, animal age, as well as the parts of the carcass used (Valsta, Tapanainen and Männistö, 2005).

Intramuscular fat has an important function in several sensory quality attributes of meat. Jeremiah *et al.* (2003b) reported a direct effect on both juiciness and flavour, with an indirect effect on tenderness was observed. Tenderness is increased when intramuscular fat deposited between fasiculi disrupts the endomysium structure and this causes the perimysial fibres to separate and thin out (Nishimura, Hattori and Takahashi, 1999). Jeremiah *et al*. (2003b) calculated intramuscular fat to be accountable for 12-14% of the variation in all palatability traits of meat.

Consumer-demand for leaner meat has caused the meat industry to respond in several ways. Resurreccion (2004) reported that the fat contents of pork was lowered by more than 30% between the 1970's and 1990's – this was achieved mostly by selective breeding, improved husbandry practices and better trimming of outside fat on retail cuts.

In meat and meat products, fat content is usually measured as crude fat (or ether extract) and extracted from meat using a mixture of chloroform and methanol (Young *et al*., 2001). A chloroform and methanol mixture is used because it extracts lipids more thoroughly than other solvents, it causes lipids to undergo little chemical change during extraction and is a good solvent for phospholipids.

7.3. Fatty acids

In the last few decades the fat content of meat has been reduced to satisfy consumer demand and as the fat content changed, the fatty acid profile of meat also changed. The percentage saturated fat of red meat is now lower than ever (Higgs, 2000) with the fat in lamb being about 51%, pork and beef being less than 50% and poultry being about 31% saturated.

7.3.1. Saturated fatty acids

A decreased saturated fatty acid intake is associated with a lowering of blood serum cholesterol levels, which in turn lowers the risk of cardiovascular heart disease. The main saturated fatty acids found in red meat are palmitic (C16:0) and stearic (C18:0) acid (Schönfeldt, 1993; Higgs, 2000; Melanson *et al.*, 2003). Stearic acid is seen as neutral and does not display the cholesterol elevating effects of other saturated fatty acids. Schönfeldt (1993) identifies myristic (C14:0) and palmitic acids as the culprits usually responsible for increased cholesterol levels and Valsta *et al*. (2005) concurs. In general, myristic acid is seen as the most atherogenic and has four times the cholesterol-raising potential of palmitic acid (Higgs, 2000). Therefore, a decrease in myristic and palmitic acids will be quite beneficial while either a decrease or increase in stearic acid should not have any affect on serum

cholesterol levels. Luckily only minor amounts of myristic acid are present in meat (Higgs, 2000), with Valsta *et al*. (2005) estimating it to be less than 6%.

7.3.2. Mono-unsaturated fatty acids

The principal mono-unsaturated fatty acid in meat is oleic acid (C18:1) and Higgs (2000) reports that mono-unsaturated fatty acids constitute about 40% of the fat in meat. Trichopoulou, Costacou, Bamia and Trichopoulos (2003) reported that oleic acid is consumed in high quantities when the traditional Mediterranean diet is eaten. The traditional Mediterranean diet is associated with improved health, such as a lower risk of cardiovascular disease. Meat is one of the best sources of mono-unsaturated fatty acids in the diet and replacing meat with dairy products (as in a vegetarian diet) may cause the fatty acid profile to worsen because dairy products have higher myristic acid and less mono-unsaturated fatty acids than red meat.

7.3.3. Polyunsaturated fatty acids

Generally it is believed that higher polyunsaturated fatty acid consumption, as opposed to saturated fatty acid consumption, leads to better health. However, in the last few years it has been found that not all polyunsaturated fatty acids are beneficial (Gibney and Hunter, 1993). Immunologists showed that omega-6 (n-6) polyunsaturated fatty acids (e.g. linoleic acid) are less advantageous than the omega-3 (n-3) polyunsaturated fatty acids (e.g. linolenic acid, EPA and DHA). During the post-absorptive metabolism of n-6 fatty acids in humans, pro-inflammatory eicosanoids are produced. Inflammatory responses are important factors in cardiovascular heart disease- and cancer-development (Gibney and Hunter, 1993). The n-3 fatty acids can act as modulators to this inflammation because of the competition between n-3 and n-6 metabolites for inclusion in the immune cells' phospholipids. Furthermore, in the GISSI investigation (Gissi-Prevenzione Investigators, 1999) an inverse relationship between serum phospholipid concentrations of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and cardiovascular heart disease risk was found.

Conjugated linoleic acid (CLA) is a mixture of geometric and positional isomers of linoleic acid (Higgs, 2000). Useful levels of CLA are only found in dairy products and meat, with ruminant meat being the richer source. Higgs (2000) estimates that 76 to 93% of meat and milk CLA is in the cis-9, trans-11-octadienoic acid form. MacRae, O'Reilly and Morgan (2005) explains that CLA is formed as an intermediate metabolite when unsaturated linoleic acid (C18:2) undergoes bio-hydrogenation to form saturated stearic acid (C18:0) during rumen fermentation. This then, is the reason why CLA is generally considered as a ruminant product and why ruminant products (milk, cheese, beef, etc.) have higher CLA contents than non-ruminant products.

CLA has contributed to various beneficial actions in animal health – it can improve plasma lipoprotein composition, reduce adiposity and significantly modulate immunity (MacRae *et al*., 2005) – and while findings in human health varied, the potential benefit of CLA to human health is encouraging. Higgs (2000) reported that CLA-inclusion into an animal's diet, regardless of the amount and type of fat consumed, had anti-mutagenic activities in test animals.

Trans-fatty acids are omega-6 fatty acids produced when vegetable oil is hydrogenated (Ronco, De Stefani and Fabra, 2003) and displays physical properties similar to saturated fatty acids. Trans-fatty acids raise serum cholesterol and triglyceride concentrations.

7.3.4. Omega-6:omega-3 ratio

The balance between omega-6 and omega-3 fatty acids is very important for human health and a n-6:n-3 ratio of 2-3:1 is recommended (Ronco *et al*., 2003). The recommendation made by the British Department of Health (1994) for n-6:n-3 ratio is less than 4.0. An excess of n-6 fatty acids may lead to the onset of coronary heart disease and cancer because of its pro-inflammatory aspects (Gibney and Hunter, 1993). The n-3 fatty acids have the ability to counteract the negative effects of the n-6 fatty acids. Ruminant meat is a very good source of n-3 fatty acids and has a low n-6:n-3 ratio, especially the meat derived from grass-fed animals (Wood *et al*., 2004).

7.3.5. Polyunsaturated: saturated fatty acid ratio

The recommended polyunsaturated: saturated fatty acid (P:S) ratio should be above 0.4 (Wood *et al*., 2004) – the British Department of Health (1994) recommends a P:S value of 0.45. The P:S value normally found in meat, reports Wood *et al*. (2004), is 0.1. Higher values have been reported for springbok (1.114 ± 0.13; Kroucamp, 2004), blesbok (1.00 ± 0.39; Smit, 2004), red hartebeest (0.75 ± 0.46; Smit, 2004) and black wildebeest (1.09; Van Schalkwyk, 2004).

7.3.6. The effect of animal diet on fatty acid composition

Animal diet can effect major changes in the fatty acid profile of meat. The biggest difference caused by diet is seen in the meat from animals fed grain-based diets (concentrates) and those consuming grass (pasture). Several authors (Kemp, Mahyuddin, Ely, Fox and Moody, 1981; Enser *et al*., 1997b; Lengyel *et al*., 2003; Wood *et al*., 2004) reported the differences in the fatty acid profiles of animals following these two distinctive feeding regimes. The most important difference is found in the linolenic acid levels and long chain n-3 polyunsaturated fatty acids, which is much higher in grass-fed beef and lamb (Wood *et al*., 2004). The grass-fed animals also have higher anti-oxidant levels that prevent oxidation of the polyunsaturated fatty acids. On the other hand, animals on a grain-based diet have higher n-6 polyunsaturated fatty acid concentrations. The reason for this major difference in fatty acid

composition between grass- and grain-based diets is the high levels of α-linolenic acid (C18:3n-3) present in grass, while grains have higher linoleic acid (C18:2n-6) levels (Marmer *et al*., 1984, as referred to by Enser *et al*., 1997b). Enser *et al*. (1997b) found the linoleic acid levels in grain-fed beef and lamb to be 2.5 times higher than in grass-fed animals, but astonishingly enough, the α-linolenic acid levels in grass-fed animals were 3.1 times higher than in grain-fed animals. Oleic acid (C18:1) was 1.6 times higher in the longissimus muscle of grass-fed animals and all other fatty acids, except the n-6 polyunsaturated fatty acids, were generally higher in grass-fed animals.

Supplementing animal diets with n-3-rich foodstuffs may lead to better n-6:n-3 ratios in meat. Wood *et al*. (2004) achieved just that when they supplemented pig diets with linseed. Their results confirmed similar results by Enser, Richardson, Wood, Gill and Sheard (2000) who found that n-6:n-3 ratios in pork could be lowered close to the recommended value (<4.0) by adding crushed whole linseed to the diet. Vatansever *et al*. (2000) studied the effect of linseed and fish oil as additions to meat animal diets and found that linolenic acid in the phospholipids of linseed-fed meat doubled in comparison to controls. This led to higher levels of EPA, but not DHA. However, in the fish oil and linseed/fish oil diets, both EPA and DHA increased. Meat from the fish oil-containing diets was more prone to oxidation than control or linseed diets.

If pigs are fed unsaturated fatty acids, the saturation of pork fat decreases, but in order to cause similar changes in ruminant fat, protected unsaturated fatty acids must be fed (Melton, 1990). Protection against changes in the rumen is necessary if fatty acid changes are to be achieved in this way.

7.3.7. The effect of fatty acids on cholesterol levels

Some fatty acids (e.g. myristic and palmitic) have the ability to increase serum cholesterol levels, while others (e.g. arachidonic) may lower serum cholesterol levels (Viljoen, 1999; Higgs, 2000). Nelson *et al*. (1995) suggest that all 12 to 16 carbon atom saturated fatty acids increase blood total-, low-density lipoprotein (LDL)- and high-density lipoprotein (HDL)-cholesterol levels, as well as the LDL:HDL ratio. Most n-6 polyunsaturated fatty acids lower LDL-cholesterol levels, while most mono-unsaturated fatty acids are neutral as pertaining to plasma cholesterol levels (Nelson *et al*., 1995).

7.3.8. The effect of fatty acids on fat firmness

The concentration of stearic acid (C18:0) is closely associated with the carcass fat firmness and the melting point of lipid in beef, lamb and pork (Wood *et al*., 2004). Fat firmness is very dependent on the melting points of the different fatty acids, for example stearic acid (C18:0) melts at 69.6ºC, oleic acid (C18:1) at 13.4ºC, linoleic acid (C18:2) at -5ºC and linolenic acid (C18:3) at -11ºC (Wood *et al*., 2004). Enser (1984) reports that melting points increases as

saturation decreases, thus, fat containing more unsaturated fatty acids has a lower melting point and is softer than fat containing more saturated fatty acids, which will be harder.

7.3.9. Gender differences in fatty acid composition

There are definite differences in the fatty acid composition between males and females within species. In crossbred sheep lambs Kemp *et al.* (1981) found the subcutaneous fat of ewes to contain more total unsaturated fatty acids and higher levels of oleic acid than that of wethers, while rams contained higher amounts of total unsaturated fatty acids and palmitoleic acid, but lower stearic acid levels than wethers. However, the intramuscular fat of rams showed higher levels of palmitoleic, linoleic and linolenic acids than that of wethers.

In the *M. longissimus dorsi* of the black wildebeest and mountain reedbuck, Van Schalkwyk (2004) reported males to have slightly higher percentages of saturated and polyunsaturated fatty acids, but females contained higher percentages mono-unsaturated fatty acids. On the other hand, Smit (2004) reported higher values (mg/100 g) of saturated and polyunsaturated fatty acids in blesbok females compared to males, with nearly the same trend in red hartebeest, except for saturated fatty acids being slightly higher in males. In springbok *M. longissimus dorsi*, the intramuscular fat of males contained higher percentages saturated and mono-unsaturated fatty acids, while females had a higher percentage of polyunsaturated fatty acids (Kroucamp, 2004).

7.4. Crude Protein

MacRae *et al.* (2005) observed that the nutritive value of animal proteins is higher than that of plant proteins. That is to say, if it is considered in terms of protein efficiency ratio, which is defined as weight gain per unit protein consumed, or in terms of biological value, which refers to the nitrogen retained per unit nitrogen absorbed. This was in corroboration with the view of Higgs (2000) who commented on the high biological value of meat protein and its rich store of essential amino acids.

Game meat is generally declared to have a fairly high protein content and was shown by several authors (Table 11) to be higher than other red meat species. Onyango *et al.* (1998) found the crude protein percentage in the loin of three other game species (Kongoni, 22.4 ± 0.8; Oryx, 20.3 ± 0.4; Zebra, 22.8 ± 0.7) to be slightly higher than that of beef (19.4±0.4).

Clearly the protein contents of the game species are much higher than that of specifically mutton and pork, which is probably a reflection of the higher fat contents found in the latter two species as opposed to the game species.

Table 11 Protein value of several game species in comparison to that of domesticated species.

Species	Protein content of carcass (g/kg)	Protein (%)
Black Wildebeest	-	19.42 (male) [3]
Blesbok	23.5 [1]	22.39 (male) [4]
Impala	22.5 [1]	-
Mountain reedbuck	-	23.68 (male) [3]
Springbok	23.7 [1]	-
Beef	19.2 [2]	
Mutton	13.9 [2]	
Ostrich	21.1 [2]	
Pork	13.9 [2]	

([1]Van Zyl and Ferreira, 2004; [2]Sayed *et al.*, 1999; [3]Van Schalkwyk, 2004; [4]Smit, 2004)

7.5. Ash

The ash content of a meat sample represents the mineral contents of that sample. AOAC (1997) methodology for ash determination is to ash the moisture-free weighed meat sample for 5-6 h at 500ºC. The sample should be allowed to cool down in a moisture-free environment and weighed to determine the ash percentage.

Kroucamp (2004), Smit (2004) and Van Schalkwyk (2004) worked on game meat and the ash values found by them are quite low (Table 12). Van Schalkwyk (2004) declared the ash percentage of game meat to be higher than that of domesticated animals.

Table 12 Ash content (g / 100 g) of several game species

Species	Black Wildebeest (male)	Blesbok (male)	Mountain reedbuck (male)	Springbok (male)
Ash	1.29 [1]	1.26 [2]	1.23 [1]	1.24 ± 0.04 [3]

([1]Van Schalkwyk, 2004; [2]Smit, 2004; [3]Kroucamp, 2004)

7.6. Mineral content

The mineral content of meat is very important as it provides several minerals that are vital in human nutrition (Higgs, 2000; MacRae *et al.*, 2005; Biesalski, 2005). Red meat has a high iron content (Higgs, 2000) and Lawrie (1998) reported potassium and phosphorus to be the two minerals most often found in the highest quantities in meat. Higgs (2000) stated that meat also provides useful amounts of copper, magnesium, cobalt, chromium and nickel.

7.6.1. Iron

The reason why red meat is considered to be such an excellent iron source is due to the fact that 50-60% is found in the haem form (Higgs, 2000). Haem iron is absorbed more effectively since its absorption in meat is through a more efficient mechanism than that of non-haem iron in plants. Iron in meat is unaffected by iron-inhibitors, such as phytate in cereals, and Higgs (2000) therefore calls it an "assured source of iron" with good reason. Not only is iron-absorption from meat higher (15-25%) than that of plant foods (1-7%), meat also enhances iron-absorption from plant foods.

Wells, Haub, Fluckey, Williams, Chernoff and Campbell (2003) found no differences between the total iron-intake of vegetarian (lacto-ovo) diets and beef-containing diets. They did, however, find that the bioavailability (the degree to which dietary iron is absorbed and made available for use or storage in the body) of iron was three to four times higher in the beef-consuming group than in the vegetarian group. These authors ascribed the higher bioavailability of iron in meat to the presence of haem iron, and also an enhancing factor, that causes iron to be absorbed and retained in greater percentages. MacRae *et al.* (2005) also found the bioavailability of meat iron to be higher than the iron of plant foods (20-30% vs. <10%). Iron is an essential ingredient in numerous biological processes (as it can act as a biological catalyst) and a few were listed by Biesalski (2005) as being essential for gas exchange through haemoglobin (at tissue and cellular levels) and oxygenation of myoglobin (in skeletal muscle); supportive of oxidative metabolism; involved in cellular energy metabolism via iron-containing enzymes; and involved in host-defence responses via iron-containing enzymes.

7.6.2. Zinc

Zinc is essential in the action of some enzymes (i.e. metalloenzymes) and is important in cell growth and -replication, osteogenesis and immunity (Biesalski, 2005). It was observed that cancer patients have lower Zinc-levels. Higgs (2000) declared red meat one of the best Zinc sources, along with poultry and seafood. Higgs (2000) observed that meat has a big influence on the Zinc-status of the diet because Zinc bioavailability is increased when its intake occurs in the presence of meat proteins. Phytate and oxalate, which can be found in fairly high amounts in some plants, inhibit Zinc bioavailability.

7.6.3. Selenium

Biesalski (2005) stated that selenium (Se) is important for its role in the active site of the glutathione peroxidase enzyme that plays a vital role in the mechanism that causes oxygen metabolism and detoxification. Studies with selenium (organic and inorganic) enlightened the role it can play in tumour growth inhibition, through inhibiting the proliferation of both normal and malignant cells. Selenium is also recognised as one of the main antioxidants that are reported to protect against coronary heart disease (Higgs, 2000). According to Higgs (2000)

meat provides about 25% of the daily selenium requirements (10 µg Se / 100 g meat) and Biesalski (2005) estimates that 17% of the total selenium in the American diet is provided by beef.

7.6.4. Mineral content of game meat

Niemenin (1992) found game meat contained higher quantities of the macro minerals calcium, magnesium and potassium, and the trace elements iron, copper and selenium than meat from domesticated animals. The values of eight minerals present in meat from different game species have been reported by several authors (Table 13).

Table 13 Mineral content (mg/100 g meat) of several game species.

Minerals	Black Wildebeest (male)	Blesbok (male)	Mountain reedbuck (male)	Springbok (male)
Phosphorus	194.43[1]	145.31[2]	207.77[1]	148.55 ± 9.53[3]
Potassium	189.72[1]	150.47[2]	204.60[1]	121.75 ± 5.63[3]
Calcium	6.98[1]	6.93[2]	8.04[1]	79.24 ± 23.03[3]
Magnesium	22.04[1]	20.40[2]	25.25[1]	17.77 ± 1.08[3]
Sodium	14.48[1]	15.82[2]	16.93[1]	14.12 ± 0.67[3]
Iron	3.64[1]	3.96[2]	4.61[1]	2.74 ± 0.21[3]
Copper	0.11[1]	0.27[2]	0.15[1]	0.09 ± 0.01[3]
Zinc	1.00[1]	1.48[2]	1.75[1]	1.29 ± 0.08[3]

([1]Van Schalkwyk, 2004; [2]Smit, 2004; [3]Kroucamp, 2004)

7.7. Micronutrient content

Red meat is a very valuable dietary source of micronutrients such as zinc, selenium and calcium (MacRae *et al*., 2005; Higgs, 2000). All B-vitamins (except folate and biotin) are found in useful amounts in meat, pork being one of the best sources of thiamine. Only foods of animal origin provide the body with vitamin B12 (cobalamin) and the active form of vitamin A, retinol (Higgs, 2000; Melanson *et al*., 2003). Some micronutrients, such as iron and folic acid, found both in meat and plants have better bioavailability when derived from meat (Biesalski, 2005). All the micronutrients found in meat are necessary for the maintenance of a healthy immune system and also assist in the prevention of various non-communicable diseases (MacRae *et al*., 2005).

8. Sensory quality

8.1. Analytical sensory work (Trained taste panel)

In analytical sensory analysis, panellists are trained to evaluate specific attributes of certain products and while test conditions are generally far removed from normal conditions they are designed to improve panellists' sensitivity, reliability and consistency. Generic descriptive

analysis is usually employed during analytical sensory analysis (Moskowitz, 1984; Stone and Sidel, 1993; Lawless and Heymann, 1998).

Chollet, Valentin and Abdi (2005) showed that trained panellists performed much better than novices in discriminating between learned beers, but not for new beers, and that trained panellists performed a matching task much better than novices for both learned and new beers. From these results they concluded that it is more difficult to generalise perceptual (or observation) learning than verbal learning. It was postulated that trained panellists used a better strategy during the matching task than novices. When asked to describe a new beer, trained panellist used the attributes and terminology they were trained to use when describing learned beers, thus they activated and applied an existing list of terminology, while novices generated terms based on the sensations experienced while tasting the beer. Rabin (1988) showed that panellists trained in a certain odour task, could adapt and use the knowledge learned during training to describe new odours and to perform new tasks. Trained panellists performed better than novices when asked to perform discrimination tasks.

8.1.1. Panel composition and training

Screening of potential panellists is very important (Stone and Sidel, 1993; Lawless and Heymann, 1998). Firstly, all panellists should have normal sensory acuity, which can be tested using various methods. Testing normal sensory acuity for food products includes testing the panellists' ability to identify the basic tastes correctly, testing their ability to rank intensities of the basic tastes and their ability to identify odours appropriate to the product. After establishing sensory acuity, further screening of potential panellists should be done using the product type that will be tested. Methods similar to those that will be used during testing should be utilised and each panellist's reproducibility should be determined through the use of replications, the number of which should also be predetermined.

Before proper analysis can be started, panellists should be trained on the methods that will be used, including interpretation and use of the questionnaires and the terminology used. During training, panellists should be familiarised with the questionnaire used and the terminology and anchors should be refined and settled upon (Stone and Sidel, 1993; Lawless and Heymann, 1998). Panellists should also be introduced and familiarised with the products to be tested. This includes showing panellists reference standards of the products, as well as providing verbal definitions for all attributes tested. During training, the panel should also be taught the language used, or must be allowed to formulate their own terminology for the attributes or products tested (Lawless and Heymann, 1998). Characteristics tested should be clearly defined and there should be no redundancy. Combination terms such as creamy, soft or fresh should be either completely discarded or broken down into the different contributing components.

Right after final training, panellist reproducibility should be tested by serving them with a triplicate of the product to be tested, using a subset of the samples to be used during the actual testing. If the panellists are well trained, there should be no significant differences between the tests of each panellist of amongst panellists. Panellists who differ significantly, should be retrained or eliminated from the panel (Lawless and Heymann, 1998).

8.1.2. Sample preparation and presentation

The proper methodology for cooking meat for sensory analysis is given by AMSA (1995). It is suggested that samples be oven roasted at around 160 ºC to an internal temperature of 71ºC. However, since the internal temperature still increases in the few minutes after the sample has been removed from the oven, it is wise to remove samples when it reaches an internal temperature about 5ºC lower than the target internal temperature (71ºC). Bejerholm and Aaslyng (2003) compared the sensory analysis results of meat samples prepared by cooking to different internal temperatures and found that meat with an internal temperature of 65ºC was better suited to studies that dealt with flavour components, but cooking to an internal temperature of 75ºC will provide a better sample for an overall discrimination in sensory characteristics. When cooking method and temperature were considered, oven cooking at low temperatures (90ºC) resulted in the most tender and juicy meat.

Before wrapping and coding samples, all surfaces that were exposed to the cooking environment should be removed from the sample so as to avoid bias and minimise the variation in samples (AMSA, 1995).

Avoiding bias in sensory testing is very important, therefore it is standard practice to use blind labelling of samples using random three-digit codes and to randomise the order in which samples are tested (Lawless and Heymann, 1998).

8.1.3. Sensory quality characteristics

8.1.3.1. Aroma

Only a small amount of the volatile compounds present in meat possess meaty aroma characteristics and these are primarily sulphur-containing compounds (Shahidi, 1998). Mottram (1998) lists the non-species related meat aroma characteristics as: the characteristic meaty aroma of all cooked meats, roast meat and fatty aromas. Species-specific aromas are related to the fat composition of each species and aldehydes are probably involved, as aldehydes are one of the chief lipid degradation products.

Meaty aroma is primarily caused by sulphur-containing compounds. Although most of these compounds are present at low levels, they have low odour thresholds (Mottram, 1998). Furans with a thiol group (at position 3) and disulphides formed from the oxidation of furan

and thiophene thiols (these are often used in simulated meat flavourings) also contribute to meaty aroma. Roast meat aroma is associated with heterocyclic compounds (e.g. pyrazines and thiazoles) formed during the Maillard-reaction. When roast and boiled beef were compared, boiled beef showed higher levels of aliphatic thiols, sulphides and disulphides. Fatty aroma is caused by the lipid fraction in meat – aldehydes, ketones and lactones all contribute to the fatty aromas that may be detected in cooked meat (Mottram, 1998).

During sensory evaluation of meat, panellists may be asked to evaluate several aromatic characteristics linked to meat, such as intensity of species-specific aroma (e.g. Beef aroma intensity), generally performed by smelling the samples (AMSA, 1995).

8.1.3.2. Juiciness

The juiciness of meat is related to its intramuscular lipid and moisture content. Warriss (2000) states that, while lipids act as lubrication and is responsible for tenderness, it is actually the remaining water after cooking that is responsible for juiciness. Cover, Ritchey and Hostetler (1962b) reported two types of moisture present in meat: 1) relatively free moisture that can be pressed out as juice, and 2) adsorbed water. The adsorbtion levels of water may vary greatly, but the authors postulated that large amounts of bound moisture might be responsible for softness to tongue and cheek, while hardness may be related to smaller values of adsorbed moisture. According to Von la Chevallerie (1972), because of its low fat content, game meat is perceived as less succulent than beef. For that reason, there is an overall perception of game meat as dry. But this is not a valid assumption to make because the moisture levels of game meat compares favourable with that of beef and thus, game meat handled and prepared correctly, should have the same juiciness as beef.

In sensory analysis, juiciness may be evaluated in different ways, such as the initial impression of juiciness, performed by pressing the sample to observe the amount of fluid exuding from the cut surfaces, and sustained juiciness, which is based on the impression formed after the first two to three chews (between the molars) of the sample (AMSA, 1995).

8.1.3.3. Tenderness

Tenderness has been discussed previously. The evaluation of tenderness in analytical sensory panels consists of evaluating the impression of tenderness at first bite, after the first two to three chews between the molar teeth, and the amount of residue left in the mouth after 20 to 30 chews (AMSA, 1995). When the amount of residue left over in the mouth is high, it is generally accepted that the sample is tougher than samples where there is very little residue.

8.1.3.4. Flavour

Flavour has an important role in sensory evaluation – because it encompasses both smell and taste properties, it is quite important in the evaluation of overall acceptability (Shahidi,

1998). Meat flavour is influenced by the combined influences of taste and smell, while juiciness and mouth feel may also contribute to the overall flavour (Mottram, 1998). Amino acids, peptides and nucleotides contribute to taste and flavour by interacting with other flavour components, producing flavour volatiles and contributing to sweet, salty, bitter and sour taste sensations of meat (Shahidi, 1998).

Meat is rich in aroma and flavour precursors (non-volatile precursors include reducing sugars, free amino acids and vitamins) and flavour enhancers, all of which are heightened by heating (Shahidi, 1998). Raw meat has very little flavour, but when meat is heated several interactions occur between the different components contributing to flavour. Mottram (1998) notes two categories of meat flavour precursors: 1) water-soluble, including peptides, amino acids, carbohydrates and thiamine, and 2) lipid components such as branched polyunsaturated fatty acids. The Maillard reaction (between amino acids and reducing sugars in which mainly cysteine and ribose are involved) and thermal degradation of lipids are the two most important causative actions of aroma volatiles (Mottram, 1998; Shahidi, 1998). Huang and Ho (2001) identified several of the precursors involved in meat flavour: Inosine manophosphate (IMP), forms sulphur-containing compounds; thiamine, forms methyl-3-furanthiol and bis- (2-methyl-3-furyl) disulfide, which are both meat aroma components; Strecker aldehydes, cooked beef components; fatty aldehydes, the largest contributor to cooked meat volatiles; and carbohydrate degradation products, several carbonyls are formed when carbohydrates are heated.

The flavour of cooked meat is usually species-specific and this is mostly due to the fat composition of the species (Shahidi, 1998). For example, the fatty acids 4-methyl nonanoic and 4-methyl octanoic acids are mutton-specific and contribute to the distinct flavour of mutton. Huang and Ho (2001) found similar aromas (basic meat flavour) on heating water-soluble (no fat) beef, pork and lamb extracts. However, when the fat of these three species were heated, the species-specific aromas could be easily detected. In a taste test of lean beef and pork, adding 10% fat to the lean meat sample caused panellists to identify the lean meats more easily.

Red meat flavour can be affected by animal nutrition. Grass-fed animals generally produce meat with less acceptable flavour than high-energy grain-fed animals (Melton, 1990). Meat from animals on the high-energy grain diet also had a more intense flavour. Grass-fed animals have higher levels of n-3 and lower levels of n-6 polyunsaturated fatty acids, which might explain the flavour-difference since fatty acids act as precursors for certain flavours.

When it comes to flavour, meat species differ in acceptability (Von la Chevallerie, 1972). Often game meat is perceived as having a ‘gamey’ flavour that is not acceptable to all consumers. This ‘gamey’ flavour can be linked to several factors: meat from old male animals

(it is common in South Africa for trophy hunters to shoot older male animals); spoilage of meat by incorrect slaughtering and bleeding methods; progressive stage of meat ripeness; and/or high polyunsaturated fatty acid levels present in meat (Pietersen, 1993; Jansen van Rensburg, 1997). Von la Chevallerie (1972) detected no 'gamey' flavours in meat from correctly bled and hung carcasses.

Even within game meat species differences in flavour acceptability occurs – Von la Chevallerie (1972) found springbok flavour was preferred and the least acceptable flavour of the seven species studied was attributed to red hartebeest. During analytical sensory evaluation panellists are normally asked to rate the overall flavour of the sample and it is described as a combination of taste and swallowing (AMSA, 1995).

8.2. Consumer panel work

The main reason for doing consumer sensory testing is to establish how consumers (current or potential consumers) will react to a product, a specific attribute of a product or a product idea (de Kock, 1993). The consumer reaction can determine acceptance, preference or both. Munoz (1997) adds that consumer opinion on products can also be valuable in testing products. Companies usually interpret and use information gathered from consumer testing to answer questions on marketing or research since consumer information is considered most important when product decisions on developing and marketing of new products are made (Munoz, 1997). If companies want to test the acceptance level of a product, consumer-liking tests can be used. During consumer sensory evaluation, target consumers are used to determine degree of liking, preferences and sometimes purchase intent and to study the responses or emotional reactions displayed by consumers to the food tested (Resurrecion, 1998).

There are several factors to consider when dealing with consumer evaluation. Since consumers are not trained to make unbiased evaluations of attributes, they always evaluate products with a frame of reference in mind (Lawless, 1995). Another potential problem is representation, but this will be addressed when panel composition is discussed.

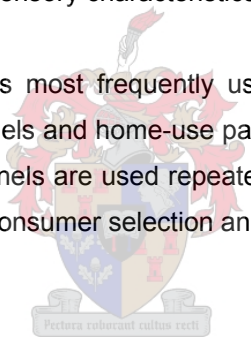
It is important to ensure that the correct criteria are being tested because consumers are used to interacting with several exterior factors when dealing with any product. Factors that may potentially bias consumers are brand and the price-to-quality-ratio. Therefore, blind labelled testing is best for testing the sensory characteristics of a product, while it would tell you nothing about how a product would fare in a real-life situation when different brands and price-classes are also competing with a product. Munoz (1997) cautions that consumer data should be used in conjunction with other product information (such as descriptive analysis data, physical or chemical data, demographics and company employee consumer data),

rather than on its own. This ensures that consumer data is better interpreted and fully understood.

Several authors have noted consumers' tendency to give an overall score to a product (Lawless and Claassen, 1993; Lawless, 1995). Consumers will generally treat individual attributes on a questionnaire as if they were interrelated. Therefore, better information will be gained from asking consumers for their overall impression during testing.

Extrinsic cues such as brand, product labelling or ingredients used can influence consumers' attitude towards a product. In a restaurant-based study by Wansink, Painter and van Ittersum (2001), two sets of six products were prepared according to the same recipes, but one set were labelled using descriptive names (e.g. Succulent Italian Seafood filet), while the second set used more basic names (e.g. Seafood filet). Products with descriptive names were chosen 27% more often during the six weeks of testing. The quality of food with the descriptive names was rated higher than their counterparts with basic names. This study shows how vulnerable consumers can be to suggestibility and therefore, it is important to control extrinsic cues when testing sensory characteristics alone (Wansink, 2003).

The four types of consumer panels most frequently used are employee panels, standing external panels, central location panels and home-use panels (Lawless and Heymann, 1998). Employee and standing external panels are used repeatedly over time, while central location and home-use panels use random consumer selection and the panel is only used for one test.



8.2.1. Panel composition

A potential problem is representation. The consumer group used in a testing session must represent a valid reference group – the target population – for example, when testing meat characteristics, use meat eaters, not vegetarians (Lawless, 1995; Lawless and Heymann, 1998; Resurreccion, 1998). The target population is defined as the consumers who would purchase and use the product being tested. Significant differences were found between heavy, light and non-users of canned soup (Wansink and Park, 2000), which shows that consumption rates and previous experience will influence sensory experience. Since consumers' prior experience with a product category can bias their taste and opinion, Wansink (2003) advises choosing (or screening) potential participants of consumer testing, which will also lower variance of the data. Asking potential panellists about the frequency at which they use the product being tested is the easiest way to determine whether or not they belong to the target group. Furthermore, Resurreccion (1998) advises 50 to 100 consumers as the most likely response-size where significant differences would be well detected.

8.2.2. Questionnaire design

When considering questionnaire design, asking for overall opinion takes less time and eliminates the possibility of taster's fatigue setting in. Lawless (1995) also advises against using double-barrelled questions such as "Do you think game meat is healthy and less fattening?" Questions like this might only serve to confuse consumers or cause them to score products differently than they otherwise would have.

The 9-point hedonic, or degree-of-liking, scale (1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like, nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely) is the most commonly used hedonic scale (Moskowitz, 1984; Lawless and Heymann, 1998). It is simple and easy to use and to understand. The 9-point hedonic scale is reliable and has a high stability of responses, irrespective of region, but its effectiveness in other languages has not been widely investigated. This scale, according to Lawless and Heymann (1998), has ruler-like properties (psychologically) because of the equal interval spacing of the words chosen for each point. This is a very important aspect, since it allows the sensory scientist to assign numerical values to the choices made by the consumer, which makes statistical analysis of the data much easier. The hedonic scale assumes that consumer preferences exist on a range and that it can be categorised by responses based on likes and dislikes. Resurreccion (1998) reports that preference tests are useful tools when consumers are asked to compare two products against each other, but cautions that, while consumers may detect differences between products, they cannot identify differences within specific characteristics.

8.3. Findings of Trained panel tests vs. Consumer panel tests.

Because consumer evaluation of a product focuses mainly on an overall impression, it is not a very reliable testing mechanism for testing the contribution of individual characteristics of the product. In that regard descriptive analysis performed by trained panels is much more reliable (Lawless, 1995). Munoz (1997) concurs that a trained panel can provide specific product information that can be used to better interpret and understand consumer responses when it is related to consumer data.

Although data gathered from analytical sensory testing can be correlated to consumer opinions, trained panels mostly do not represent consumers accurately and there are discrepancies on the accuracy of the regression of consumer acceptance against descriptively analysed attributes (Lawless, 1995).

Trained panellists are better equipped to detect and quantify differences in the characteristics that they are trained to investigate. However, Moskowitz (1984) stated that it is very important to keep in mind that, if consumers are not able to detect differences between products when trained panellists are able to do so, it means that the differences detected by the trained panellists are not

as relevant when the products are consumed by the consumer, away from a laboratory environment.

9. Consumers

The consumer's perception of food is compiled from the inherent attributes of the food, its interaction with the immediate external factors surrounding it and the previous experience of the consumer (Dransfield *et al*., 1998).

Several models for consumer perception of food have been proposed over the years. Pilgrim (1957) stated that food perception depended on three factors: properties of the food; perception of sensory attributes; and environmental factors. The model proposed by Steenkamp (1997) focuses more on the consumer's decision making and is based on four stages: need recognition; search for information; evaluation of alternatives; and choice. This author found that consumers were more concerned about the consequences or benefits that products would bring instead of product attributes. While meat attributes can be defined as the physical qualities (concrete, such as fatty acid composition, or abstract, such as fattening), consequences and benefits are related to product use and is a representation of what the consumer perceives the product to be doing for him or her.

Bocker (1997) found that a consumer's overall impression of a product is based on a compensatory decision rule. This means that the presence of highly valued attributes in a product can compensate for the lack of certain attributes or the presence of unsatisfactory attributes. The overall impression formed during consumption is usually most important for food products.

Consumers make food decisions based mostly on three types of factors: characteristics of the food product (supplied by industry); factors related to the person engaged in food consumption; and environmental factors (Steenkamp, 1997). The means-end theory (Audenaert and Steenkamp, 1997) suggests that consumers view products as a way through which they can attain certain valued outcomes ("ends"). In other words, the reason why consumers demand certain products is not related simply to either the product or the consumer, but to the consequences (linked to life values) that will be reached by consuming these products.

Consumer-involvement is defined by Verbeke and Vackier (2004) as the "level of perceived personal importance, interest or relevance evoked by a stimulus/stimuli, which are linked by the consumer to enduring or situation-specific goals." A consumer's behaviour can be greatly explained by his involvement in a product. The stimuli involved can be anything from the products themselves, brands, and advertisements to the purchase decisions made by the consumer. It is more likely that consumers will be involved in products with a high potential

reflection on self-image and those products usually at high cost or risk and/or high social pressure (Verbeke and Vackier, 2004). The level of involvement can explain many of the steps in the decision-making process of consumers. These steps may include: length of the decision-making process, extensiveness of information search, attitudes and intentions and formation of beliefs. Several behavioural outcomes such as brand switching, brand commitment or loyalty, variety-seeking behaviour, shopping enjoyment and frequency of product usage can also be attributed to involvement level (Verbeke and Vackier, 2004).

A low level of involvement excludes extensive information processing, but rather associates with routine, impulsive or habitual behaviour. On the other hand, Vebeke and Vackier (2004) list the steps taken at a high level of involvement as: an active search, information use after careful processing, weighing and evaluating product characteristics prior to forming beliefs and developing an attitude. All these steps are necessary before the consumer can move on to behavioural intentions and actual behaviour because high involvement requires extensive problem solving.

Most food products, especially low-priced and frequently purchased products, are considered as low involvement products. That is because most food products are associated with a low potential reflection of self-image and low social pressure, with some exceptions, mainly risk-associated – whether it is real or perceived. Such risks include products with possible health implications and the probability of making a wrong choice (Verbeke and Vackier, 2004). Meat is one of the exceptions to the usual food-involvement rule, especially since meat has attained its negative image associated with various health risks. Meat is still perceived as having a high hedonic or pleasure value, even though its perceived symbolic value is fairly low. Verbeke and Vackier (2004) have found that in general consumers viewed the pleasure value of fresh meat as dominant over symbolic value, risk probability and risk importance.

9.1. Meat consumers

In the last few years, consumers have been attaching more value to attributes such as animal welfare, animal feeding assurance and environmentally friendly production practices, mostly because of concerns about health, safety and ethical factors being given new urgency by various groups (Bernues, Olaizola and Corcoran 2003b). Several authors have noted that consumers' perception of food quality, especially meat quality, is changing and that consumers are becoming more demanding about quality (Issanchou, 1996; Grunert, 1997; Bernues, Olaizola and Corcoran 2003a). There has been a shift away from focussing on the product, to rather focussing on the quality of the production process, especially since issues such as animal welfare, ethics and traceability have become more important.

Verbeke and Vackier (2004) classified Belgian meat consumers into four groups according to their level of involvement in meat: straightforward meat lovers (enjoy meat consumption, without perceiving much risk in its consumption); cautious meat lovers (choose to eat meat,

but make a much more cautious choice of meat); indifferent meat consumers (do not consider the negative consequences of poor choice as highly important, perceive the probability of making a wrong choice as high and report a low pleasure value for meat consumption); and concerned meat consumers (highly concerned about perceived risk). They found that more men belonged to the first group that was linked to men attaching a higher pleasure value and lower risk importance than women. The indifferent meat consumers group is made up of more consumers under 25 years than any other age group, while families with children were mostly divided between cautious meat lovers and concerned meat consumers. Kubberod, Ueland, Rodbotten, Westad and Risvik (2002) also found that men supported "pro-red meat" statements much more then women.

When looking into issues that may concern meat consumers, it was found that concern about BSE, antibiotics, hormones and fat and cholesterol content were the main concerns. Meat lovers and indifferent meat consumers were in general less concerned about all issues than the other two groups. The cautious meat lovers and concerned meat consumers were more concerned about BSE, antibiotics and hormones with only concerned meat consumers showing high concern in regard to fat and cholesterol content. With higher education, concern for BSE and fat and cholesterol were much lower, women were more concerned about all issues than men, while families with children showed slightly more concern (except for fat and cholesterol) than other groups (Verbeke and Vackier, 2004).

Working with Australian consumers, Russell and Cox (2004) looked at age-group differences. These authors found that young and middle-aged (40-60 years) consumers perceived white meat and fish as healthy meat options. While older consumers perceived red meat as healthy. Middle-aged consumers shared views on different meat-related issues with both young and older age groups. Since the middle-aged consumers group of industrialised populations is large and growing, they are recognised as an important consumer segment with different needs than other age groups. These consumers may not respond positively to products focussed at elderly consumers or even all products focussing on younger consumers. For example, middle-aged consumers do not share younger consumers' views on lamb and pork chops, roasted chicken and comminuted or processed products, but rather tend to perceive these products more positively like the older consumers. Red meat consumption among younger women was found to be declining (Kubberod *et al*., 2002).

When consumers were asked to identify the factors responsible for their attitude towards beef, McCarthy *et al*. (2003) found health, eating enjoyment to be the two most important factors, with price, animal welfare and environment of lesser importance. European beef and lamb consumers were asked which non-physical (extrinsic) attributes they considered important and the following list of attributes was generated: animal feeding; origin of meat; environmentally friendly production; animal welfare; and storage (Bernues *et al*., 2003a).

It was found that consumers who were primarily interested in the safety, nutritional value and health aspects of meat, attached special importance to most of the extrinsic characteristics of meat, except origin (Bernues *et al*., 2003a). Consumers concerned with the origin of meat showed average or lower than average concern for safety, nutritional value and health. Ethical values played an important role in consumer consideration of meat as the relative importance of environmental concerns and animal feeding were rated more important by consumers who rated safety, nutritional value and health the most valued attributes of meat (Bernues *et al*., 2003a).

Consumers seeking convenience considered processing, packaging, knowledge of preparation and ease of purchasing as very important aspects of meat (Bernues *et al*., 2003a).

Beef consumers considered labels and brands to provide reliable information about quality. Especially consumers concerned about safety, nutritional value and health attached a lot of value to label information (Bernues *et al*., 2003b). Lamb consumers considered label and brand as important sources of information, but "own assessment" at the time of purchase was also important.

Consumers prefer and demand lean meat. Resurreccion (2004) showed that visible fat could severely influence purchase behaviour. Consumers became biased against pork chops with high amounts of visible fat and did not purchase it. Out of 142 consumers, 42% purchased lean chops, 40% purchased medium marbled chops and 18% purchased highly marbled chops. As long as consumers could not visibly detect fat, the fat content of meat did not influence purchasing behaviour to a great extent.

While studying the effect of different factors surrounding meat products, Dransfield *et al*. (1998) found that steak tenderness influenced consumer purchase behaviour tremendously. After consumption, most consumers preferred to purchase the most tender steaks, even if those turned out to be the most expensive steaks offered. Various other authors have highlighted the importance of tenderness to consumers (Koohmaraie, Whipple and Crouse, 1990; Girolami, Marsico, D'Andrea, Braghieri, Napolitano and Cifuni, 2003; Robbins, Jensen, Ryan, Homco-Ryan, McKeith and Brewer, 2003).

Over a two month period, Miller *et al.* (1995) had consumers rate steaks on tenderness and overall acceptability at home and then had them rate a steak a week in a restaurant over seven weeks. These authors found consumers to be more critical in regard to beef tenderness in their homes than at restaurants. Although tenderness is regarded as the most important quality characteristic valued by consumers, it is not the only characteristic

contributing to the overall acceptability of steaks. In the study by Miller *et al*. (1995) this fact was proven when restaurant consumers rated 81.3% of the total amount of steaks as acceptably tender, but 87.6% of all the steaks were considered acceptable overall. Meat quality characteristics such as flavour and juiciness also have a part in overall acceptability of meat. Huffman, Miller, Hoover, Wu, Brittin and Ramsey (1996) reported that 51% of 67 consumers participating in a study to determine consumer acceptability of beef tenderness at home and in a restaurant, chose tenderness as the most important meat quality characteristic, 39% considered flavour to be most important and 10% rated juiciness as most important.

9.2. Perceived quality

Perceived quality is defined as the consumer's perception of the product's fitness for use with regards to the purpose it was intended for and relative to alternative products (van Trijp, Steenkamp and Candel, 1997). Dransfield (2001) expanded on this idea by stating that a consumer develops an expected quality perception of a product and will purchase the product if this expected perceived quality satisfies his needs. Only after purchase would the consumer actually experience the product's quality and this experienced quality will be used, along with perceived quality when the product is bought in the future. According to Issanchou (1996) perceived quality of food depends on the consumer and the context in which food is consumed and could, therefore, change after consumption of the product.

Issanchou (1996) identified three stages in quality perception: perceived quality prior to purchase (formed from beliefs and attitude of the consumer and depends on social, personal and psychological factors as well as previous experience); perceived quality at the point of purchase (mostly dependent on intrinsic cues such as physical attributes of the product, extrinsic cues, quality cues such as labels and the price of the product are used to evaluate the perceived quality); and perceived quality upon consumption (sensory characteristics of the product is most important).

Because food products are measured against other similar products, price can be an important factor (Issanchou, 1996), especially when deciding between unknown products. Dransfield *et al*. (1998) found that with no knowledge of eating quality a third of consumers chose higher priced steaks when a study was conducted on steaks similar in appearance and intrinsic qualities, but differing in price. As soon as the higher priced steaks were labelled "Charolais and tender", the preference for those steaks increased. This shows that previous experience and product information have a definite impact on perceived quality.

Carpenter *et al*. (2001) found beef colour and packaging influenced purchasing behaviour but not perceived eating quality. The importance of colour in meat purchasing is followed by flavour, odour and texture (Kubberod *et al*., 2002).

9.3. Health concerns

Consumers form their opinions on health and the healthiness of food products mostly on what they hear from friends and family, doctors, nutritionists and the media. The opinions of medical professionals usually weigh heavily and people tend to take their advice to heart. Modern consumers are very health-conscious and nutritional concerns, together with the vilification of animal fats, have caused consumers to become more selective in their purchasing behaviour (Kupiec, 2001; Resurreccion, 2004). These health views of consumers were confirmed by a survey in which 76% of all participants concurred that they consider the health aspects of food products before purchasing (Hoffman *et al*., 2005).

Unnevehr and Bard (1993, as cited by Issanchou, 1996) reported that nutritionists in the USA advised consumers to reduce their beef intake so as to reduce saturated fat intake which would In turn lead to a lesser risk of heart and coronary diseases and cancer. This way beef (and red meat in general) was negatively associated with health. Recommendations made about beef consumption are partly responsible for a decline in beef consumption seen in most industrialised countries (Porin and Mainsant, 1996). Dietary cholesterol intake, although it influences blood cholesterol levels very little, scares many consumers. Consumers have associated meat with a negative influence on serum cholesterol levels (Higgs, 2000).

Red meat has been linked to coronary heart disease, which also negatively influence consumers' attitude towards it (Melanson *et al*., 2003). The saturation of animal fats have particularly been blamed in this regard (Wood *et al*., 2004) and Girolami *et al*. (2003) reported that a high ratio of n-6:n-3 fatty acids increased the risk of arteriosclerosis and coronary heart disease. A dietary intake of 1g per day of n-3 polyunsaturated fatty acids had a protective effect against cardiovascular death and the risk of fatal heart disease can furthermore be reduced by regularly consuming α-linolenic acid or fish (Gissi-Prevenzione Investigators, 1999).

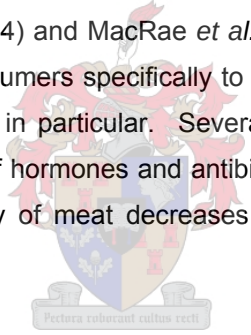
The fatty acid composition rather than the total amount of fat is important in human nutrition, especially the saturation levels and ratios (Lengyel *et al*., 2003). In the UK, the Department of Health (1994) has recommended fat intake be reduced by 30% of the total energy intake and that saturated fatty acid intake should not exceed 10%.

Recently red meat has become associated with various cancers, such as colorectal, breast and prostate cancer (Higgs, 2000; Stoeckli and Keller, 2004) even though the majority of epidemiological studies could not confirm the part of meat in most cancers (Biesalski, 2005). However, consuming fatty forms of white meat, such as fried fish and chicken with skin, were associated with increased risk of breast cancer (Ronco *et al*., 2003), showing that any meat high in fat should be considered a risk, not just red meat in general.

Biesalski (2005) reported a positive correlation between fat intake and breast, colon and prostate cancer, although controversy remains. Reddy (1981) reported red meat consumption, which increased dietary fat intake, increased colon cancer risk. Because animal fat is generally more saturated in nature, it is related to cancerogenesis, while plant fats are considered as more protective because of its high polyunsaturated fat content (Biesalski, 2005). While linoleic acid (n-6 fatty acid) enhanced cancerogenesis in rodents, linolenic acid (n-3 fatty acids) suppressed colon cancer development through the inhibition of the arachidonic pathway.

9.4. Safety concerns

As previously mentioned, food product safety is important to consumers. Issanchou (1996) noted the importance of consumer perception vs. actual food safety. Perceived safety is always in a fragile state, especially when a potentially high-risk product such as meat is involved. Because of this precarious state of perceived safety, it is easily influenced negatively by any new information, regardless of its medical or scientific soundness. Issanchou (1996) mentions the Creutzfeldt-Jakob disease scare (linked to BSE) as a good example of how non-scientific information can cause havoc with the perceived safety of beef. Kubberod *et al*. (2002), Sadler (2004) and MacRae *et al.* (2005) also stated that the various BSE scares caused European consumers specifically to become very concerned about food safety in general, and meat safety in particular. Several such examples exist regarding a variety of different topics, the use of hormones and antibiotics being two of them (Issanchou, 1996). When the perceived safety of meat decreases meat sales and consumption also drops considerably.



Borchard and Arinder (2002) mentioned that problems in the basic hygiene routine in the meat production cycle could cause illness and even death due to foodborne pathogens. A good example of what the effects of improper handling and preparation of meat and meat products could have on health is the *Escherichia coli* O157:H7 outbreak during 1992 (Fang *et al*. (2001). The outbreak was caused by undercooked hamburger in a fast food chain in the Pacific Northwest and resulted in 501 cases of infection and four deaths. This case opened the eyes of many consumers to the possible health and safety risks associated with meat and meat products and resulted in government policy and regulation changes improving food safety in all areas of the food industry. Food safety and prevention systems such as Hazard Analysis of Critical Control Points (HACCP) are implemented to control and prevent food contamination by foodborne pathogens (Warriss, 2000).

9.5. Quality characteristics valued by consumers

Food quality perception and the characteristics involved are very complex and influenced by various interior and exterior factors. According to Steenkamp (1990) the consumer receives quality information in the form of quality cues. These cues provide information about the

product and can be either intrinsic (relating to the physical aspects of the product, e.g. colour or shape) or extrinsic (relating to the product, but not physically, e.g. brand or packaging). The consumer uses these cues to form a perception of the quality of the product.

When Hoffman *et al*. (2005) asked consumers about the qualities they normally considered important when buying meat, fat content (29.4%) colour (13.5%) and freshness (13.2%) were considered most important.

Marshall (2003) stated that British consumers rated price as most important, with taste as second most important factors when buying food. Quality, family health, appearance, freshness, brand name, nutritional value and food safety were also mentioned.

In a study conducted in the USA by Resurreccion (2004), it was found that consumers' demand for meat and meat products were chiefly influenced by an increased concern for health; changes in demographic characteristics; a need for convenience; distribution changes; and changes in relative price. Resurreccion (2004) reported that American consumers were concerned about cholesterol and calorie content, artificial ingredients, convenience and price, when asked about meat and meat products. Grunert (1997) reported that European (from France, Germany, Spain and the UK) consumers were mainly concerned about the taste (that it tastes good), tenderness, juiciness, freshness, leanness, healthiness and nutritional value of beef.

In their study on the quality of meat (beef, lamb and pork) collected from several retail outlets in the USA, Bickerstaff *et al*. (2001) reported that 20% of supermarket consumers were not satisfied with the eating quality of beef. Furthermore these authors revealed that several countries have recognised the existence of inconsistent quality of retail meat and that some countries have taken drastic steps in improving the quality of meat. Thus, Australia has incorporated the five-star quality grading system, the UK and France have introduced the "blue print" and "label range" guidelines, while New Zealand introduced the New Zealand Beef and Lamb Quality Mark Standard. The latter goes so far as to set standards for animal welfare, microbiological quality, storage life, as well as meat eating quality.

Colour (or appearance) changes, along with changes in texture and flavour (when off-flavours are not present) can affect meat preference with consumers (Risvik, 1994). Appearance is important to consumers since consumers prefer leaner meat and would therefore discriminate against meat containing visible fat. Consumers prefer meat with a bright red colour as they associate it with freshness and wholesomeness (Hood and Riordan, 1973). Appearance is, however, not a reliable predictor of eating quality.

10. Enhancement of meat

Meat enhancement generally focuses on improving tenderness, and juiciness to a lesser degree, by preventing or minimising the toughening phase or by accelerating or improving the tenderisation phase (Koohmaraie, 1996). Meat can be enhanced in several ways, such as hanging the carcass by the pelvis (Bouton *et al*., 1973), freezing the carcass immediately after storage and then storing at sub-freezing temperatures to prevent cold shortening or by marinating or injecting with inorganic salt solutions. For this study, enhancement through injection of inorganic salt solutions will be focussed on.

10.1. Inorganic salts used

Several inorganic salts can be used to enhance meat, calcium salts being the most frequently studied, but all inorganic salts do not have the same effect on meat properties (Table 14).

For instance, enhancement with lactic acid is known to increase shelf life of meat by inhibiting bacterial growth. Eilers, *et al*., (1994) and Djenane, Sanchez-Escalante, Beltran and Roncales (2003) found lactic acid-treated steaks to have decreased levels of microbial growth compared to Ca-treated or untreated steaks. The downside of using lactic acid as enhancement-tool is the adverse effects it has on flavour. Not only do lactic acid-treated steaks score lower for flavour intensity, it has a notable increased amount of off-flavours (Morris *et al*., 1997).

10.1.1. Calcium

Koohmaraie *et al*. (1990) showed that infusing carcasses or injecting portions (i.e. cuts or muscles) of the carcass with calcium chloride improved ultimate tenderness in young animals by accelerating post-mortem ageing. Morgan, Miller, Mendez, Hale and Savell (1991) hypothesised that the positive effect of calcium chloride-injection on meat tenderness is achieved by an increase of intracellular calcium concentration, which in turn, activates the calcium-dependent proteases (i.e. calpain).

Calcium chloride is mostly used when studying the effects of calcium-salt injections on meat quality aspects, but various researchers have noted certain quality problems when this salt is used. Detrimental effects on flavour intensity (Wheeler *et al.*, 1997; Lawrence *et al.*, 2003a) and more noticeable off-flavours (Benito-Delgado *et al.*, 1994; Lawrence *et al.*, 2003a) are some of the negative aspects noted. Microbial growth was higher when calcium chloride rather than calcium lactate was used (Wheeler *et al.*, 1993; Lawrence *et al.*, 2003b) and calcium chloride also caused muscle darkening and faster meat discolouration (Kerth *et al.*, 1995). These side effects of calcium chloride prompted examination of other calcium salts, particularly calcium lactate and calcium ascorbate.

Table 14 Effect of different inorganic salts used in meat-enhancement on various meat properties as compared to that of non-enhanced meat.

Meat Property	Calcium chloride	Calcium ascorbate	Calcium lactate	Phosphate + salt	Sodium chloride	Sodium phosphate
Colour (raw/retail)	-	-	Increased colour stability[2]	Decreased[14]	-	-
Colour (cooked)	Increased[1]	-	-	-	-	-
Cooking loss (%)	Increased [1, 13]	-	-	Decreased [some Na phosphates] [15]	-	Decreased [some Na phosphates] [15]
Discolouration (faster)	Higher & faster [3, 11]	Faster [2]	Slower [2]	-	-	-
Flavour intensity	Decreased [1, 2, 6]	Decreased [2]	-	Decreased [5]	Increased [14]	Increased [14]
Juiciness	Increased [1]	-	-	Increased [15]	Increased [14]	Increased [10, 14]
Off-flavours	More – bitter, metallic [1, 2, 4, 6, 7, 8, 9]	More [2]	More [7]	-	-	-
Overall acceptability	-	-	-	-	Increased [14]	Increased [14]
Saltiness	Increased [4]	-	-	-	Increased [14]	Increased [14]
Tenderness (consumer)	-	-	-	-	-	Increased [14]
Tenderness	Increased [1, 4]	Increased [2]	Increased [2]	Increased [14, 15]	Increased [8, 12, 14]	Increased [10]
Water holding capacity	Increased [8, 12]	-	Increased [2]	Increased [5, 15]	Increased [8, 15]	Increased [8]

([1]Wheeler *et al*., 1997; [2]Lawrence, Dikeman, Hunt, Kastner and Johnson 2003a; [3]Kerth, Miller and Ramsey, 1995; [4]Benito-Delgado, Marriott, Claus, Wang and Graham, 1994; [5]Lawrence, Dikeman, Hunt, Kastner and Johnson, 2003b; [6]Eilers, Morgan, Martin, Miller, Hale and Acuff 1994; [7]Morris, Theis, Miller, Acuff and Savell, 1997; [8]Deatherage, 1963; [9]Scanga, Delmore Jr., Ames, Belk, Tatum and Smith, 2000; [10]Smith, Simmons, McKeith, Betchel and Brady, 1984; [11]Wheeler *et al*., 1996a; [12]Wierbicki, Cahill and Deatherage, 1957; [13]Koohmaraie *et al*., 1990; [14]Robbins *et al.*, 2003; [15]Baublits *et al*., 2005)

Lawrence *et al.* (2003a) found calcium lactate-treated beef *M. longissimus dorsi* had lower aerobic microbial plate counts than either calcium chloride- or calcium ascorbate-treated samples and also experienced calcium-lactate to have a more positive effect on beef flavour intensity and off-flavour rating than the other two calcium treatments. Calcium lactate injections resulted in less discolouration than either calcium chloride or calcium ascorbate (highest amount of discolouration). Red colour retention was improved in samples injected with calcium lactate and Lawrence *et al.* (2003a) reported this positive influence on colour stability on the increased lactate concentration in the system.

Calcium ascorbate injections inhibited lipid oxidation, while Lawrence *et al.* (2003a) found calcium chloride and calcium lactate to act as pro-oxidants for lipid oxidation. Even so, calcium ascorbate-treated steaks received lower colour scores than calcium chloride- or calcium lactate-treated steaks. This colour deterioration was due to a higher degree of myoglobin oxidation (Lawrence *et al.*, 2003a). Liu and Watts (1970) proved that ascorbic acid could be a pro-oxidant when iron is present. When vitamin C (ascorbic acid) were added to steak solely or in addition to calcium chloride, Wheeler *et al.* (1996a) found that steaks had more red colour and less surface discolouration on 5 and 7 days of display at 1°C than either non-treated or calcium chloride-treated steaks.

Non-calcium treated beef showed no change in m-calpain activity during storage, its ų-calpain activity decreased tremendously and only a moderate decrease in calpastatin activity was seen during storage (Gerelt, Rusman, Nishiumi and Suzuki, 2005). On the other hand, no ų-calpain or calpastatin activity was observed after 48 hours at cold-room temperatures in calcium chloride-treated beef. The m-calpain activity in treated meat was reduced to only 6.1% of its activity after 48 hours. These authors concluded that calpain autolysis and proteolytic degradation of calpastatin occur if enough calcium is present. These processes lead to diminished calpain and calpastatin activities and it was found that improved tenderness (reduced toughness) was related to reduced calpain and calpastatin activities. Whipple and Koohmaraie (1993) concluded that improved tenderness was achieved through m-calpain activation.

No differences were found between calcium salts for tenderness or juiciness, according to Lawrence et *al.* (2003a). These authors did, however, recommend using a solution of calcium-lactate, rather than calcium chloride or calcium ascorbate, to achieve tenderness with display colour stability and microbial inhibition of meat.

10.1.2. Phosphates

There are conflicting opinions on the relationship between calcium and phosphate. Some researchers reported that phosphates bind with calcium to form chelates when found in a

solution (Lawrence *et al.*, 2003b), thus preventing positive results when used together in brines. Others believe that phosphates cannot complex with calcium already bound to meat proteins (Inklaar, 1967) and since about 60% of calcium in meat is bound to meat protein, most of the calcium is not free to chelate with the phosphates. Inklaar (1967) also found no effect of phosphate addition on calcium and Mg concentrations left in meat. Lawrence *et al.* (2003b) suggested adding calcium to the muscle before adding phosphates, thus accelerated tenderisation can be initiated by calcium and yields can be maximised by adding phosphates which will also reduce losses through purge.

Consumers found bison steaks injected with up to 0.3% sodium tripolyphosphate and 0.5% sodium chloride more tender, juicier, more flavourful and overall more acceptable than non-treated steaks (Dhanda, Pegg, Janz, Aalhus and Shand, 2001, as cited by Robbins *et al*., 2003). Robbins *et al.* (2003) reported beef steaks and pork chops treated with phosphates to be more tender and juicy than non-treated meat by a trained sensory panel.

Phosphate addition caused meat to show a higher WHC (Baublits *et al.*, 2005), regardless of phosphate type. When it came to cooking losses, a difference in type of phosphate was observed: sodium hexameta-phosphate caused higher (same as non-treated) cooking losses than either sodium tripolyphosphate or tetrasodium pyrophosphate (both less than non-treated meat). In their study on the effect of either sodium chloride- or different phosphate salt-solutions on beef, Baublits *et al.* (2005) found 12% phosphate-pumped steaks to be juicier than sodium chloride- and non-treated steaks, although steaks pumped to 18% phosphate solution were not experienced as juicier than sodium chloride-treated steaks.

10.1.3. Sodium chloride

Deatherage (1963) reported that sodium chloride accentuated the following effects on meat when heated: the pH-change increased; juice expressed was reduced; WHC was heightened; and tenderness was increased. During cooking temperature (40-70°C) there is a shift in calcium, magnesium, sodium and potassium ions so as to counteract shrinkage. This ability of sodium chloride (when added before heating) to increase WHC of meat proteins on heating (to 70°C) corroborates the work of Wierbicki *et al.* (1957).

10.1.4. Other inorganic salts

Sodium lactate (sodium lactate) was noted to enhance beef flavour and to minimise the decline in flavour during storage (Papadopoulos, Miller, Ringer and Cross, 1991). Increasing sodium lactate concentration (from 0 to 4%) caused meat to have a darker red colour with less surface grey and also led to increased cooking yields (increased WHC). However, increased sodium lactate concentration beyond 1% did not improve palatability any further. Tenderness and juiciness were improved for all sodium lactate concentrations compared to

untreated samples, but increasing sodium lactate above 1-2% resulted in no further improvement.

Sodium nitrate and nitrite infusion (at 10% of weight) of an old cow before dressing-out caused all muscles to be very tender and no drip loss was reported when meat was frozen or thawed (Deatherage, 1963).

Potassium chloride and magnesium chloride accounted for higher WHC values in heated meat, but had detrimental effects on meat flavour (Wierbicki *et al.*, 1957; Deatherage, 1963). Magnesium chloride-treated meat expressed less juice on heating than potassium chloride.

10.2. Tenderisation effects

The entire motivation for enhancing meat with inorganic salts is to ultimately result in more tender meat. Most authors agree that tenderness is improved by inorganic salt-treatment of meat (Morgan *et al.*, 1991; Papadopoulos *et al.*, 1991; Lawrence *et al.*, 2003a, b).

Koohmaraie *et al.* (1990) proved that tenderness of whole carcasses, cuts or individual muscles could be improved by calcium chloride-treatment. Morgan *et al.* (1991) found that calcium chloride-treatment lowered the Warner-Bratzler shear force values of strip loin by approximately 50% compared to untreated samples. In the same study it was also shown how calcium chloride accelerated post-mortem ageing when untreated top sirloin samples aged for 14 days had higher shear force values than calcium chloride-treated samples aged only one day (Morgan *et al*., 1991).

M. longissimus dorsi of beef and sheep were more tender after injection with calcium chloride and calcium chloride-treatment had to effect that treated samples were more tender with a marked reduction in post-mortem storage time (Benito-Delgado *et al.*, 1994). Similar results were found by Koohmaraie *et al.* (1990) on lamb meat. Several authors reported that calcium chloride-injections increased beef tenderness (Whipple and Koohmaraie, 1993; Kerth *et al.*, 1995) while accelerating ageing times (Koohmaraie *et al.*, 1990; Benito-Delgado *et al.*, 1994). Koohmaraie *et al.* (1990) also reported that shear force values of calcium chloride-injected beef *M. longissimus dorsi* decreased by approximately 1 kg during 14 days of storage, while non-treated samples decreased by 2.8 kg, although treated beef still had much lower shear force values than untreated samples. At one day of storage treated beef had lower shear force values than untreated samples. Calcium chloride-treated beef shear force values at day 1 were similar, but lower than non-injected beef after 14 days of ageing. This shows that there really is no need to age calcium chloride-treated beef for as long as untreated beef, since the tenderness is already improved and does not improve any further with ageing.

No differences between calcium chloride, calcium lactate and calcium ascorbate were found in regard to tenderisation effects (Lawrence *et al.*, 2003a) and all of these calcium salts improved analytical sensory tenderness ratings equally. Calcium-treatment of beef *M. longissimus dorsi* muscle increased both myofibrillar and overall tenderness significantly, regardless of which salt was used.

While Lawrence *et al.* (2003a) found no difference in the tenderisation effects of different calcium salts, higher concentrations of calcium salts (0.3 M) caused lower shear force values, thus more tender meat, than lower (0.1M) concentrations. In sensory analysis, meat treated with 0.3 M calcium salts was also judged as more tender. In the same study steaks were considered as tough when shear force values were higher than 4.5 kg and of all calcium-treated steaks, 4.2% qualified as tough, while 37.5% of untreated steaks were found to be tough.

Koohmaraie *et al.* (1990) reported that calcium salts affected tenderness by increasing the calpain activity in meat due to an increased calcium ion concentration and then went on to explain that this activation of calpain caused degradation of Z-disks and cytoskeletal proteins (Koohmaraie, 1994). Solubilisation of myofibrillar proteins were suggested by Takahashi, Kim and Yano (1987) as the main effect contributing to tenderisation, caused by a non-enzymatic salting-in of calcium ions. Treatment with calcium chloride caused an increase in calcium concentration high enough to activate the calpain system, which leads to increased muscle fragmentation (Eilers *et al.*, 1994).

Sodium lactate treatment caused improved tenderness in top round roasts (Papadopoulos *et al.*, 1991), but using concentrations above 1.0-2.0% brought no further improvement. Vote *et al.* (2000) reported similar results when sodium lactate was used to enhance *M. longissimus dorsi* samples.

Phosphates, and most commonly sodium phosphate, are frequently used in meat processing to improve protein solubility (Deatherage, 1963) and enhancing meat with phosphates has increased meat tenderness as well (Smith *et al.*, 1984; Scanga *et al.*, 2000; Lawrence *et al.*, 2003b; Robbins *et al.*, 2003). In sensory analysis, steaks treated with sodium hexameta-phosphate, sodium tripolyphosphate or tetrasodium pyrophosphate, were scored higher in tenderness than sodium chloride-treated or untreated steaks (Baublits *et al.*, 2005) even though no differences were found in Warner-Bratzler shear force values. All three phosphate-solutions received higher ratings for myofibrillar, connective tissue and overall tenderness than untreated samples, which also confirmed similar findings by Scanga *et al.* (2000). Prestat, Jensen, McKeith and Brewer (2002) reported an improvement in Warner-Bratzler shear force values when pork *M. longissimus dorsi* was injected with a phosphate-salt-solution (0.4% each) and found that this treatment stabilised tenderness under a variety of

conditions. Sodium phosphate (pyrophosphate or hexameta-phosphate) addition to freshly slaughtered beef reportedly prevents rigor mortis and thus contributes to increased tenderness (Streitel, Ockerman and Cahill, 1977).

10.3. Effect on juiciness

Several authors have reported that enhancing meat with inorganic salt solutions improves juiciness (Papadopoulos *et al.,* 1991; Wheeler *et al.*, 1997; Scanga *et al.*, 2000; Robbins *et al.*, 2003; Baublits *et al.*, 2005). Wheeler *et al.* (1997) found that a calcium chloride-injection improved juiciness of cooked meat because it caused the meat to retain enough added water to effectively withstand moisture losses due to purge during ageing and cooking.

Smith *et al.* (1984) found pork and beef juiciness increased when sodium tripolyphosphate was injected and Deatherage (1963) reported that sodium phosphate increased WHC of meat. Bison steaks injected with sodium tripolyphosphate and sodium chloride were juicier than untreated steaks (Dhanda *et al.*, 2001, as cited by Robbins *et al.*, 2003). Analytical sensory panels also found beef steaks treated with solutions of sodium chloride (2.0%) and either sodium hexametaphosphate, sodium tripolyphosphate or tetra sodium pyrophosphate to be juicier on consumption than untreated steaks (Baublits *et al.*, 2005). There were no differences in juiciness between phosphate types, but all phosphate types achieved higher juiciness ratings than sodium chloride-treated steaks. Prestat *et al.* (2002) found phosphate addition improved juiciness and thought that the improved juiciness was caused by added moisture as well as increased moisture retention because of increased pH levels caused by phosphate addition. In the work of Baublits *et al.* (2005) it was shown that phosphate addition caused increased water retention where untreated samples had greater levels of free water, but phosphate-treated samples contained a higher total moisture percentage.

The effect of lactate injection on meat juiciness depends on its concentration. During storage, the juiciness of top rounds injected with 1.0% sodium lactate decreased significantly, while injecting 1.0-4.0% increased juiciness (Papadopoulos *et al.*, 1991) and stabilised it during storage.

10.4. Effect on other meat characteristics

10.4.1. Colour

The bright red colour favoured by consumers during display is achieved by the formation of oxymyoglobin when myoglobin reacts with oxygen on the surface. During display, various changes occur in meat that may be detrimental to its colour. These changes can mainly be ascribed to myoglobin and lipid oxidation. When myoglobin undergoes oxidation, it forms metmyoglobin and meat will start to turn brown. Consumers actively discriminate against meat without even, bright red colouration and any discolouration will lead to a no-purchase decision.

Wheeler *et al*. (1996a) found that display time and display temperature influenced colour score, discolouration score, a* value and hue angle of meat. With higher display temperatures and longer display times, more discolouration was observed. Surface discolouration was minimal from 1 to 3 days of retail display, at less than 1% surface discolouration on day 3, but on day 5 discolouration levels were greatly elevated, at around 50% surface discolouration. Wheeler *et al.* (1997) observed that a display temperature of 1ºC caused steaks to show no discolouration through five days of retail display, despite calcium chloride treatment.

The display properties of meat treated with vitamin C as an antioxidant, were mainly influenced by the vitamin C concentration, although together with display time and temperature a three-way interaction was formed (Wheeler *et al*., 1997). Vitamin C addition stabilised colour, but lower concentrations (0.5% and 1.0%) caused greater colour stability than 1.5% vitamin C, and all vitamin C concentrations produced better colour scores than untreated steaks. Steaks with a 1.0% vitamin C-treatment was the reddest (a* values), while untreated steaks showed the least amount of lean red colour. The other vitamin C concentrations tested, i.e. 0.25%, 0.5% and 4%, caused intermediate values.

Sodium lactate also improves meat colour, with darker red colour and less grey visible on the surface of treated, than untreated top round roasts (Papadopoulos *et al.*, 1991). It was found that sodium lactate concentrations of more than 1.0% did not improve colour scores any further. Untreated meat had lower a* (redness) values than treated meat. Sodium lactate concentrations differed in their effects on L* (lightness) and b* (yellowness) values. Up to 2.0% sodium lactate, the L* valued decreased with increasing sodium lactate levels, but more than 2.0 % sodium lactate had no further effect on L* values. Higher b* values were found in untreated samples (0 %) and up to 1.0 % sodium lactate addition, while meat treated with 2.0-4.0% were less yellow.

Calcium chloride was shown to accelerate discolouration (Kerth *et al.*, 1995) and Lawrence *et al.* (2003a) reported induced muscle darkening when calcium chloride was used. Steaks treated with calcium chloride were more brown with more surface discolouration than untreated steaks at 5 and 7 days of display but when vitamin C was added in conjunction with calcium chloride, it resulted in more red colour with less discolouration (Wheeler *et al.*, 1996a).

Phosphate enhancement of pork caused a* values to increase, while b* values decreased (Prestat *et al.,* 2002).

10.4.2. Flavour

Many of the chemical substances used in enhancement solutions have adverse effects on meat flavour and several off flavours may be perceived after enhancement. Calcium chloride injected along with lactic acid caused liver, metallic, sour and medicinal off flavours and beef and brothy flavours were decreased (Wheeler *et al.*, 1997; Scanga *et al.*, 2000), while Morris *et al.* (1996) found that a bloody flavour was also detectable in beef steaks. In addition, Wheeler *et al*. (1997) reported that calcium chloride lowered beef flavour intensity.

The concentration at which calcium chloride is added to meat also affects the degree to which flavour is influenced. Lawrence *et al.* (2003a) found higher beef flavour intensities when 0.1 M solutions were used in marinating beef steaks compared to a 0.3 M solution. The 0.3 M solutions caused more off-flavours. This trend was also reported by Eilers *et al.* (1994) and Morris *et al.* (1996) who found that even a 10% addition of a 0.3 M calcium chloride can cause bitter, metallic and sour tastes in cooked meat.

Different calcium salts affect flavour differently. Calcium lactate-injected beef was judged to have a higher flavour intensity than either calcium ascorbate- or calcium chloride-treated meat (Lawrence *et al.*, 2003a).

Lawrence *et al.* (2003b) found that phosphate salts tend to lower flavour intensity, while Prestat *et al.* (2002) found that a phosphate and salt (0.4% each) solution lowered the amount of off flavours of pork chops in comparison to control samples. Dhanda *et al.* (2001, as cited by Robbins *et al*., 2003) reported higher flavour acceptability for bison steaks after treatment with a 0.3% sodium tripolyphosphate and 0.5% sodium chloride solution. Papadopoulos *et al.* (1991) reported that sodium lactate (1.0%) had no effect on ham flavour, while it enhanced fresh beef flavour.

Several authors (Morris *et al.*, 1996; Scanga *et al.*, 2000) have reported a marked improvement in flavour intensity and overall flavour of meat when commercial beef flavouring was added to calcium chloride- or lactic acid-injected meat. The flavouring increased beefy, brothy and oniony flavours, while it effectively decreased the sour and bitter flavours caused by calcium chloride or lactic acid. Analytical sensory panellists rated the flavour of beef flavouring-marinated steaks higher than untreated steaks or steaks treated with calcium chloride or sodium phosphate (Scanga *et al.*, 2000). Adding beef flavouring to steaks did make the meat saltier than the other treatments.

10.4.3. pH

Different calcium salt solutions have different pH-values. For instance, calcium ascorbate solutions are slightly acidic, increasing slightly in acidity as molar concentrations increases, calcium chloride solutions are basic, increasing in alkalinity with increased molar

concentrations, and calcium lactate solutions are slightly alkaline and increases in alkalinity, while staying very close to a neutral pH, with increased molar concentrations (Table 15) (Lawrence *et al.*, 2003a).

Table 15 Differences in pH between different calcium salts for different molar concentrations.

Calcium salt	0.1 M	0.2 M	0.3 M
Calcium ascorbate	5.9	5.8	5.8
Calcium chloride	9.7	10.0	10.1
Calcium lactate	7.5	7.4	7.4

(From Lawrence *et al.*, 2003a)

Morris *et al.* (1996) found that beef steaks treated with 0.3 M calcium chloride (pH 5.1) had lower pH values than cold-boned, untreated (control) steaks. Wierbicki *et al.* (1957) found calcium- and magnesium chlorides to lower pH values of raw meat.

The pH of beef samples treated with sodium hexametaphosphate was lower than that of untreated samples and was similar to the pH values of samples treated with sodium chloride (Baublits *et al.*, 2005). Sodium tripolyphosphate- and tetrasodium pyrophosphate-treated samples had higher pH values than untreated samples and sodium chloride- or sodium hexametaphosphate-treated samples. There was no difference in pH values of different concentrations or pumped rates.

Lactic acid treatment of meat caused meat pH to decline to values below untreated samples (Eilers *et al*, 1994). Morris *et al.* (1996) reported similar findings in terms of cold-boned non-injected samples, with no differences between treated sample pH values and that of hot-boned untreated samples. Papadopoulos *et al.* (1991) found an inverse relationship between sodium lactate and the pH of top round roasts and found that pH values decreased over time. Low levels (1.0%) of sodium lactate had no significant effect on pH levels.

10.4.4. Cooking loss

Wheeler *et al.* (1997) reported a higher percentage cooking loss for calcium chloride-treated steaks than for untreated steaks and explained that it was due to the higher amount of water absorbed by calcium chloride-treated steaks. Scanga *et al.* (2000) reported similar results although steaks treated with calcium chloride, phosphate or beef flavouring showed higher final yields. Lamb meat treated with calcium chloride showed higher cooking losses than untreated samples at day 1, but this difference disappeared after 14 days of ageing and the same results were found for calcium chloride-treated beef (Koohmaraie *et al.*, 1990).

A solution of sodium chloride and sodium tripolyphosphate (0.4% each) had no effect on cooking loss of steaks or roasts (Robbins *et al.*, 2003). Treatment with sodium

hexametaphosphate caused no cooking loss differences to untreated steaks, but sodium tripolyphosphate- and tetrasodium pyrophosphate-treated steaks had lower cooking losses (Baublits *et al.*, 2005). It was also shown that both phosphate concentration (0.2% and 0.4%) and pumped rates (12% and 18%) caused lower cooking losses than untreated steaks.

As sodium lactate level increased (1.0-4.0%), cooking yields increased (lower cooking losses) significantly ($P < 0.001$) and was higher than untreated samples (Papadopoulos *et al.*, 1991). Reid (1969, as cited by Papadopoulos *et al.*, 1991) explained that these higher cooking yields were probably due to a combined effect of the humectant properties of sodium lactate and the higher levels of sodium ions. Salt increased the ionic strength of meat (Schmidt and Trout, 1982, referred to by Papadopoulos *et al.*, 1991), thus causing increased WHC and therefore lowering cooking losses (Pearson and Tauber, 1984, as cited by Papadopoulos *et al.*, 1991).

10.5. Pumped gain

Pumped gain refers to the weight meat gains after injection enhancement and is mostly ascribed to an increased WHC. Lawrence *et al.* (2003a) found differences in pumped gain between calcium salts – calcium ascorbate marination produced the highest, calcium chloride intermediate and calcium lactate the lowest yields. It was also observed that with molar increase in calcium chloride or calcium ascorbate concentrations, a linear increase in pumped yield resulted. Injecting calcium lactate along with phosphates consequently had higher pumped yield than treating meat with only calcium lactate (Lawrence *et al.*, 2003b).

10.6. Effect on shelf life

Shelf life of meat is, economically speaking, very important. Wheeler *et al.* (1996) declared poor shelf life (most notably lean colour) resulted in tremendous retail losses. Meat colour is the meat property that influences consumer purchasing behaviour the most and if the lean colour of meat cannot be retained on display, this leads to the meat being discounted or processed into products of lesser value. Oxidation of both lipids and myoglobin shortens shelf life and cause detrimental effects on meat quality. The usual culprit involved in lipid deterioration is unsaturated fatty acids (UFA) and Sanchez-Escalante *et al.* (2001) observed that peroxidation of UFA of the phospholipids often occur and results in rancid meat. As for myoglobin and oxymyoglobin, its oxidation leads to metmyoglobin formation, which causes an undesirable brown discolouration of the meat surface (Sanchez-Escalante *et al.*, 2001; Wood *et al.*, 2004).

Marshall and Bal'a (2001) reported that meat preservation procedures (and ultimately shelf life) have been focussing on inhibiting microbial growth or the elimination of contaminants through chemical, physical or biological measures. The idea behind these measures was to thwart or at least slow down the growth of microbes that could lead to spoilage. Thus meat can be preserved long enough to allow delivery and shelf life can be prolonged.

The meat properties most commonly influencing shelf life is colour and microbial spoilage, while flavour may also deteriorate during retail display, but cannot be observed on display. Various treatments can be applied to inhibit or prevent the processes leading to decreased shelf life. Antioxidant-treatment proved to delay myoglobin and lipid oxidation and Robbins *et al.* (2003) declared such treatments extended the shelf life of meat, while other treatments, such as inorganic salt addition, might shorten shelf life.

Faster discolouration was observed whenever the molar concentration of any of the calcium salts used in enhancement solutions were increased and specifically calcium ascorbate accelerated myoglobin oxidation (Wheeler *et al.*, 1997). Although Sanchez-Escalante *et al.* (2001) observed that when rosemary powder (1 000 ppm) was administered along with ascorbic acid, it was very effective in inhibiting myoglobin and lipid oxidation, whereas rosemary powder alone was a pronounced antioxidant at all storage times. When vitamin C was added to meat alone or in conjunction with calcium chloride, Wheeler *et al.* (1996a) found those steaks less discoloured and redder on 5 and 7 days of retail display than either untreated or calcium chloride-treated steaks. Treating steaks with only vitamin C resulted in the most stable lean colour. The antioxidant properties of ascorbic acid depend very much on the ascorbic acid concentration, the presence of metal ions (specifically iron) and the tocopherol content of the meat (Sanchez-Escalante *et al.*, 2001). Thus ascorbic acid may act as either an antioxidant or a pro-oxidant. Phosphate salts used in enhancement solutions caused adverse effects on pork and beef colour during retail display (Jensen, Robbins, Ryan, Homco-Ryan, McKeith and Brewer, 2003; Robbins *et al.*, 2003).

Microbial spoilage of meat is another potentially harmful complication that can result in meat during retail display. Djenane *et al.* (2003) established that lactic acid treatment, alone or along with a modified 40% CO_2 / 60% O_2 atmosphere, effectively inhibited the growth of lactic acid bacteria (*Brochothrix thermosphacta*) and *Pseudomonas* species. However, lactic acid treatment did not affect myoglobin oxidation. Various authors have mentioned the positive inhibitory effects of lactic acid on microbial spoilage of meat (Papadopoulos *et al.*, 1991; Morris *et al.*, 1996).

Air exposure can lead to oxidised flavour within one hour in comminuted meat (Sanchez-Escalante *et al.*, 2001). Papadopoulos *et al.* (1991) found sodium lactate inhibits flavour deterioration during storage and that there was an improvement of the flavour notes identified with fresh beef. In pigs, Morrissey, Sheehy, Galvin, Kerry and Buckley (1998) reported iron-release from cells and the shutdown of the glutathione enzyme system after slaughter to be two of the factors influencing flavour oxidation.

The animal's diet may also influence shelf life – Wood *et al.* (2004) observed a high degree of lipid oxidation and a faster occurrence of rancidity in the meat of sheep and beef fed a fish oil-rich diet. The malonaladehyde levels were much higher than 2 mg/kg meat, the level at which consumers can perceive rancidity (Younathan and Watts, 1959), in the meat of the sheep and beef fed fish oil-rich diets (Wood *et al.*, 2004). It was also shown that colour deterioration at retail display occurred faster in meat from the fish oil-rich diet. Warren *et al.* (2002) reported the bright red colour of beef from grass-fed cattle lasted longer during retail display than that of grain-fed cattle. Grass is rich in natural antioxidants and subsequent grass consumption possibly led to higher vitamin E levels in the tissue, explained Young *et al.* (2001), and this had an inhibitant effect on lipid oxidation, which resulted in better colour retention even though its fatty acid composition would normally favour lipid oxidation.

11. Conclusion and objectives

Springbok is the African wild ungulate most often farmed with, exported and consumed and is regularly available in South African butcheries and restaurants. Blesbok is also favoured by game farmers and, together with springbok, have been studied since the seventies (Huntley, 1971; Von la Chevallerie, 1972) and data is available for most characteristics, be it physical or proximate. However, the data available is usually limited to a single muscle (quite often the *M. longissimus dorsi* muscle) or to the whole carcass and data on several different muscles of the same animals are lacking. Data on the inorganic enhancement of game meat is also very limited.

The objectives of this study, therefore, were to investigate the possible differences that might occur in the physical characteristics and chemical composition of five different muscles (*M. biceps femoris, M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus*) in both blesbok and springbok. Furthermore, two muscles (*M. biceps femoris* and *M. longissimus et lumborum*) were used in analytical sensory analysis and consumer sensory analysis was also performed on one muscle (*M. longissimus et lumborum*) of both species. No data on consumer sensory analysis of game meat were available in the literature.

The five muscles were also enhanced with an inorganic salt solution to investigate the possible positive influences that such treatments may have on the different meat quality aspects and results were compared between muscles.

This study aims to broaden the data available on wild ungulates, specifically springbok and blesbok, regarding most aspects of meat quality.

12. References

AMSA (American Meat Science Association). (1995). *Research Guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat*. Chicago: National Livestock and Meat Board.

AOAC. (1997). *Official Methods of Analysis*. 15th ed. Arlington, VA. USA: Association of Official Analytical Chemists.

Azarkan, M., El Moussaoui, A., van Wuytswinkel, D., Dehon, G. & Looze, Y. (2003). Fractionation and purification of the enzymes stored in the latex of *Carica papaya*. *Journal of Chromatography B* 790, 229-238.

Bailey, A.J. & Light, N.D. (1989). *Connective tissue in meat and meat products*. London: Elsevier.

Baublits, R.T., Pohlman, F.W., Brown Jr., A.H. & Johnson, Z.B. (2005). Effects of sodium chloride, phosphate type and concentration, and pump rate on beef *biceps femoris* quality and sensory characteristics. *Meat Science* 70, 205-214.

Bejerholm, C. & Aaslyng, M.D. (2003). The influence of cooking technique and core temperature on results of a sensory analysis of pork – depending on the raw meat quality. *Food Quality and Preference* 15, 19-30.

Benito-Delgado, J., Marriott, N.G., Claus, J.R., Wang, H. & Graham, P.P. (1994). Chuck *longissimus* and *infraspinatus* muscle characteristics as affected by rigor state, blade tenderisation and calcium chloride injection. *Journal of Food Science* 59, 295-299.

Bernues, A., Olaizola, A. & Corcoran, K. (2003a). Extrinsic attributes of red meat as indicators of quality in Europe: an application for market segmentation. *Food Quality and Preference* 14, 265-276.

Bernues, A., Olaizola, A. & Corcoran, K. (2003b). Labelling information demanded by European consumers and relationships with purchasing motives, quality and safety of meat. *Meat Science* 65, 1095-1106.

Berry, B.W., Smith, G.C. & Carpenter, Z.L. (1974). Relationships of certain muscle, cartilage and bone traits to tenderness of beef *longissimus*. *Journal of Food Science* 39, 819-824.

Bickerstaffe, R., Bekhit, A.E.D., Robertson, L.J., Roberts, N. & Geesink, G.H. (2001). Impact of introducing specifications on the tenderness of retail meat. *Meat Science* 59, 303-315.

Biesalski, H.K. (2005). Meat as a component of a healthy diet – are there any risks or benefits if meat is avoided in the diet? Meat Science 70, 509-524.

Bocker, A. (1997). Consumer search and surplus in markets with differentiated food products. In: B. Wierenga, A. van Tilburg, K. Grunert, J.E.M. Steenkamp & M. Wedel, (Eds). *Agricultural marketing and consumer behaviour in a changing world* (pp. 231-244). Dordrecht: Kluwer Academic Publishers.

Borchand, E. & Arinder, P. (2002). Bacteriological safety issues in red meat and ready-to-eat meat products, as well as control measures. *Meat Science* 62, 381-390.

Bouton, P.E. & Harris, P.V. (1972). A comparison of some objective methods used to assess meat tenderness. *Journal of Food Science* 37, 218-221.

Bouton, P.E., Harris, P.V. & Shorthose, W.R. (1971). Effect of ultimate pH upon the water-holding capacity and tenderness of mutton. *Journal of Food Science* 36, 435-439.

Bouton, P.E., Carroll, F.D., Harris, P.V. & Shorthose, W.R. (1973). Influence of pH and fibre contraction state upon factors affecting tenderness of bovine muscle. *Journal of Food Science* 38, 404-407.

Briskey, E.J. (1963). Influence of ante- and post-mortem handling practices on properties of muscle which are related to tenderness. In *Proceedings meat tenderness symposium* (pp. 195-223). Camden: Campbell Soup Company.

Bronkhorst, N. (2005). Is koedoe en springbok op jou inkopielys? *Landbouweekblad* 24 Junie, 67.

Carpenter, C.E., Cornforth, D.P. & Whittier, D. (2001). Consumer preferences for beef colour and packaging did not affect eating satisfaction. *Meat Science* 57, 359-363.

Chizzolini, R., Zanardi, E., Dorigoni, V. & Ghidini, S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. *Trends in Food Science and Technology* 10, 119-128.

Chollet, S., Valentin, D. & Abdi, H. (2005). Do trained assessors generalize their knowledge to new stimuli? *Food Quality and Preference* 16, 13-23.

Commission International De l'Eclairage (1976). *Colorimetry*, 2nd ed. CIE, Vienna.

Committee on Medical Aspects of Food Policy (1984). 'Diet and Cardiovascular Disease.' *Report on Health and social subjects*, Department of Health and Social Security, No. 28, HMSO, London.

Conroy, A.M. & Gaigher, I.G. (1982). Venison, Aquaculture and ostrich meat production: Action 2003. *South African Journal of Animal Science* 2, 219-233.

Cover, S., Ritchey, S.J. & Hostetler, R.L. (1962a). Tenderness of Beef. I. The connective-tissue component of tenderness. *Journal of Food Science* 27, 469 - 475.

Cover, S., Ritchey, S.J. & Hostetler, R.L. (1962b). Tenderness of Beef. II. Juiciness and the softness components of tenderness. *Journal of Food Science* 27, 476-482.

Cover, S., Ritchey, S.J. & Hostetler, R.L. (1962c). Tenderness of Beef. III. The muscle-fibre components of tenderness. *Journal of Food Science* 27, 483-488.

Crafford, K. (2002). An exploratory study in the Western Cape on game meat as a consumer product. M.Sc. (Cons.) thesis. Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Deatherage, F.E. (1963). The effect of water and inorganic salts on tenderness. In *Proceedings meat tenderness symposium* (pp. 45-68). Camden: Campbell Soup Company.

De Kock, R. (1993). Consumer sensory evaluation. In *Forum: The venison industry. Research requirements and possibilities* (pp. 61-64). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Department of Health. (1994). Department of Health, Nutritional Aspects of Cardiovascular Disease. In: *Report on Health and Social Subjects no. 46*, HMSO, London.

Dhanda, J.S., Taylor, D.G. & Murray, P.J. (2003). Part 2. Carcass composition and fatty acid profiles of adipose tissue of male goats: effects of genotype and live weight at slaughter. *Small Ruminant Research* 50, 67-74.

Djenane, D., Sanchez-Escalante, A., Beltran, J.A. & Roncales, P. (2003). The shelf life of beef steaks treated with DL-lactic acid and antioxidants and stored under modified atmospheres. *Food Microbiology* 20, 1-7. (Abstract).

Dransfield, E. (2001). Consumer issues and acceptance of meat. *47th International Congress of Meat Science and Technology* (pp. 72-78). Krakòw, Poland.

Dransfield, E., Wakefield, D.K. & Parkman, I.D. (1992). Modelling post-mortem tenderisation - I: Texture of electrically stimulated and non-stimulated beef. *Meat Science* 31, 57-73.

Dransfield, E., Zamora, F. & Bayle, M. (1998). Consumer selection of steaks as influenced by information and price index. *Food Quality and Preference* 9, 321-326.

Eilers, J.D., Morgan, J.B., Martin, A.M., Miller, R.K., Hale, D.S. & Acuff, G.R. (1994). Evaluation of calcium chloride and lactic acid injection on chemical, microbiological and descriptive attributes of mature cow beef. *Meat Science* 38, 443-451.

Elliot, J. (1993). Farmed Venison, the new meat comes of age. *Nutrition and Food Science* 4, 26-29.

Enser, M. (2001). The role of fats in human nutrition. In B. Rossell (Ed.). *Oils and fats, Vol.2. Animal carcass fats* (Pp. 77-122). Leatherhead, Surrey, UK: Leatherhead Publishing.

Enser, M. (1984). The chemistry, biochemistry and nutritional importance of animal fats. In J. Wiseman (Ed.) *Fats in animal nutrition* (pp. 23-51), London: Butterworths.

Enser, M., Hallett, K., Hewett, B., Fursey, G.A.J. & Wood, J.D. (1996). Fatty acid content and composition of English beef, lamb and pork at retail. *Meat Science* 44, 443-458.

Enser, M., Hallett, K., Hewett, B., Fursey, G.A.J., Wood, J.D. & Harrington, G. (1998). Fatty acid composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. *Meat Science* 49, 329-341.

Enser, M., Hallett, K.G., Hewett, B., Fursey, A.J., Wood, J.D. & Harrington, G. (1997b). Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. *Meat Science* 49, 329-341.

Enser, M., Hallett, K.G., Hewett, B., Fursey, G.A.J., Wood, J.D. & Harrington, G. (1997a). The polyunsaturated fatty acid composition of beef and lamb liver. *Meat Science* 49, 321-327.

Enser, M., Richardson, R.I., Wood, J.D., Gill, B.P. & Sheard, P.R. (2000). Feeding linseed to increase the n-3 polyunsaturated fatty acids of pork: fatty acid composition of muscle, adipose tissue, liver and sausages. *Meat Science* 55, 201 – 212.

Fang, D.Y.C., Hajmeer, M.N., Kastner, C.L., Kastner, J.J., Marsden, J.L., Penner, K.P., Phebus, R.K., Smith, J.S. & Vanier, M.A. (2001). Meat safety. In Hui, Nip, Rogers & Young (Eds.) *Meat Science and applications* (pp. 171-205). New York: Marcel Dekker.

Fiems, L.O., De Campeneere, S., De Smet, S., Van de Voorde, G., Vanacker, J.M. & Boucque, Ch. V. (2000). Relationship between fat depots in carcasses of beef bulls and the effect on meat colour and tenderness. *Meat Science* 56, 41-47.

Gerelt, B., Ikeuchi, Y. & Suzuki, A. (2000). Meat tenderisation by proteolytic enzymes after osmotic dehydration. *Meat Science* 56, 311-318.

Gerelt, B., Rusman, H., Nishiumi, T. & Suzuki, A. (2005). Changes in calpain and calpastatin activities of osmotically dehydrated bovine muscle during storage after treatment with calcium. *Meat Science* 70, 55-61.

Gibney, M.J. & Hunter, B. (1993). The effects of short- and long-term supplementation with fish oil on incorporation of n-3 polyunsaturated fatty acids into cells of the immune system in health volunteers. *European Journal of Clinical Nutrition* 47, 255-259.

Girolami, A., Marsico, I., D'Andrea, G., Braghieri, A., Napolitano, F. & Cifuni, G.F. (2003). Fatty acid profile, cholesterol content and tenderness of ostrich meat as influenced by age at slaughter and muscle type. *Meat Science* 64, 309-315.

Gissi-Prevenzione Investigators (1999). Dietary supplementation with n-3 polyunsaturated fatty acids and vitamin E after myocardial infarction: results from the GISSI-Prevenzione trial. *Lancet* 354, 447-455.

Grunert, K.G. (1997). What's in a steak? A cross-cultural study on the quality perception of beef. *Food Quality and Preference* 8, 157-174.

Guignot, F., Touraille, C., Ouali, A. & Renerre, M. (1994). Relationships between post mortem pH changes and some traits of sensory quality in veal. *Meat Science* 37, 315-325.

Hanks, J. (1983). *Mammals of Southern Africa* (pp. 27 & 38). Johannesburg, South Africa: McGraw-Hill Book Co.

Hannula, T. & Puolanne, E. (2004). The effect of cooling rate on beef tenderness: The significance of pH at 7 °C. *Meat Science* 67, 403-408.

Hertzman, C., Olsson, U. & Tornberg, E. (1993). The influence of high temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. *Meat Science* 35, 119-141.

Higgs, J.D. (2000). The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science and Technology* 11, 85-95.

Hoelscher, L.M., Savell, J.W., Harris, J.M., Cross, H.R. & Rhee, K.S. (1987). Effect of initial fat level and cooking method - cholesterol content and calorific value of ground beef patties. *Journal of Food Science* 52, 883-1253.

Hoffman, L.C. (2001). The effect of different culling methodologies on the physical meat quality attributes of various game species. In H. Ebedes, B. Reilly, W. van Hoven & B. Penzhorn (Eds.). *Sustainable utilisation - conservation in practice*. *Proceedings of the 5th International Wildlife Ranching Symposium*.

Hoffman, L.C. (2000). The yield and carcass chemical composition of impala (*Aepyceros melampus*), a southern African antelope species. *Journal of the Science of Food and Agriculture* 80, 752-756.

Hoffman, L.C. & Bigalke, R.C. (1999). Utilizing wild ungulates from southern Africa for meat production: Potential research requirements for the new millennium. *Congress of the Wildlife Management Association of SA* (pp. 1-14). George, South Africa.

Hoffman, L.C. & Ferreira, A.V. (2000). pH decline of the *M. longissimus thoracis* of night-cropped Grey Duiker (*Sylvicapra grimmia*). Short communication. *South African Journal of Animal Science* 30, 16-17.

Hoffman, L.C., Crafford, K., Muller, M. & Schutte, De W. (2003). Perceptions and consumption of game meat by a group of tourists visiting South Africa. *South African Journal of Wildlife Research* 33, 125-130.

Hoffman, L.C., Muller, M., Schutte, De W., Calitz, F.J. & Crafford, K. (2005). Consumer expectations, perceptions and purchasing of South African game meat. *South African Journal of Wildlife Research* 35, 33-42.

Hoffman, L.C., Muller, M., Schutte, De W. & Crafford, K. (2004). Retail of South African game meat: current trade and marketing trends. *South African Journal of Wildlife Research* 34, 123-134.

Honikel, K.O. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science* 49, 447-457.

Honikel, K.O. & Arneth, W. (1996). Cholesteringehalt in Fleisch und Eiern. *Fleischwirtschaft* 76, 1244-1253.

Hood, D.E. & Riordan, E.B. (1973). Discoloration in pre-packed beef: measurement by reflectance spectroscopy and shopper discrimination. *Journal of Food Technology* 8, 333-343.

Hopkins, D.L. & Thompson, J.M. (2001). Inhibition of protease activity. Part 1. The effect on tenderness and indicators of proteolysis in ovine muscle. *Meat Science* 59, 175-185.

Huang, T. & Ho, C. (2001). Flavours of meat products. In Hui, Nip, Rogers & Young (Eds.) *Meat Science and applications* (pp. 71-102). New York: Marcel Dekker.

Huff-Lonergan, E. and Lonergan, S.M. (2005). Mechanisms of water-holding capacity of meat: The role of post-mortem biochemical and structural changes. *Meat Science* 71, 194-204.

Huffman, K.L., Miller, M.F., Hoover, L.C., Wu, C.K., Brittin, H.C. & Ramsey, C.B. (1996). Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. *Journal of Animal Science* 74, 91-97.

Huntley, B.J. (1971). Carcass composition of mature blesbok and kudu. *South African Journal of Animal Science* 1, 125-128.

Husaini, S.A., Deatherage, F.E., Kunkle, L.E. & Draudt, H.N. (1950). Studies on Meat I. The biochemistry of beef as related to tenderness. *Food Technology* 4, 313-316.

Immonen, K., Ruusenen, M. & Puolanne, E. (2000). Some effects of residual glycogen concentration on the physical and sensory quality of normal pH beef. *Meat Science* 55, 33-38.

Inklaar, P.A. (1967). Interaction between polyphosphates and meat. *Journal of Food Science* 32, 525-526.

Issanchou, S. (1996). Consumer expectations and perceptions of meat and meat product quality. *Meat Science* 43, S5-S19.

Jansen van Rensburg, D.M. (2001). Venison as health food. In: H. Ebedes, B. Reilly, W. van Hoven & B. Penzhorn (Eds.). *Sustainable utilisation - conservation in practice*. *Proceedings of the 5th International Wildlife Ranching Symposium* (pp. 196-198).

Jansen van Rensburg, D.M. (1997). The physical, chemical and sensory quality characteristics of Springbok (*Antidorcas marsupialis marsupialis*) meat. D. Tech. (Food and Nutrition). Department of Food and Nutrition. Technikon Pretoria, Pretoria.

Jensen, J., Robbins, K., Ryan, K.J., Homco-Ryan, C., McKeith, F.K. & Brewer, M.S. (2003). Effects of lactic and acetic acid salts on quality characteristics of enhanced pork. *Meat Science* 63, 501-508.

Jeremiah, L.E., Dugan, M.E.R., Aalhus, J.L. & Gibson, L.L. (2003a). Assessment of the chemical and cooking properties of the major beef muscles and muscle groups. *Meat Science* 65, 985-992.

Jeremiah, L.E., Dugan, M.E.R., Aalhus, J.L. & Gibson, L.L. (2003b). Assessment of the relationship between chemical components and palatability of major beef muscles and muscle groups. *Meat Science* 65 1013-1019.

Jeremiah, L.E., Smith, G.C. & Carpenter, Z.L. (1972). Ovine yield grades. II. Palatability attributes within various quality grades. *Journal of Animal Science* 34, 196-202.

Jeremiah, L.E., Smith, G.C. & Carpenter, Z.L. (1971). Palatability of individual muscles from ovine leg steaks as related to chronological age and marbling. *Journal of Food Science* 35, 45-47.

Jeremiah, L.E., Tong, A.K.W. and Gibson, L.L. (1991). The usefulness of muscle colour and pH for segregating beef carcasses into tenderness groups. *Meat Science* 30, 97-114.

Kemp, J.D., Mahyuddin, M., Ely, D.G., Fox, J.D. & Moody, W.G. (1981). Effect of feeding systems, slaughter weight and sex on organoleptic properties, and fatty acid composition of lamb. *Journal of Animal Science* 51, 321-330.

Kerth, C.R., Miller, M.F. & Ramsey, C.B. (1995). Improvement of beef tenderness and quality traits with calcium chloride injection in beef loins 48 hours post mortem. *Journal of Animal Science* 73, 750-756.

Kirton, A.H. & Barton, R.A. (1962). Study of some indices of the chemical composition of lamb carcasses. *Journal of Animal Science* 21, 553-557.

Koohmaraie, M. (1996). Biochemical factors regulating the toughening and tenderisation processes of meat. *Meat Science* 43, S193-S201.

Koohmaraie, M. (1994). Muscle proteinases and meat ageing. *Meat Science* 36, 93-104.

Koohmaraie, M., Whipple, G. & Crouse, J.D. (1990). Acceleration of post-mortem tenderisation in lamb and Brahman-cross beef carcasses through infusion of calcium chloride. *Journal of Animal Science* 68, 1278-1283.

Kroon, F.E., van Rensburg, W.J.J. & Hofmeyr, H.S. (1972). Seisoenale veranderinge in chemiese samestelling van volwasse blesbokramme (*Damaliscus dorcas phillipsi*) van die Van Riebeeck natuurreservaat. *Suid Afrikaanse Tydskrif van Veekunde* 2, 41-44.

Kroucamp, M. (2004). Meat quality characteristics of the springbok (*Antidorcas marsupialis*). M. Sc. (Foods). Department of Food Science. University of Stellenbosch, Stellenbosch.

Kubberod, E., Ueland, O., Rodbotten, M., Westad, F. & Risvik, E. (2002). Gender specific preferences and attitudes towards meat. *Food Quality and Preference* 13, 285-294.

Kupiec, B.E. (2001). Integrated food product development. *47th International Congress of Meat Science and Technology* (Pp. 100-106). Krakòw, Poland.

Lampkin, N.H. & Padel, S. (1994). *The economics of organic farming: An international perspective*. Oxon: CAB International.

Landman, W.A. (1963). Enzymes and their influence on meat tenderness. In *Proceedings meat tenderness symposium* (pp. 87-98). Camden: Campbell Soup Company.

Lawless, H. (1995). Dimensions of sensory quality: a critique. *Food Quality and Preference* 6, 191-199.

Lawless, H.T. & Claassen, M.R. (1993). Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. *Journal of Food Science* 58, 108-112.

Lawless, H.T. & Heymann, H. (1998). *Sensory evaluation of food: Principles and practices*. New York: Chapman & Hall.

Lawrence, T.E., Dikeman, M.E., Hunt, M.C., Kastner, C.L. & Johnson, D.E. (2003a). Effects of calcium salts on beef *longissimus* quality. *Meat Science* 64, 299-308.

Lawrence, T.E., Dikeman, M.E., Hunt, M.C., Kastner, C.L. & Johnson, D.E. (2003b). Staged injection marination with calcium lactate, phosphate and salt may improve beef water-binding ability and palatability traits. *Meat Science* 65, 967-972.

Lawrie, R.A. (1998). *Lawrie's Meat Science* (6th ed.). Cambridge, England: Woodhead Publishing Ltd.

Lengyel, Z., Husvèth, F., Polgar, P., Szabo, F. & Magyar, L. (2003). Fatty acid composition of intramuscular lipids in various muscles of Holstein-Friesian bulls slaughtered at different ages. Meat Science 65, 593-598.

Light, N., Champion, A.E., Voyle, C. and Bailey, A.J. (1985). The role of epimysial, perimysial, and endomysial collagen in determining texture in six bovine muscles. *Meat Science* 13, 137-149.

Liu, H.P. & Watts, B.M. (1970). Catalysis of lipid peroxidation in meats. 3. Catalysts of oxidative rancidity in meats. *Journal of Food Science* 35, 596-598.

MacDougall, D.B., Shaw, B.G., Nute, G.R. & Rhodes, D.N. (1979). Effect of pre-slaughter handling on the quality and microbiology of venison from farmed young red deer. *Journal of the Science of Food and Agriculture* 30, 1160-1167.

MacRae, J., O'Reilly, L. & Morgan, P. (2005). Desirable characteristics of animal products from a human health perspective. *Livestock Production Science*, 94, 95-103.

Madge, D.G. (1995). *Organic Agriculture*. Australia: Agriculture Victoria.

Mancini, R.A. and Hunt, M.C. (2005). Review: Current research in meat colour. *Meat Science* 71, 100-121.

Marsh, B.B., Ringkob, T.P., Russell, R.L., Swartz, D.R. & Pagel, L.A. (1987). Effects of early-post-mortem glycolytic rate on beef tenderness. *Meat Science* 21, 241-248. (Abstract).

Marshall, D. (2003). Commentary on Garber et al. measuring consumer response to food products. *Food Quality and Preference* 14, 17-21.

Marshall, D.L. & Bal'A, M.F. (2001). Microbiology of meats. In Hui, Nip, Rogers & Young (Eds.) *Meat Science and applications* (pp. 149-169). New York: Marcel Dekker.

McCarthy, M., de Boer, M., O'Reilly, S. & Cotter, L. (2003). Factors influencing intention to purchase beef in the Irish market. *Meat Science* 65, 1071-1083.

Melanson, K., Gootman, J., Myrdal, A., Kline, G. & Rippe, J. (2003). Weight loss and total lipid profile changes in overweight women consuming beef or chicken as the primary protein source. *Nutrition* 19, 409- 414.

Melton, S.L. (1990). Effects of feeds on flavour of red meat: a review. *Journal of Animal Science* 68, 4421-4435.

Miller, M.F., Hoover, L.C., Cook, K.D., Guerra, A.L., Huffman, K.L., Tinney, K.S., Ramsey, C.B., Brittin, H.C. & Huffman, L.M. (1995). Consumer acceptability of beef steak tenderness in the home and restaurant. *Journal of Food Science* 60, 963-965.

Morgan, J.B., Miller, R.K., Mendez, F.M., Hale, D.S. & Savell, J.W. (1991). Using calcium chloride injection to improve tenderness of beef from mature cows. *Journal of Animal Science* 69, 4469-4476.

Morris, C.A., Theis, R.L., Miller, R.K., Acuff, G.R. & Savell, J.W. (1997). Improving the flavour of calcium chloride and lactic acid injected mature beef top round steaks. *Meat Science* 45, 531-537.

Morrissey, P.A., Sheehy, P.J.A., Galvin, K., Kerry, J. and Buckley, D.J. (1998). Lipid stability in meat and meat products. In *Proceedings of the 44th International Congress of Meat Science and Technology* (pp. 120-131).

Moskowitz, H.R. (1984). Sensory analysis, product modelling and product optimisation. In G. Charalambous (Ed.). *Analysis of foods and beverages. Modern techniques* (pp. 13-67). Orlando: Academic Press Inc.

Mottram, D.S. (1998). Flavour of muscle foods - an overview. In F. Shahidi (Ed.). *Flavour of meat, meat products and seafoods* (pp. 5-24). London: Blackie Academic & Professional.

Munoz, A.M. (1997). Importance, types, and applications of consumer data relationships. In A.M. Munoz (Ed.). *Relating consumer, descriptive, and laboratory data to better understand consumer responses* (pp. 1-7). West Conshohocken: ASTM.

Nelson, G.J., Schmidt, P.C. & Kelley, D.S. (1995). Low-fat diets do not lower plasma cholesterol levels in healthy men compared to high-fat diets with similar fatty acid composition and constant caloric intake. *Lipids* 30, 969-976.

Niemenin, M. (1992). Meat production and chemical composition of reindeer meat. In *Proceedings of the 3rd International Wildlife Ranching Symposium*. Pretoria, South Africa.

Nishimura, T., Hattori, A. & Takahashi, K. (1999). Structural changes in intramuscular connective tissue during the fattening of Japanese black cattle. Effect of marbling on beef tenderisation. *Journal of Animal Science* 77, 93-104.

Offer, G. & Trinick, J. (1983). On the mechanism of water holding in meat: The swelling and shrinking of myofibrils. *Meat Science* 4, 245-281.

Olsson, U., Hertzman, C. & Tornberg, E. (1994). The influence of low temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. *Meat Science* 37, 115-131.

Onyango, C.A., Izumimoto, M. & Kutima, P.M. (1998). Comparison of some physical and chemical properties of selected game meats. *Meat Science* 49, 117-125.

Papadopoulos, L.S., Miller, R.K., Ringer, L.J. & Cross, H.R. (1991). Sodium lactate effect on sensory characteristics, cooked meat colour and chemical composition. *Journal of Food Science* 56, 621-626.

Paul, P.C. (1963). Influence of methods of cooking on meat tenderness. In *Proceedings meat tenderness symposium* (pp. 225-242). Camden: Campbell Soup Company.

Pauw, J. (1993). The development of venison marketing. In *Forum: The venison industry. Research requirements and possibilities* (pp. 3-5). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Pearson, A.M. (1963). Objective and subjective measurements for meat tenderness. In *Proceedings meat tenderness symposium* (pp. 135-160). Camden: Campbell Soup Company.

Pietersen, T. (1993). Utilisation of venison for processed meat production. In *Forum: The venison industry. Research requirements and possibilities* (pp. 41-46). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Pietrasik, Z. & Shand, P.J. (2004). Effect of blade tenderisation and tumbling time on the processing characteristics and tenderness of injected cooked roast beef. *Meat Science* 66, 871-879.

Pilgrim, F.J. (1957). The components of food acceptance and their measurement. *American Journal of Clinical Nutrition* 5, 171-175.

Porin, F. and Mainsant, P. (1996). In *Consumer attitudes towards meat, AIR-CAT Measurements of consumer attitudes and their influence on food choice and acceptability* (pp.19-20). Clermont-Ferrand.

Prestat, C., Jensen, J., McKeith, F.K. & Brewer, M.S. (2002). Cooking methods and endpoint temperature effects on sensory and colour characteristics of pumped pork loin chops. *Meat Science* 60, 395-400.

Rabin, M.D. (1988). Experience facilitates olfactory quality discrimination. *Perception and Pshychophysics* 44, 532-540.

Reddy, B.S. (1981). Diet and excretion of bile acids. *Cancer Research* 41, 3766-3768.

Resurreccion, A.V.A. (1998). *Consumer sensory testing for product development*. Gaithersburg, MD, USA: Aspen Publication.

Resurreccion, A.V.A. (2004). Sensory aspects of consumer choices for meat and meat products. *Meat Science* 66, 11-20.

Risvik, E. (1994). Sensory properties and preferences. Meat Science 36, 67-77.

Robbins, K., Jensen, J., Ryan, K.J., Homco-Ryan, C., McKeith, F.K. & Brewer, M.S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Science* 65, 721-729.

Ronco, A.L., De Stefani, E. & Fabra, A. (2003). White meat intake and the risk of breast cancer: a case-control study in Montevideo, Uruguay. *Nutrition Research* 23, 151-162.

Russell, C.G. & Cox, D.N. (2004). Understanding middle-aged consumers' perceptions of meat using repertory grid methodology. *Food Quality and Preference* 15, 317-329.

Sales, J. (1995). Nutritional quality of meat from some alternative species. *World review of Animal Production* 30, 47-56.

Sanchez-Escalante, A., Djenane, D., Torrescano, G., Beltran, J.A. & Roncales, P. (2001). The effects of ascorbic acid, taurine, carnosine and rosemary powder on colour and lipid stability of beef patties packaged in modified atmosphere. *Meat Science* 58, 421-429.

Sayed, N., Frans, Y. & Schönfeldt, H.C. (1999). *Composition of South African foods*. Parow: Medical Research Council.

Scanga, J.A., Delmore Jr., R.J., Ames, R.P., Belk, K.E., Tatum, J.D. & Smith, G.C. (2000). Palatability of beef steaks marinated with solutions of calcium chloride, phosphate, and (or) beef-flavouring. *Meat Science* 55, 397-401.

Schönfeldt, H. (1993). Nutritional content of venison. In: *Forum: The venison industry. Research requirements and possibilities*. Meat industry centre, Irene Agricultural research Council, Pretoria, Pp. 51-60.

Sentandreu, M.A., Coulis, G. & Ouali, A. (2002). The role of muscle endopeptidases and their inhibitors in meat tenderness. *Trends in Food Science and Technology* 13, 400-421.

Shackelford, S.D., Wheeler, T.L. & Koohmaraie, M. (1999). Evaluation of slice shear force as an objective method of assessing beef longissimus tenderness. *Journal of Animal Science* 77, 2693-2699.

Shackelford, S.D., Wheeler, T.L. & Koohmaraie, M. (1995). Relationship between shear force and trained sensory panel tenderness ratings of 10 major muscles from *Bos indicus* and *Bos taurus* cattle. *Journal of Animal Science* 73, 3333-3340.

Shahidi, F. (1998). Flavour of muscle foods - an overview. In F. Shahidi (Ed.). *Flavour of meat, meat products and seafoods* (pp. 1-4). London: Blackie Academic & Professional.

Shorthose, W.R. & Harris, P.V. (1990). Effect of animal age on the tenderness of selected beef muscles. *Journal of Food Science* 55, 1-8.

Silva, J.A., Patarata, L. & Martins, C. (1999). Influence of ultimate pH on bovine meat tenderness during ageing. *Meat Science* 52, 453-459.

Skinner, J.D. & Louw, G.N. (1996). *The Springbok – Antidorcas marsupialis (*Zimmerman, 1780*)* 1st ed. (pp. 10-33). A. Dreyer (Ed.). South Africa: Transvaal Museum.

Smit, K. (2004). Meat quality characteristics of blesbok (*Damaliscus dorcas phillipsi*) and red hartebeest (*Alcelaphus buselaphus caama*) meat. M. Consumer Sc. (Food) thesis. Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Smith, L.A., Simmons, S.L., McKeith, F.K., Betchel, P.J. and Brady, P.L. (1984). Effects of sodium tripolyphosphate on physical and sensory properties of beef and pork roasts. *Journal of Food Science* 49, 1636-1637.

Smithers, R.H.N. (1983). *The mammals of the Southern African subregion* (pp. 615-617, 627-631). University of Pretoria, Pretoria.

Steenkamp, J.E.M. (1997). Dynamics in consumer behaviour with respect to agricultural and food products. In Wierenga, B., Van Tilburg, A., Grunert, K., Steenkamp, J.E.M., Wedel, M. (Eds). *Agricultural Marketing and consumer behaviour in a changing world* (pp. 143-188). Boston: Kluwer Academic Publishers.

Steenkamp, J.E.M. (1990). Conceptual model of the quality perception process. *Journal of Business Research* 21, 309-333.

Stevenson, J.M., Seman, D.L., Weatherall, I.L. & Littlejohn, R.P. (1989). A research note. Evaluation of venison colour by an objective method using CIELAB values. *Journal of Food Science* 54, 1661-1662.

Stoeckli, R. & Keller, U. (2004). Nutritional fats and the risk of type 2 diabetes and cancer. *Physiology and Behaviour* 83, 611-615.

Stone, H. & Sidel, J.L. (1993). *Sensory evaluation practices*, 2nd ed. San Diego, CA, USA: Academic Press.

Streitel, R.H., Ockerman, H.W. & Cahill, V.R. (1977). Maintenance of beef tenderness by inhibition of rigor mortis. *Journal of Food Science* 42, 583-585.

Swatland, H.J. (1994). *Structure and development of meat animals and poultry* (pp.143-228). Lancaster: Technomic Publishing Co.

Swatland, H.J. (1984). *Structure and development of meat animals*. Ontario Agricultural College, University of Guelph, Englewood Cliffs, NY: Prentice Hall.

Takahashi, K., Kim, O.H. & Yano, K. (1987). Calcium-induced weakening of Z-discs in post mortem skeletal muscle. *Journal of Biochemistry* 101, 767-773.

Thomas, A.R., Gondoza, H., Hoffman, L.C., Oosthuizen, V. & Naudè, R.J. (2004). The roles of the proteasome, and cathepsins B,L,H and D, in ostrich meat tenderisation. *Meat Science* 67, 113-120.

Trichopoulou, A., Costacou, T., Bamia, C. & Trichopoulos, D. (2003). Adherence to a Mediterranean diet and survival in a Greek population. *New England Journal of Medicine* 348, 2599-2608.

Valsta, L.M., Tapanainen, H. & Männistö, S. (2005). Meat fats in nutrition - a review. *Meat Science* 70, 525-530.

Van Schalkwyk, S. (2004). Meat quality characteristics of three South African game species: Black wildebeest (*Connochaetes gnou*), Blue wildebeest (*Connochaetes taurinus*) and Mountain reedbuck (*Redunca fulvorufula*). M. Sc. Cons. (Foods). Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Van Trijp, H.C.M., Steenkamp, J.E.M. & Candel, M.J.J.M. (1997). Quality labelling as instrument to create product equity: The case of IKB in the Netherlands. In Wierenga, B., Van Tilburg, A., Grunert, K., Steenkamp, J.E.M., Wedel, M. (Eds). *Agricultural Marketing and consumer behaviour in a changing world* (pp. 201-215). Boston: Kluwer Academic Publishers.

Van Zyl, L. & Ferreira, A.V. (2004). Physical and chemical carcass composition of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*). *Small Ruminant Research* 53, 103-109.

Van Zyl, J.H.M., Von la Chevallerie, M. & Skinner, J.D. (1969). A note on the dressing percentage in the springbok (*Antidorcas marsupialis*) and impala (*Aepyceros melampus*). *Proceedings of the South African Society for Animal Production* 8, 199-200.

Vatansever, L., Kurt, E., Enser, M., Nute, G.R., Scollan, N.D., Wood, J.D. and Richardson, R.I. (2000). Shelf life and eating quality of beef from cattle of different breeds given diets differing in n-3 polyunsaturated fatty acid composition. *Animal Science* 71, 471-482.

Verbeke, W. & Vackier, I. (2004). Profile and effects of consumer involvement in fresh meat. *Meat Science* 67, 159-168.

Viljoen, J.J. ‘n Vergelyking van die lipiedkomponente van springbokvleis met die van beesvleis en die verwante belangrikheid vir aspekte van die menslike gesondheid. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie* 18, 51-53.

Von la Chevallerie, M. (1972). Meat quality of seven wild ungulate species. *South African Journal of Animal Science* 2, 101-103.

Vote, D.J., Platter, W.J., Tatum, J.D., Schmidt, G.R., Belk, K.E., Smith, G.C. & Speer, N.C. (2000). Injection of beef strip loins with solutions containing sodium tripolyphosphate, sodium lactate and sodium chloride to enhance palatability. *Journal of Animal Science* 78, 952-957.

Wada, M., Suzuki, T., Yaguti, Y. & Hasegawa, T. (2002). The effects of pressure treatments with kiwi fruit protease on adult cattle *semitendinosus* muscle. *Food Chemistry* 78, 167-171.

Wansink, B. (2003). Response to “Measuring consumer response to food products”. Sensory tests that predict consumer acceptance. *Food Quality and Preference* 14, 23-26.

Wansink, B. & Park, S.B. (2000). Comparison methods for identifying heavy users. *Journal of Advertising Research* 40, 61-72.

Wansink, B., Painter, J.M. & van Ittersum, K. (2001). Descriptive menu labels. Effect on sales. *Cornell Hotel and Restaurant administrative Quarterly* 42, 68-72.

Warren, H.E., Scollan, N.D., Hallett, K., Enser, M., Richardson, R.I., Nute, G.R. and Wood, J.D. (2002). The effects of breed and diet on the lipid composition and quality of bovine muscle. *Proceedings of the 48th Congress of Meat Science and Technology* (pp. 370-371).

Warriss, P.D. (2000). *Meat Science: an introductory text*. Wallingford, Oxon: CAB International Publishing.

Webb, R. (2001). It's all in the game. *Diabetes Forecast* 54, 30-33.

Wells, A.M., Haub, M.D., Fluckey, J., Williams, D.K., Chernoff, R. & Campbell, W.W. (2003). Comparisons of vegetarian and beef-containing diets on haematological indexes and iron stores during a period of resistive training in older men. *Journal of the American Dietetic Association* 103, 594-601.

Wheeler, T.L., Koohmaraie, M. & Shackelford, S.D. (1997). Effect of post-mortem injection time and postinjection ageing time on the calcium-activated tenderisation process in beef. *Journal of Animal Science* 75, 2652-2660.

Wheeler, T.L., Koohmaraie, M. & Shackelford, S.D. (1996a). Effect of vitamin C concentration and co-injection with calcium chloride on beef retail display colour. *Journal of Animal Science* 74, 1846-1853.

Wheeler, T.L., Shackelford, S.D. & Koohmaraie, M. (1996b). Sampling, cooking, and coring effects on Warner-Bratzler shear force values in beef. *Journal of Animal Science* 74, 1553-1562.

Whipple, G. & Koohmaraie, M. (1993). Calcium chloride marination effects on beef steak tenderness and calpain proteolytic activity. *Meat Science* 33, 265-275.

Whipple, G., Koohmaraie, M., Dikeman, M.E., Crouse, J.D., Hunt, M.C. & Klemm, R.D. (1990). *Journal of Animal Science* 68, 2716-2728.

Wierbicki, E., Cahill, V.R. & Deatherage, F.E. (1957). Effects of added sodium chloride, potassium chloride, calcium chloride, magnesium chloride and citric acid on meat shrinkage at 70 °C and of added sodium chloride on drip losses after freezing and thawing. *Food Technology* 11, 74-76.

Wiklund, E., Barnier, V.M.H., Smulders, F.J.M., Lundström, K. & Malmfors, G. (1997). Proteolysis and tenderisation in reindeer (*Rangifer tarandus tarandus L.*) Bull *longissimus thoracis* muscle of varying ultimate pH. *Meat Science* 46, 33-43.

Wismer-Pedersen, J. & Briskey, E.J. (1961). Relationship of post-mortem acidity and temperature. *Food Technology* 15, 232 - 236.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R. & Enser, M. (2004). Effects of fatty acids on meat quality: a review. *Meat Science* 66, 21-32.

Younathan, M.T. and Watts, B. (1959). Relationship of meat pigments to lipid oxidation. *Food Research* 24, 728-734.

Young, O.A. & West, J. (2001). Meat colour. In Hui, Nip, Rogers & Young (Eds.) *Meat Science and applications* (pp. 39-69). New York: Marcel Dekker.

Young, O.A., Frost, D.A., West, J. & Braggins, T. (2001). Analytical methods. In Hui, Nip, Rogers & Young (Eds.) *Meat Science and applications* (pp. 103-126). New York: Marcel Dekker.

Yu, L.P. and Lee, Y.B. (1986). Effects of post-mortem pH and temperature on bovine muscle structure and meat tenderness. *Journal of Food Science* 51, 774-780.

Chapter 3

The effect of enhancement on the physical characteristics of five muscles of the blesbok (*Damaliscus dorcas phillipsi*) and springbok (*Antidorcas marsupialis*)

Abstract

Five muscles (*M. biceps femoris*, *M. longissimus et lumborum*, *M. rectus femoris*, *M. semitendinosus* and *M. supraspinatus*) from springbok (n=10) and blesbok (n=10) originating from the Gariep Nature Reserve in South Africa were used in this investigation. There were marked differences among the five muscles for most of the physical characteristics investigated, but in both species there were no significant differences amongst the five muscles for the two colour characteristics a* value and chroma. The influence of an inorganic salt solution, injected into the meat post mortem, on the drip loss, cooking loss, tenderness (in terms of its effect on the Warner-Bratzler shear force values) and colour properties was investigated. Both drip and cooking losses were higher in the enhanced muscles versus the untreated muscles, whilst the Warner-Bratzler shear force values were much lower in the enhanced muscles. The colour characteristics were, in general, lower in the enhanced muscles as compared to untreated samples. Results indicate that the tenderness of game meat may be enhanced with the injection of an inorganic salt solution with a minimal negative influence on the tested physical characteristics of the muscles.

Key words: Blesbok, Springbok, Game meat, Injected meat, Cooking loss, Drip loss, Tenderness, Colour

1. Introduction

Over the last few years, the increased health consciousness of consumers may have created the perfect marketing niche for game meat. Kritzinger (2002) noted that the cause of game meat may be moved forwards in the meat industry by marketing it to especially health conscious red meat consumers. Various health reports, such as that by the British Government's Committee on Medical Aspects of Food and Nutrition (COMA, 1984), have caused consumers to consider red meat as unhealthy – this is in complete disagreement with the view held before such reports surfaced. Traditionally meat was seen as an overall healthy, nutritious food necessary for the maintenance of good health (Higgs, 2000). Since then red meat has become linked to a high fat and cholesterol content (Scönfeldt, 1993; Higgs, 2000) and with various health-conditions such as coronary heart disease and cancer. Chizzolini, Zanardi, Dorigoni and Ghidini (1999) reported a relationship between high intake of particularly saturated fat and an increased risk of cancer, such as breast and colon cancer. Even though Higgs (2000) reported that there is insufficient scientific evidence to directly associate meat with the development of human cancers, some consumers have eliminated

red meat completely from their diets. A new world trend that addresses this fear is the marketing of "new" meat types derived from "wild" animals such as deer (venison) (Malmfors and Wiklund, 1996; Wiklund, Stevenson-Barry, Duncan and Littlejohn, 2001), game meat (Hoffman, Muller, Schutte and Crafford, 2004) and ostrich (Sales, 1995).

Several authors have reported that game species have fat contents less than 3.0g/100g (Kroon, Van Rensburg and Hofmeyr, 1972, Schönfeldt, 1993; Pauw, 1993; Hoffman, 2000). For example, the fat content of seven wild ungulate species varied between 1.4g/100g and 2.4g/100g, with springbok and blesbok both having fat contents of 1.7g/100g (Von la Chevallerie, 1972). Furthermore, Schönfeldt (1993) stated that game meat had higher levels of polyunsaturated fatty acids and a lower saturated fat content than beef and this view has been confirmed by other authors (Viljoen, 1999; Hoffman, 2000). Game meat can thus be considered a healthier red meat because of its low fat and cholesterol and its beneficial fatty acid composition.

Another blow to the image of meat in the last decade has been the outbreak of various diseases (foot-and-mouth disease and *Bovine Spongiform Encepalopathy* (BSE) or mad cow disease, to name but two) among meat animals, with consumers' concern about hormone- and antibiotic-use in animal production systems also mounting (Swatland, 1984; Higgs, 2000). Furthermore, various animal rights organizations have lobbied against meat production and this has made consumers very aware of animal rights and their welfare. Animal welfare, along with animal and product safety and environmentally friendly production, have indeed become hot topics with consumers in the past few years (Bernues, Olaizola and Corcoran, 2003). In this regard game meat is the ideal red meat source because it can be viewed as a wholesome product – game animals contain no added antibiotics, growth hormones or other chemicals readily used in conventional farming systems. South African game animals are generally farmed in extensive, free range farming systems with minimal contact with humans and therefore game meat can be considered an organic product (Pauw, 1993; Hoffman and Bigalke, 1999, Jansen van Rensburg, 2001).

In the past, the image of game meat has suffered mainly because of ignorance – consumers are ill informed about the potential health benefits of game meat and are left in the dark as to proper preparation methods (Webb, 2001; Hoffman *et al*., 2004). Consumers often end up with "tough, dry and chewy" meat because of incorrect preparation and cooking techniques (Webb, 2001) and game meat quality is generally seen as unpredictable (Bronkhorst, 2005). Enhancement of meat with various different combinations of inorganic salts and lactates has improved the tenderness of the muscles and also resulted in a more consistent quality product (Lawrence, Dikeman, Hunt, Kastner and Johnson, 2003a,b; Hoffman, 2006).

Springbok and blesbok are two of the most common game species favoured by game farmers in South Africa (Conroy and Gaigher, 1982). Springbok was found to be the game species most often consumed by South African consumers (Hoffman, Muller, Schutte, Calitz and Crafford, 2005) and was found to be one of the three game meat species that are

regularly available in South African supermarkets, butcheries and restaurants (Hoffman *et al*., 2004).

The aim of this study was to determine the physical characteristics of five blesbok and springbok muscles (*M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus*) and to investigate the effects that enhancing game meat with an inorganic salt solution might have on the physical meat quality.

2. Materials and Methods

2.1 Animals

Ten blesbok (*Damaliscus dorcas phillipsi*) and ten springbok (*Antidorcas marsupialis*) were randomly harvested at the Gariep Nature Reserve in the Free State Province of South Africa. All animals were male and carcass weight varied between 16.4 kg and 42.2 kg and 17.4 kg and 30.4 kg for blesbok and springbok, respectively. Animals were harvested at night by a professional cull team, using similar culling methods to those described by Lewis, Pinchin and Kestin (1997), and only head or neck shots were taken. Animals were exsanguinated within 5 minutes of harvesting and together with the culling methods used this resulted in animals being exposed to minimal stress conditions. Carcasses were hung by the Achilles tendon. Bled and eviscerated skin-on carcasses were transported, in a temperature-controlled vehicle, to Stellenbosch where they were skinned and processed further approximately 24 h after harvesting.

An inorganic salt solution (Freddy Hirsch Tenderbite #802539; P.O. Box 2554, Cape Town, 8000) with a chemical composition of sodium (5.21%) and potassium (2.53%) di- and triphosphates (3.45%), lactate (12.40%) and water (75.75%) to give a pumped gain of 20%, with a retention value of approximately 15%, after a resting period of 2h, was injected into the left halves of the springbok carcasses. The right and left hand side *M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus* of each springbok carcass were removed. The muscles were trimmed of visible fat and connective tissue. As the blesbok is a larger antelope species and the halved blesbok carcasses were too large to fit into the Rühle Curing Centre, the same five muscles were first removed and trimmed as described above prior to the muscles from the left hand side being injected with the same inorganic salt solution. Injection was performed at a pressure of 2.4 bar at 30 strokes per minute on a Rühle Curing Centre IR56 (Rühl GmbH, D-79865, Grafenhausen, Germany). Springbok carcass halves and blesbok muscles were weighed before injection and again after injection (with a resting period of 2 hours) to assess final pumped gain. All the right hand samples served as controls. After the required samples for the determination of physical characteristics had been removed, the remaining samples were individually vacuum packed and frozen at –20 ºC until required for either chemical or sensory analyses.

2.2. Physical analyses

The colour of the raw samples was measured 24 h postmortem with a GmbH Colorimeter, after a 20-minute period of blooming was allowed. Four measurements were performed at randomly selected positions on each sample. L*, a* and b* values were measured on the meat samples, while chroma and hue angle were calculated (Commission International De l'Eclairage, 1976).

Drip loss and cooking loss were performed according to the procedures described by Honikel (1998) and expressed as a percentage of the initial weight. Four 1.0cm thick samples were cut from each of the five muscles (two each for cooking loss and drip loss) with an approximate weight of 61g and 42g for *M. biceps femoris*, 45g and 31g for *M. longissimus et lumborum*, 33g and 22g for *M. rectus femoris*, 25g and 17g for *M. semitendinosus*, and 30g and 18g for *M. supraspinatus* of blesbok and springbok, respectively. Drip loss was determined by placing individually weighed samples in a net inside a polythene bag (under atmospheric pressure) for a period of 24h at 4ºC. Samples were removed, dried and weighed.

Cooking loss was performed by submerging individually weighed samples sealed inside thin-walled polythene bags, in a water-bath at 75ºC for 1 h. Samples were removed, allowed to cool in cold water, dried and weighed.

The cooled cooking loss samples were used to determine the toughness of the meat by measuring the maximum force (Newton) necessary to shear a cylindrical core (1.27 diameter) of cooked meat perpendicular to the grain at a crosshead speed of 200mm/min. Shear force measurements were produced with a Warner-Bratzler shear attachment fitted to an Instron Universal Testing machine.

Crison 507 pH meters were used to measure pH. pH measurements were performed on springbok samples before and after inorganic salt solution was injected.

2.2 Statistical analyses

The experiment consisted of a randomised block design with two main effects: salt, i.e. salt enhanced or not, and muscle, i.e. *M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus,* replicated in 10 blocks (10 animals) per species. The standard GLM procedure was used when the physical data were statistically analysed (SAS, 1999) after determining that the data was normally distributed. Differences between treatments were tested for by means of the Bonferroni t-test. The objective of this investigation was not to compare species, but rather differences within species, therefore no statistical comparisons were made with species as main effect.

3. Results and discussion

3.1. Pumped gain

The pumped gain experienced by the halved springbok carcasses was 23.33%, while the mean pumped gain for the five blesbok muscles was 16.60% (*M. biceps femoris*, 18.03%;

M. longissimus et lumborum, 12.28%; *M. rectus femoris*, 14.91%; *M. semitendinosus*, 20.08%; and *M. supraspinatus*, 16.99%). The retention objective of 15% was therefore achieved with the blesbok muscles, but the springbok carcass halves retained more moisture than was anticipated. The pumped gain is the direct measurement of the amount of moisture added to the meat and may shed light on such characteristics as cooking loss, drip loss and juiciness. These results show that moisture was definitely added to the enhanced meat. However, the question remains whether the added moisture would be able to contribute to the eating quality of the meat in the form of juiciness, or whether it is bound too tightly, in which case the meat would remain dry, or whether it is bound too loosely and may escape as drip or cooking loss.

3.2. Cooking loss, drip loss, tenderness and pH

3.2.1. Muscle differences

The results of the untreated (control) muscles were used to determine the differences amongst the five muscles investigated in both species (Table 1).

Water holding capacity (WHC) has an important function in meat quality. By affecting tenderness and juiciness it influences meat-eating quality and also directly influences physical properties, such as cooking loss and drip loss (Honikel, 1998; Lawrie, 1998). All untreated blesbok muscles, except *M. semitendinosus* and *M. supraspinatus,* differed significantly ($P<0.05$) in terms of cooking loss, while there were significant ($P<0.05$) differences between most untreated springbok muscles with the exception of *M. rectus femoris*, which did not differ significantly from either the *M. semitendinosus* or *M. biceps femoris*.

In terms of blesbok drip loss, no significant differences were found between the *M. biceps femoris* and either the *M. longissimus et lumborum,* or the *M. semitendinosus*, and the *M. semitendinosus* and *M. supraspinatus* did not differ significantly from one another either. The *M. rectus femoris* differed significantly from the other muscles in terms of drip loss. There was less variation in the drip loss of springbok muscles, with *M. longissimus dorsi*, *M. semitendinosus* and *M. rectus femoris* not differing significantly, and *M. biceps femoris*, *M. supraspinatus* and *M. rectus femoris* not differing significantly, while these two groups, with the exception of the *M. rectus femoris*, differed significantly ($P<0.05$) from each other.

The blesbok muscles could be arranged in descending order of tenderness (from most tender to least tender) as follows: *M. longissimus et lumborum*, *M. rectus femoris*, *M. biceps femoris*, *M. supraspinatus* and *M. semitendinosus*. The *M. longissimus et lumborum*, *M. rectus femoris* and *M. biceps femoris* did not differ significantly, also the *M. biceps femoris* and *M. supraspinatus* did not differ significantly from each other, but there were significant differences between these groups, except for the *M. biceps femoris* which only differed significantly ($P<0.05$) from the *M. semitendinosus* in terms of tenderness.

In the springbok, the *M. semitendinosus* and *M. supraspinatus* did not differ significantly, while the *M. biceps femoris* and *M. rectus femoris* did not differ significantly from each other, but the three groups of muscles differed significantly ($P<0.05$) in terms of

tenderness. The five springbok muscles could be arranged in descending order of tenderness as follows: *M. longissimus et lumborum*, *M. rectus femoris*, *M. biceps femoris*, *M. semitendinosus* and *M. supraspinatus*. These results differ slightly from tenderness results reported for different beef muscles (Shackelford, Wheeler and Koohmaraie, 1995). These authors found the *M. longissimus dorsi* to have the lowest (2.7) and also the highest (6.7) Warner-Bratzler shear force value (kg), with *M. biceps femoris*, following (3.2 min.; 6.0 max.), then *M. supraspinatus* (3.0 min.; 5.8 max.),with *M. semitendinosus* (3.3 min.; 5.8 max.) showing the lowest values. Jeremiah, Smith and Carpenter (1971) reported that the *M. rectus femoris* and *M. semitendinosus* received the highest sensory tenderness rating of the five sheep muscles investigated in their study. According to the shear force values obtained for enhanced muscles in this study, the muscles can be arranged from the most tender to the toughest muscle as follows: *M. longissimus et lumborum* (most tender), *M. rectus femoris, M. biceps femoris*, *M. semitendinosus* and *M. supraspinatus* (least tender), with both species showing the same tendency.

The five springbok muscles could be divided into two clear groups for pH value: the *M. rectus femoris* and *M. supraspinatus* being in the one group and the *M. biceps femoris* and *M. longissimus dorsi* being in the other group, with only *M. semitendinosus* belonging to both groups and the two groups differing significantly ($P<0.05$) from each other.

3.2.2. Treatment differences

Treatment differences were investigated in both species by comparing the results of the enhanced muscles with the results found for the untreated muscles.

In this study the cooking loss of the five enhanced muscles averaged 37.79%, while the untreated muscle had a mean of 36.86% for blesbok and 34.92% for enhanced and 34.01% for untreated springbok (Table 1). In all cases the upper limit was set by the *M. supraspinatus*, while the lower limit was set by the *M. longissimus et lumborum*. It is expected that the enhanced muscles would experience greater moisture losses upon cooking because of the added moisture (because of the water content of the injected solution). The enhanced muscles showed significantly ($P<0.05$) higher cooking losses than the untreated muscles in both species. There were, however, no significant differences found in the treatments of blesbok *M. longissimus et lumborum* and *M. rectus femoris* or in springbok *M. biceps femoris* and *M. semitendinosus*.

Cooking loss is the moisture lost from muscle during cooking and, along with drip loss, is a measure of the WHC of meat. Cooking loss can mostly be attributed to structural changes occurring in the muscle because of the denaturing of various proteins at varying temperatures (37-75ºC). Cooking loss is associated with tenderness and several authors found a significant relationship between tenderness and cooking loss, where increased tenderness was found in meat with decreased cooking loss (Briskey, 1963; Silva, Patarata and Martins, 1999; Thomas, Gondoza, Hoffman, Oosthuizen and Naudè, 2004). In the present study, however, the enhanced samples showed higher tenderness than the untreated

samples even though the untreated samples displayed lower cooking losses than the enhanced samples. This may be ascribed to a diluting effect of the bound water – when more water is bound (in a fixed area), a smaller amount of muscle fibres will be found, and therefore less resistance is offered (Thomas *et al*., 2004).

Smit (2004) reported cooking for male blesbok as 36.11%, while Kroucamp (2004) reported values of 31.50 ± 0.47% for the cooking of male springbok. The cooking loss results of this study were found to be higher in both the untreated and enhanced muscles.

Table 1 Least squared means for physical analyses of five blesbok and springbok muscles, either enhanced with an inorganic salt solution or left untreated.

Muscles	Blesbok			Springbok			
	Cooking loss (%)	Drip loss (%)	Tough-ness (N/1.27cmØ)	Cooking loss (%)	Drip loss (%)	Tough-ness (N/1.27cmØ)	pH
Biceps femoris							
Enhanced	38.092	4.476	25.406	34.092	2.737	23.322	5.924
Untreated	36.365 [b]	3.214 [a, b]	40.077 [b, c]	32.902 [c]	1.981 [b]	32.740 [b]	5.660 [b]
SEM	0.287	0.252	1.306	0.571	0.104	0.967	0.013
P-value	0.0002	0.0013	<0.0001	0.1511	<0.0001	<0.0001	<0.0001
Longissimus et lumborum							
Enhanced	33.368	3.507	18.860	30.416	3.779	16.083	5.944
Untreated	32.987 [d]	4.694 [a]	41.201 [c]	28.482 [d]	2.818 [a]	26.603 [c]	5.642 [b]
SEM	0.394	0.162	1.644	0.475	0.189	0.888	0.010
P-value	0.4987	<0.0001	<0.0001	0.0074	0.0011	<0.0001	<0.0001
Rectus femoris							
Enhanced	35.684	2.845	20.730	34.454	3.361	19.480	6.029
Untreated	35.957 [c]	2.781 [c]	40.783 [c]	35.403 [b, c]	2.421 [a, b]	33.061 [b]	5.762 [a]
SEM	0.306	0.175	0.892	0.313	0.120	0.655	0.015
P-value	0.5341	0.7974	<0.0001	0.0405	<0.0001	<0.0001	<0.0001
Semitendinosus							
Enhanced	40.483	3.451	27.164	36.931	3.419	28.943	5.968
Untreated	39.345 [a]	2.708 [b, c]	45.313 [a]	35.620 [b]	2.860 [a]	40.367 [a]	5.696 [a, b]
SEM	0.300	0.145	0.997	0.506	0.138	1.003	0.008
P-value	0.0118	0.0011	<0.0001	0.0774	0.0078	<0.0001	<0.0001
Supraspinatus							
Enhanced	41.330	3.135	33.632	38.688	2.673	31.973	5.968
Untreated	39.646 [a]	3.364 [c]	51.387 [b]	37.638 [a]	2.182 [b]	41.674 [a]	5.806 [a]
SEM	0.232	0.206	1.216	0.315	0.105	1.413	0.011
P-value	<0.0001	0.4374	<0.0001	0.0200	0.0018	<0.0001	<0.0001

[a, b, c, d] Muscles from the control group with different superscripts differ significantly (P<0.05).

The addition of several chemical components to meat, as is the case here where the meat was enhanced with an inorganic salt solution, will undoubtedly lead to several changes, including the ion-protein relationship existing in the muscle. Changing the ion-protein relationship can lead to increased WHC because of the changes brought on through the K^+-

absorption and Ca^{2+}-release and this can clearly be observed in comminuted meats when the salts of weak acids (particularly phosphates and polyphosphates) are added (Lawrie, 1998). An increased water up-take by myofibrils in strong salt solutions was reported and attributed mainly to the disruption in the forces determining the arrangement of the filaments at the Z- and M-lines and between the myosin heads and the actin filaments (Offer and Trinick, 1983). This happens when the lattice of thick and thin filaments expand when the increasingly negatively charged components repel one another.

Adding phosphate to meat improved juiciness and Prestat, Jensen, McKeith and Brewer (2002) postulated that it was because of the added moisture (the water included in the enhancement solution) as well as the increased moisture retention due to the increased pH levels caused by the added phosphate. Phosphate addition also caused increased water retention in the work by Baublits, Pohlman, Brown Jr. and Johnson (2005). The untreated samples in their study had greater levels of free water, but the phosphate-treated samples contained a higher total moisture percentage. This was probably the case in the present study where higher moisture losses (loss of free water as drip and cooking losses) were found.

Jeremiah, Dugan, Aalhus and Gibson (2003) observed that muscles differed extensively when cooking loss was considered. Those cuts that contained more fat showed lower cooking losses and cuts that contained more insoluble and total hydroxyproline sustained greater total cooking losses because of higher connective tissue content. However, in this study the enhanced samples showed slightly lower fat contents (chapter 4) than the untreated samples, probably due to a diluent effect caused by the added enhancement solution, as was suggested by Thomas *et al*. (2004). Therefore, the bulk of the differences observed in the cooking losses of enhanced vs. untreated muscles must be due to the addition of some of the inorganic salts present in the enhancement solution.

The mean drip loss value for blesbok was 3.48% for enhanced and 3.35% for untreated samples, while the average drip loss for enhanced springbok muscles was 3.19% and 2.45% for untreated springbok muscles. Significant treatment differences were observed in most of the muscles in both species, except in blesbok *M. rectus femoris* and *M. supraspinatus*. However, this time the two species did not follow the same trend – all of the enhanced springbok muscles had significantly higher ($P<0.01$) drip losses than the untreated muscles, but the differences in the blesbok muscles were slightly haphazard. While the enhanced *M. biceps femoris* and *M. semitendinosus* had significantly higher ($P<0.01$) values than the untreated muscles, the treatment difference in the *M. longissimus et lumborum* was highly significant ($P<0.0001$), with the untreated muscle having a higher value than the enhanced muscle.

Drip loss can mostly be attributed to the free water component found in meat, which has the ability to freely flow from meat as purge (Cover, Ritchey and Hostetler, 1962). Thomas *et al.* (2004) observed that cooking loss and drip loss showed opposite tendencies and that, as percentage cooking loss increased, drip loss percentage decreased as shear

force values increased. In this study, however, it was found that the enhanced samples had both higher drip and cooking losses as well as lower shear force values (indicating higher tenderness values).

The observed drip losses of the control muscles compare well with those reported by Smit (2004) (4.30% for male blesbok) and Kroucamp (2004) (2.80 ± 0.19%male springbok). Clearly enhancing meat with an inorganic salt solution causes it to have higher moisture contents and therefore higher cooking and drip losses were observed, in the most part, in the enhanced muscles as compared to the untreated muscles. Indeed, in springbok meat, all the enhanced muscles (except the *M. supraspinatus*) had significantly ($P<0.01$) higher moisture levels, while most of the blesbok muscles (except *M. biceps femoris* and *M. longissimus et lumborum*) had significantly higher moisture ($P<0.0001$) levels (results not shown).

Tenderness is the most important quality attribute of meat, as far as consumers are concerned (Lawrie, 1998; Pietrasik and Shand, 2004). Tenderness was described by Deatherage (1963) as "a quality representing the summation of properties of the various protein structures of skeletal muscle." Furthermore, this author stated that tenderness could be directly related to the protein structure of the muscle and the denaturation, coagulation and hydrolysis of those proteins.

In the current study, a highly significant ($P<0.0001$) improvement was found in the Warner-Bratzler shear force values of all five enhanced muscles in both species. The shear force values were found to be an average of 25.16 N/1.27cm for enhanced and 43.75 N/1.27cm for untreated blesbok muscles and 23.96 N/1.27cm for enhanced and 34.89 N/1.27cm for untreated springbok muscles (Table 1). The tenderness of the game meat was significantly improved by the injected inorganic salt solution.

Several authors have reported on the improved tenderness caused by enhancing meat with various inorganic salt solutions (Papadopoulos, Miller, Ringer and Cross, 1991; Scanga, Delmore Jr., Ames, Belk, Tatum and Smith, 2000; Lawrence *et al*., 2003b). Treating top round roasts with sodium lactate improved the tenderness, reported Papadopoulos *et al*. (1991), but using concentrations higher than 2.0% did not cause further improvements.

Phosphate addition has also been shown to improve meat tenderness (Scanga *et al*, 2000; Lawrence *et al*, 2003b) and Deatherage (1963) reported that sodium phosphate is commonly used in the meat industry to improve protein solubility. Baublits *et al*, (2005) reported that steaks enhanced with sodium hexameta-phosphate, sodium tripolyphosphate or tetrasodium pyrophosphate, received higher sensory tenderness scores than steaks treated with sodium chloride or left untreated, even though no differences could be detected in the Warner-Bratzler shear force values between the treatments. When pork *M. longissimus dorsi* was injected with a phosphate-salt-solution, Prestat *et al*. (2002) reported improved Warner-Bratzler shear force values and observed that the tenderness was stabilised under a variety of conditions.

Hoffman (2006) reported improved shear force values in both the *M. longissimus* and *M. semitendinosus* of mature cows enhanced with a similar inorganic salt solution as the one

used in this study. Warner-Bratzler shear force values of 50.40 ± 8.7 N/1.27cm for untreated and 36.73 ± 7.1 N/1.27cm for enhanced *M. longissimus* and 48.72 ± 6.8 N/1.27cm for untreated and 42.03 ± 6.74 N/1.27cm for enhanced *M. semitendinosus* were reported by Hoffman (2006). The treatment difference for the *M. longissimus* was highly significant (P<0.0001) and a significant difference (P<0.05) was found in the treatment of the *M. semitendinosus*.

There were highly significant (P<0.0001) differences observed between the pH values of enhanced and untreated muscles, with enhanced muscles having higher pH values than the untreated muscles (Table 1) because of the added phosphates (Hoffman, 2006). pH measurements were only performed on springbok muscles. The mean pH for the enhanced muscles was 5.97 and 5.71 for the untreated muscles. The results of the untreated muscles are in agreement with the results of Kroucamp (2004). However, the results of the enhanced muscles are not supported by the literature. Eilers, Morgan, Martin, Miller, Hale and Acuff (1994) reported that the pH of lactic acid-treated meat declined to values below those of untreated samples. Baublits *et al*. (2005) found the pH values of beef treated with sodium hexameta-phosphate to be lower than untreated samples and similar to sodium chloride-treated beef. Although, these authors did report that the pH values of beef treated with either tripolyphosphate or tetrasodium pyrophosphate were higher than untreated samples.

3.3. Colour

Meat colour is extremely important during the purchasing decision process of consumers, since consumers use colour as a cue for the freshness of meat (Jeremiah, Smith and Carpenter, 1972; Young and West, 2001). When the untreated muscles were investigated (Table 2), it was found that there were definite differences between muscles in both species for all the colour characteristics, except for the a* values and the chroma values for which none of the five muscles of either blesbok or springbok differed significantly.

In blesbok, the *M. supraspinatus* did not differ significantly from the *M. biceps femoris*, *M. rectus femoris* or the *M. longissimus et lumborum* and there were no significant differences between the *M. biceps femoris* and *M. rectus femoris*, however, there were significant (P<0.05) differences between the *M. semitendinosus* and *M. supraspinatus* and between the *M. biceps* and *M. rectus femoris* and the *M. longissimus et lumborum* and *M. semitendinosus* when the L* value was investigated. The five springbok muscles could be divided into two significantly (P<0.05) different groups when the L* value was considered, with the *M. rectus femoris*, *M. semitendinosus* and *M. supraspinatus* being in the one group (not differing significantly from each other), the *M. longissimus et lumborum* being in the other group, differing significantly from the first group and the *M. biceps femoris* not differing significantly from either group. When the b* values are considered, the blesbok *M. biceps femoris*, *M. longissimus et lumborum*, *M. rectus femoris* and *M. supraspinatus* showed no significant difference, but these four muscles all differed significantly (P<0.05) from the *M. semitendinosus*. For the same characteristic in the springbok, the *M. semitendinosus* and *M.*

supraspinatus did not differ significantly from each other, but there was a significant difference (P<0.05) between these two muscles and the *M. longissimus et lumborum*, whereas there was no significant difference between the three muscles already mentioned and the *M. biceps femoris* and *M. rectus femoris* (both the latter two muscles did not differ significantly from each other).

When hue was considered, the blesbok muscles followed a similar trend as was shown with the b* value – there were no significant differences between the *M. biceps femoris*, *M. longissimus et lumborum*, *M. rectus femoris* and *M. supraspinatus* and all these muscles differed significantly (P<0.05) from the *M. semitendinosus*. In the springbok, the *M. rectus femoris* and *M. supraspinatus* did not differ significantly from each other in terms of hue and both these muscles did not differ significantly from any of the other three muscles. However, there were significant hue differences (P<0.05) between *M. biceps femoris*, *M. longissimus et lumborum* and *M. semitendinosus*.

Young and West (2001) found that differences in muscle colour could be mostly attributed to the myoglobin and iron differences between muscles. Wheeler, Koohmaraie and Shackelford (1997) found the *M. longissimus dorsi* to have the greatest colour stability, but there were no indication of other colour characteristics and the differences between muscles.

In this study, the colour properties of enhanced muscles were slightly lower than the untreated samples through all muscles investigated. This means that the enhanced meat was slightly darker and a little less red than the untreated samples. Young and West (2001) reported that game meat has a high tendency to form a brown colour and that it appears darker than the meat from domesticated meat animals because of its higher myoglobin concentration. Van Schalkwyk (2004) noted that game meat had lower L* values than that of other meat species and that is partly why game meat is perceived as being darker in colour than beef.

Meat colour may also be influenced by pH. Swatland (1984) observed that meat with a low ultimate pH appeared to be bright red, while meat with high ultimate pH values appeared darker. Meat will appear brighter when both its a* and b* values are high (Honikel, 1998). According to Volpelli, Valusso, Morgante, Pittia and Piasentier (2003), there are colour measurement properties characteristic to the dark red colour of venison and these are: L*<40, high a* values and low b* values.

Hoffman (2000) reported very dark meat in wounded impala (L*, 25.44; a*, 9.13; b*, 4.88), while Smit (2004) and Kroucamp (2004) reported the colour values for male blesbok and springbok *M. longissimus dorsi*, respectively, to be compliant with the colour measurement properties supplied by Volpelli *et al*. (2003).

The colour data generated in this study (Table 2) for the five blesbok muscles show that the L*, a* and b* values do not quite meet the 'characteristic' criteria set by Volpelli *et al*. (2003) for venison. All L* values are lower than 40, but a* and b* values are very close together. The springbok L*, a* and b* values definitely follow the 'characteristic' colour trend of venison – L* values are lower than 40 and the a* values are much higher than the b*

Table 2 Least squared means (± SE) of colour analyses of five inorganic salt-enhanced and untreated blesbok and springbok muscles.

	Blesbok					Springbok				
Muscles	L* value	a* value	b* value	Hue	Chroma	L* value	a* value	b* value	Hue	Chroma
Biceps femoris										
Enhanced	33.727	14.121	11.300	38.273	18.016	30.115	20.983	8.681	22.420	22.739
Untreated	34.535[b]	16.412	12.857[b]	37.816[b]	20.984	32.493[a, b]	23.343	10.721[a, b]	24.518[b]	25.713
SEM	0.298	0.196	0.235	0.613	0.180	0.994	0.370	0.235	0.458	0.397
P-value	0.0650	<0.0001	<0.0001	0.6019	<0.0001	0.1014	<0.0001	<0.0001	0.0030	<0.0001
Longissimus et lumborum										
Enhanced	31.970	14.150	11.201	38.331	18.060	27.165	21.992	8.127	20.091	23.488
Untreated	32.737[c]	15.491	12.145[b]	38.049[b]	19.718	29.469[b]	24.198	9.218[b]	20.721[c]	25.930
SEM	0.253	0.246	0.233	0.756	0.232	0.697	0.437	0.281	0.626	0.450
P-value	0.0405	0.0006	0.0076	0.7941	<0.0001	0.0266	0.0013	0.0102	0.4825	0.0006
Rectus femoris										
Enhanced	33.446	13.769	10.437	37.169	17.307	31.552	20.345	9.329	24.625	22.412
Untreated	34.363[b]	16.756	13.645[b]	39.091[b]	21.623	32.340[a]	22.624	10.341[a, b]	24.416[a, b]	24.916
SEM	0.291	0.210	0.232	0.588	0.246	0.686	0.355	0.238	0.583	0.357
P-value	0.0340	<0.0001	<0.0001	0.0280	<0.0001	0.4227	<0.0001	0.0054	0.8015	<0.0001
Semitendinosus										
Enhanced	32.534	13.787	10.811	38.066	17.543	31.600	21.077	9.729	24.486	23.279
Untreated	34.165[a]	16.533	12.408[a]	37.077[a]	20.567	34.167[a]	22.983	11.622[a]	26.676[a]	25.787
SEM	0.151	0.209	0.196	0.500	0.214	0.633	0.381	0.226	0.548	0.388
P-value	<0.0001	<0.0001	<0.0001	0.1728	<0.0001	0.0076	0.0014	<0.0001	0.0084	<0.0001
Supraspinatus										
Enhanced	36.087	13.349	11.778	41.236	17.865	32.969	22.452	10.215	24.464	24.692
Untreated	38.006[b, c]	16.187	14.386[b]	41.576[b]	21.670	31.518[a]	22.617	10.374[a]	24.580[a, b]	24.907
SEM	0.213	0.197	0.241	0.622	0.237	0.774	0.475	0.307	0.678	0.492
P-value	<0.0001	<0.0001	<0.0001	0.7023	<0.0001	0.1758	0.7992	0.7045	0.9000	0.7482

[a, b, c, d] Muscles from the control group with different superscripts differ significantly (P<0.05).

values, with the b* values reported for the springbok meat also being much lower than the b* values reported for the blesbok meat. Springbok meat had the characteristic dark red colour venison usually displays. The L*, a* and b* values of all enhanced muscles were lower than their untreated counterparts for both species. Most muscles had L* values that significantly differed (P<0.05) between treatments, except blesbok *M. biceps femoris* and springbok *M. biceps femoris*, *M. rectus femoris* and *M. supraspinatus*.

The treatment differences in a* and b* values were highly significant (P<0.01) for all muscles, except for springbok *M. supraspinatus* (both a* and b* were not significantly different). In blesbok meat the average L* values were 33.55 for the enhanced and 34.76 for the untreated samples, the average a* values were 13.84 for the enhanced and 16.28 for the untreated samples, with the average b* values being 11.11 for the enhanced and 13.09 for the untreated samples, while the average values of springbok were: 30.69 (enhanced) and 32.00(untreated) for L*; 21.37 (enhanced) and 23.15 (untreated) for a*; and 9.22 (enhanced) and 10.46 (untreated) for b*. Thus, the enhanced samples would appear darker in colour than the untreated samples (lower L*) and less bright (lower a* and b*) although the colour of the enhanced meat was not negatively influenced – no discolouration was perceived.

As far as hue angle and chroma of blesbok meat are considered, there were no significant differences for hue angle between muscles, except for the *M. rectus femoris* in which the untreated sample had significantly higher (P<0.05) values than the enhanced sample, whereas all muscles presented highly significant (P<0.0001) treatment differences for chroma, with untreated muscles having higher values. The mean blesbok hue angle was 38.62 for enhanced and 38.72 for untreated samples, while the average chroma values were 17.76 for enhanced and 20.91 for untreated samples. Both hue angle and chroma observed for blesbok meat in this study were much higher than the values reported by Smit (2004) for blesbok *M. longissimus dorsi*. In springbok meat, only two muscles (*M. biceps femoris* and *M. rectus femoris*) presented significantly different (P<0.01) treatment values for hue angle, while chroma differed significantly (P<0.01) between treatments in all muscles, except *M. supraspinatus*. Springbok meat had a fairly low hue angle, the average value for enhanced samples being 23.22 and 24.18 for untreated samples, much lower than those reported by Kroucamp (2004) for springbok *M. longissimus dorsi* muscles, while the chroma values averaged 23.32 for enhanced and 25.45 for untreated samples. In most cases the untreated muscles had higher values for both hue angle and chroma than the enhanced samples. These chroma values are much higher than those reported by Kroucamp (2004). Higher chroma values represent higher colour saturation levels and the muscle will appear brighter in colour (Stevenson, Seman, Weatherall and Littlejohn, 1989).

Papadopoulos *et al*. (1991) found that treated with sodium lactate improved meat colour in top round roasts, with higher a* values (meat appeared more red) and lower L* and b* values. Phosphate-enhanced pork presented higher a* and lower b* values than its untreated counterparts (Prestat *et al*., 2002). On the other hand, several authors (Kerth,

Miller and Ramsey, 1995; Lawrence *et al*., 2003a) have reported that calcium chloride caused accelerated discolouration and darkening in calcium chloride-enhanced meat.

Even though the enhanced springbok muscles do have slightly lower colour values than the untreated samples, it would still appear brighter and much redder than the (untreated) springbok samples observed in the work of Kroucamp (2004). The same goes for the presented blesbok data. Compared to the blesbok samples observed in the work of Smit (2004), the blesbok colour data presented in the current study shows that the enhanced blesbok muscles would indeed appear brighter and more red in colour.

4. Conclusion

The respective muscles of the springbok and blesbok differed in terms of the physical characteristics investigated in this study. There were significant ($P<0.05$) differences between different muscles and groups of muscles for all the characteristics investigated, except for the two colour characteristics, a*-value and chroma for which there were no significant differences for any of the five muscles.

Enhancing blesbok and springbok meat with an inorganic salt solution has definite advantages in terms of tenderness and moisture absorption, with enhanced meat being more tender (much lower shear force values) and juicy (slightly higher drip and cooking losses shows higher water-absorption) than untreated meat. No improvement was observed in terms of the colour properties of meat samples of both species. However, both treated and untreated meat from both species investigated in this study, displayed better colour properties (in terms of bright red colour) than what has previously been reported for game meat.

5. References

Baublits, R.T., Pohlman, F.W., Brown Jr., A.H. & Johnson, Z.B. (2005). Effects of sodium chloride, phosphate type and concentration, and pump rate on beef *biceps femoris* quality and sensory characteristics. *Meat Science* 70, 205-214.

Bernues, A., Olaizola, A. & Corcoran, K. (2003). Labelling information demanded by European consumers and relationships with purchasing motives, quality and safety of meat. *Meat Science* 65, 1095-1106.

Briskey, E.J. (1963). Influence of ante- and post-mortem handling practices on properties of muscle which are related to tenderness. In *Proceedings meat tenderness symposium* (pp. 195-223). Camden: Campbell Soup Company.

Bronkhorst, N. (2005). Is koedoe en springbok op jou inkopielys? *Landbouweekblad* 24 Junie, 67.

Chizzolini, R., Zanardi, E., Dorigoni, V. & Ghidini, S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. *Trends in Food Science and Technology* 10, 119-128.

Commission International De l'Eclairage (1976). *Colorimetry*, 2nd ed. CIE, Vienna.

Committee on Medical Aspects of Food Policy (1984). 'Diet and Cardiovascular Disease. *Report on Health and social subjects*, Department of Health and Social Security, No. 28, HMSO, London.

Conroy, A.M. & Gaigher, I.G. (1982). Venison, Aquaculture and ostrich meat production: Action 2003. *South African Journal of Animal Science* 2, 219-233.

Cover, S., Ritchey, S.J. & Hostetler, R.L. (1962). Tenderness of Beef. II. Juiciness and the softness components of tenderness. *Journal of Food Science* 27, 476-482.

Deatherage, F.E. (1963). The effect of water and inorganic salts on tenderness. In *Proceedings meat tenderness symposium* (pp. 45-68). Camden: Campbell Soup Company.

Eilers, J.D., Morgan, J.B., Martin, A.M., Miller, R.K., Hale, D.S. & Acuff, G.R. (1994). Evaluation of calcium chloride and lactic acid injection on chemical, microbiological and descriptive attributes of mature cow beef. *Meat Science* 38, 443-451.

Higgs, J.D. (2000). The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science and Technology* 11, 85-95.

Hoffman, L.C. (2006). Sensory and physical characteristics of enhanced vs. non-enhanced meat from mature cows. *Meat Science* 72, 195-202.

Hoffman, L.C. (2000). Meat quality attributes of night-cropped impala (*Aepyceros melampus*). *SA Journal of Animal Science* 30, 133-137.

Hoffman, L.C. and Bigalke, R.C. (1999). Utilizing wild ungulates from southern Africa for meat production: Potential research requirements for the new millennium. *Congress of the Wildlife Management Association of SA* (pp. 1-14). George, South Africa.

Hoffman, L.C., Muller, M., Schutte, De W., Calitz, F.J. & Crafford, K. (2005). Consumer expectations, perceptions and purchasing of South African game meat. *South African Journal of Wildlife Research* 35, 33-42.

Hoffman, L.C., Muller, M., Schutte, De W. & Crafford, K. (2004). Retail of South African game meat: current trade and marketing trends. *South African Journal of Wildlife Research* 34, 123-134.

Honikel, K.O. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science* 49, 447-457.

Jansen van Rensburg, D.M. (2001). Venison as health food. In H. Ebedes, B. Reilly, W. van Hoven & B. Penzhorn (Eds.). *Sustainable utilisation - conservation in practice*. Proceedings of the 5th International Wildlife Ranching Symposium (pp. 196-198).

Jeremiah, L.E., Dugan, M.E.R., Aalhus, J.L. & Gibson, L.L. (2003). Assessment of the relationship between chemical components and palatability of major beef muscles and muscle groups. *Meat Science* 65 1013-1019.

Jeremiah, L.E., Smith, G.C. & Carpenter, Z.L. (1972). Ovine yield grades. II. Palatability attributes within various quality grades. *Journal of Animal Science* 34, 196-202.

Jeremiah, L.E., Smith, G.C. & Carpenter, Z.L. (1971). Palatability of individual muscles from ovine leg steaks as related to chronological age and marbling. *Journal of Food Science* 35, 45-47.

Kerth, C.R., Miller, M.F. & Ramsey, C.B. (1995). Improvement of beef tenderness and quality traits with calcium chloride injection in beef loins 48 hours post mortem. *Journal of Animal Science* 73, 750-756.

Kritzinger, B. (2002). Meat quality parameters of the Impala (*Aepyceros melampus*). M.Sc. Agric (Animal Science) thesis. Department of Animal Science. University of Stellenbosch, Stellenbosch.

Kroon, F.E., van Rensburg, W.J.J. & Hofmeyr, H.S. (1972). Seisoenale veranderinge in chemiese samestelling van volwasse blesbokramme (*Damaliscus dorcas phillipsi*) van die Van Riebeeck natuurreservaat. *Suid Afrikaanse Tydskrif van Veekunde* 2, 41-44.

Kroucamp, M. (2004). Meat quality characteristics of the springbok (*Antidorcas marsupialis*). M. Sc. (Foods). Department of Food Science. University of Stellenbosch, Stellenbosch.

Lawrence, T.E., Dikeman, M.E., Hunt, M.C., Kastner, C.L. & Johnson, D.E. (2003a). Effects of calcium salts on beef *longissimus* quality. *Meat Science* 64, 299-308.

Lawrence, T.E., Dikeman, M.E., Hunt, M.C., Kastner, C.L. & Johnson, D.E. (2003b). Staged injection marination with calcium lactate, phosphate and salt may improve beef water-binding ability and palatability traits. *Meat Science* 65, 967-972.

Lawrie, R.A. (1998). *Lawrie's Meat Science* (6th ed.). Cambridge, England: Woodhead Publishing Ltd.

Lewis, A.R., Pinchin, A.M. & Kestin, S.C. (1997). Welfare implications of the night shooting of wild impala (*Aepyceros melampus*). *Animal Welfare* 6, 123-131.

Malmfors, G. & Wiklund, E. (1996). Pre-slaughter handling of reindeer – effects on meat quality. *Meat Science* 43, 257-264.

Offer, G. & Trinick, J. (1983). On the mechanism of water holding in meat: The swelling and shrinking of myofibrils. *Meat Science* 4, 245-281.

Papadopoulos, L.S., Miller, R.K., Ringer, L.J. & Cross, H.R. (1991). Sodium lactate effect on sensory characteristics, cooked meat colour and chemical composition. *Journal of Food Science* 56, 621-626.

Pauw, J. (1993). The development of venison marketing. In *Forum: The venison industry. Research requirements and possibilities* (pp.3-5). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Prestat, C., Jensen, J., McKeith, F.K. & Brewer, M.S. (2002). Cooking methods and endpoint temperature effects on sensory and colour characteristics of pumped pork loin chops. *Meat Science* 60, 395-400.

Pietrasik, Z. & Shand, P.J. (2004). Effect of blade tenderisation and tumbling time on the processing characteristics and tenderness of injected cooked roast beef. *Meat Science* 66, 871-879.

Sales, J. (1995). Nutritional quality of meat from some alternative species. *World review of Animal Production* 30, 47-56.

SAS (1999). *SAS/STAT User's Guide*, Version 8 (Volume II). SAS Institute Inc., North Carolina.

Scanga, J.A., Delmore Jr., R.J., Ames, R.P., Belk, K.E., Tatum, J.D. & Smith, G.C. (2000). Palatability of beef steaks marinated with solutions of calcium chloride, phosphate, and (or) beef-flavouring. *Meat Science* 55, 397-401.

Shackelford, S.D., Wheeler, T.L. & Koohmaraie, M. (1995). Relationship between shear force and trained sensory panel tenderness ratings of 10 major muscles from *Bos indicus* and *Bos taurus* cattle. *Journal of Animal Science* 73, 3333-3340.

Schönfeldt, H. (1993). Nutritional content of venison. In *Forum: The venison industry. Research requirements and possibilities* (pp. 51-60). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Silva, J.A., Patarata, L. & Martins, C. (1999). Influence of ultimate pH on bovine meat tenderness during ageing. *Meat Science* 52, 453-459.

Smit, K. (2004). Meat quality characteristics of blesbok (*Damaliscus dorcas phillipsi*) and red hartebeest (*Alcelaphus buselaphus caama*) meat. M. Consumer Sc. (Food) thesis. Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Stevenson, J.M., Seman, D.L., Weatherall, I.L. & Littlejohn, R.P. (1989). A research note. Evaluation of venison colour by an objective method using CIELAB values. *Journal of Food Science* 54, 1661-1662.

Swatland, H.J. (1984). *Structure and development of meat animals*. Ontario Agricultural College, University of Guelph, Englewood Cliffs, NY: Prentice Hall.

Thomas, A.R., Gondoza, H., Hoffman, L.C., Oosthuizen, V. & Naudè, R.J. (2004). The roles of the proteasome, and cathepsins B,L,H and D, in ostrich meat tenderisation. *Meat Science* 67, 113-120.

Van Schalkwyk, S. (2004). Meat quality characteristics of three South African game species: Black wildebeest (*Connochaetes gnou*), Blue wildebeest (*Connochaetes taurinus*) and Mountain reedbuck (*Redunca fulvorufula*). M. Sc. Cons. (Foods). Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Viljoen, J.J. (1999). 'n Vergelyking van die lipiedkomponente van springbokvleis met die van beesvleis en die verwante belangrikheid vir aspekte van die menslike gesondheid. *SA Tydskrif vir Natuurwetenskap enTegnologie* 18, 51-53.

Volpelli, L.A., Valusso, R., Morgante, M., Pittia, P. & Piasentier, E. (2003). Meat quality in male fallow deer (Dama dama): effects of age and supplementary feeding. *Meat Science* 65, 555-562.

Von la Chevallerie, M. (1972). Meat quality of seven wild ungulate species. *South African Journal of Animal Science* 2, 101-103.

Webb, R. (2001). It's all in the game. *Diabetes Forecast* 54, 30-33.

Wheeler, T.L., Koohmaraie, M. & Shackelford, S.D. (1997). Effect of post-mortem injection time and post-injection ageing time on the calcium-activated tenderisation process in beef. *Journal of Animal Science* 75, 2652-2660.

Wiklund, E., Stenvenson-Barry, J.M., Duncan, S.J. & Littlejohn, R.P. (2001). Electrical stimulation of red deer (*Cervus elaphus*) carcasses – effects on rate of pH-decline, meat tenderness, colour stability and water holding capacity. *Meat Science* 59, 211-220.

Young, O.A. & West, J. (2001). Meat colour. In Hui, Nip, Rogers & Young (Eds.) *Meat Science and applications* (pp. 39-69). New York: Marcel Dekker.

Chapter 4

The effect of enhancement on the chemical characteristics of five springbok (*Antidorcas marsupialis)* and blesbok (*Damaliscus dorcas phillipsi)* muscles

Abstract

Very little is known about the proximate composition, mineral content and fatty acid profile of different springbok and blesbok muscles. In the present investigation, the chemical composition of *M. biceps femoris*, *M. longissimus et lumborum*, *M. rectus femoris*, *M. semitendinosus* and *M. supraspinatus* of springbok (n=10) and blesbok (n=10) were determined. The influence that an inorganic salt solution, injected into the meat, could have thereupon was also investigated. Significant differences were detected amongst the five control muscles for moisture in both species, while the protein content of blesbok and the fat content of springbok differed significantly amongst the five control muscles. When the mineral content is considered, significant muscle differences were detected amongst the control muscles of the springbok for magnesium, iron and zinc, while the control muscles of the blesbok differed significantly for calcium and magnesium. When the mineral content of the enhanced muscles were investigated, significant muscle differences were detected for potassium, iron and zinc in the springbok, and for iron in the blesbok. Fatty acid analysis was performed on untreated muscles only and the high polyunsaturated fatty acid to saturated fatty acid (P:S) ratio and low n-6:n-3 ratios of springbok and blesbok compared to those of domesticated species has shown that springbok and blesbok meat do indeed have a fatty acid profile that may positively influence human health. In both species it was found that the moisture and ash percentages were significantly higher for the majority of the enhanced muscle while fat and protein percentages were lower in the untreated muscles when compared to the enhanced muscles. Potassium and sodium were the two minerals present in significantly higher values in the enhanced springbok meat, while phosphorus, potassium and sodium were significantly higher in enhanced blesbok meat. Magnesium was significantly higher in untreated muscles of both species.

Key words: Game meat, Springbok, Blesbok, Inorganic salt injection, Enhancement, Fatty acids, Minerals, Chemical analysis

1. Introduction

Ever since reports, such as that of the British Government's Committee on Medical Aspects of Food and Nutrition (COMA, 1984) dealing with coronary heart disease, identified meat as a substantial source of saturated fat, meat consumption has steadily declined. People have become more health-conscious and consumers have become much more informed about food components with potential health benefits, as well as those posing health

threats. Of the latter, saturated fat and cholesterol have become the main culprits usually focussed on. Higgs (2000) noted that consumers perceive all fat in meat to be saturated although serious effort has been made by the meat industry to improve the fatty acid content of various meat species. Consumers have since been demanding food products with low cholesterol and low fat contents.

South African consumers were shown to consider fat content as a very important criterion when purchasing meat (Hoffman, Muller, Schutte and Crafford, 2004), which clearly paves the way for the possibility of promoting game meat as a low fat red meat – several authors have commented on the low fat content of game meat (Von la Chevallerie, 1972; Elliot, 1993; Hoffman, 2000).

Several authors have reported that the fatty acid composition of meat, rather than its total fat content, is more important for health reasons (Nelson, Schmidt and Kelley, 1995; Chizzolini, Zanardi, Dorigoni and Ghidini, 1999; Higgs, 2000). In this regard, the ratio of polyunsaturated fatty acids to saturated fatty acids (P:S) is very important. Schönfeldt (1993), Viljoen (1999) and Hoffman (2000) have all remarked on the high levels of polyunsaturated fatty acids present in game meat.

Meat is also associated with a high cholesterol level because it is an essential constituent of all cells of animal origin (Higgs, 2000). Even though nutritional guidelines advises a cholesterol-intake of no more than 300mg per day (Chizzolini *et al*., 1999), Nelson *et al*. (1995) reported that blood low-density lipoprotein (LDL) cholesterol levels apparently remained unaffected by fat calories (saturated or unsaturated) in the diet. The latter authors suggested that blood cholesterol level-changes might be attributed to fatty acid ratios in the diet. Higgs (2000) noted that lean beef as part of a low saturated fat diet caused plasma cholesterol and LDL-cholesterol levels to be reduced in a fashion similar to equal amounts of chicken and fish, although, including beef fat in the diet did cause an increase in blood cholesterol levels. Thus, red meat with a fairly high amount of lean muscle (low in fat) definitely has a place in the modern consumer's nutrition as far as health benefits are concerned. Elliot (1993) reported venison to have a cholesterol content half of what was reported for lamb and beef.

Game meat has moisture levels favourably comparable to those of other domesticated meat species (Von la Chevallerie, 1972). Consumers are demanding meat that is more tender and juicy, thus, meat with higher moisture levels might be more favourably accepted by consumers. Moisture levels of meat can be increased by various methods, including injecting various inorganic salts post-mortem. Baublits, Pohlman, Brown Jr. and Johnson (2005) found that injecting steaks with a solution of sodium chloride and different phosphates at 18% of the raw weight increased moisture percentages and caused the treated steaks to be rated more tender and juicy. Enhancing meat with inorganic salts may thus affect meat favourably in several different ways, although some negative effects have been reported, for example the adverse flavour effects caused by several of the calcium salts (Wheeler, Koohmaraie and Shackelford, 1997; Scanga, Delmore Jr., Ames, Belk, Tatum and

Smith, 2000). The effects of inorganic salt-injection on the proximate composition of game meat have not been intensively researched and part of the aim of this study was to report the effects that inorganic salt-enhancement may have on the chemical composition of springbok meat.

Springbok is presently the most extensively cropped game species in South Africa (Hoffman, 2000). Hoffman, Muller, Schutte, Calitz and Crafford (2005) found that most respondents to their questionnaire have eaten springbok meat before and that it was one of the three game species found to be regularly available in supermarkets and restaurants. Blesbok was also noted by Conroy and Gaigher (1982) as one of the most common game species found naturally on farms in South Africa.

Where fatty acids are concerned, Lengyel, Husveth, Polgar, Szabo and Magyar (2003) found the polyunsaturated fatty acid levels in bull *M. semitendinosus* were much higher than that of the *M. longissimus dorsi*, while the latter muscles contained much higher levels of both saturated and mono-unsaturated fatty acids. Enser, Hallett, Hewett, Fursey, Wood and Harrington (1998), as well as Lengyel *et al*. (2003), noted that predominantly red oxidative muscles (such as the *M. semitendinosus*) contain higher levels of phospholipids and therefore have higher levels of polyunsaturated fatty acids than muscles low in oxidative fibres (such as the *M. longissimus dorsi*).

The aim of this study was firstly, to report on the chemical differences between five muscles of the springbok and blesbok, and secondly, to investigate the effects of inorganic salt-enhancement on these chemical attributes. No information exists on muscle differences of game meat – usually only data on the *M. longissimus dorsi* or *M. biceps femoris* are reported. Thus, this study aspires to expand the amount of information currently available on game meat.

2. Materials and Methods

2.1. Animals and sampling

Ten springbok (*Antidorcas marsupialis*) and ten blesbok (*Damaliscus dorcas phillipsi*) were randomly harvested at the Gariep Nature Reserve in South Africa. All animals were male and carcass weight varied between 17.4 kg and 30.4 kg for springbok and 16.4 kg and 42.2 kg for blesbok. Animals were harvested at night by a professional cull team, using similar culling methods to those described by Lewis, Pinchin and Kestin (1997), and only head or neck shots were taken to minimise animal stress. Animals were exsanguinated within 5 minutes of harvesting and carcasses were hung by the Achilles tendon. Bled and eviscerated skin-on carcasses were transported to Stellenbosch, with a temperature-controlled vehicle, where they were skinned and processed further approximately 24 h after harvesting.

The left halves of the springbok carcasses were injected with an inorganic salt solution (Freddy Hirsch Tenderbite #802539; P.O. Box 2554, Cape Town, 8000) with a chemical composition of sodium (5.21%) and potassium (2.53%) di- and triphosphates

(3.45%), lactate (12.40%) and water (75.75%) to give a pumped gain of 15%, with a retention level of approximately 12%. Injection was performed at a pressure of 2.4 bar at 30 strokes per minute on a Rühle Curing Centre IR56 (Rühl GmbH, D-79865, Grafenhausen, Germany). The right and left side *M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus* of each carcass of both species were removed and trimmed of any carcass connective tissue and fat (although these game species seldom have any visible fat). As the blesbok is a larger antelope species and the halved blesbok carcasses were too large to fit into the Rühle Curing Centre, the muscles were first removed before the left muscles of blesbok carcasses were injected with the same inorganic salt solution. Samples were individually vacuum packed and frozen at –20 ºC.

2.2. Chemical analyses

Chemical analyses were performed on finely minced muscle samples. Total moisture (100ºC, 24 h) and ash content (500ºC, 5h) were determined according to AOAC method numbers 934.01 and 942.05, respectively (AOAC, 1997). Total lipid content was determined by extracting lipids with a chloroform: methanol (2:1 v/v) solution by the solvent extraction method described by Lee, Trevino and Chaiyawat (1996). Total crude protein was determined by means of the Dumas Combustion method (AOAC method 968.06; AOAC, 1997) using the LECO FP 528, while the mineral composition was determined by direct current plasma emission spectrometry (Pinta, 1982).

Fatty acid analyses were only executed on untreated samples. The fatty acid content was determined by extracting a 2 g sample of meat with a chloroform/methanol (CM 2:1; v/v) solution according to a modified method of Folch, Lees and Sloane-Stanley (1957). An antioxidant (0.01% butylated hydroxytoluene (BHT)) was added to all extraction solvents. Heptadecanoic acid ($C_{17}H_{34}O_2$) (Sigma-Aldrich Inc., 3050 Spruce St., St. Louis, MO, 63103, USA; Cat. no. H3500) was used as an internal standard to quantify the individual fatty acids. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenise the sample within the extraction solvent and the isolated lipids were transmethylated with a transmethylating reagent (methanol/sulphuric acid; 19:1; v/v) for 2 hours at 70ºC. After cooling, the resulting fatty acid methyl esters (FAME) were extracted with water and hexane and the top hexane phase was transferred to a spotting tube and dried under nitrogen.

The FAME were purified using thin layer chromatography plates (TLC, silica gel 60 plates) and analysed with a Thermo Finnigan Focus Gas chromatograph (Thermo Electron S.p.A., Strada Rivoltana, 20090 Rodano, Milan, Italy). A 60 m BPX70 capillary column (SGE Int. Pty. Ltd., 7 Argents Place, Ringwood, Victoria, 3134, Australia) with an internal diameter of 0.25mm was utilised and Hydrogen (30 ml/min.) was used as carrier gas. Temperature programming was linear at 4ºC/min., with the different temperature settings as follows: an initial temperature of 140ºC, a final temperature of 240ºC, an injector temperature of 220ºC and a detector temperature of 260ºC. The FAME were identified by comparing the retention

times to those of a standard FAME mixture, Supelco 37 Component FAME Mix C4 – C24 (Supelco, 595 North Harrison Rd., Bellefonte, PA, 16823-0048, USA; Cat. no. 18919).

2.3. Statistical analysis

The experiment consisted of a randomised block design with two main effects: salt, i.e. salt enhanced or not, and muscle, i.e. *M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus,* replicated in 10 blocks (10 animals) per species. The standard GLM procedure was used when the chemical data were statistically analysed (SAS, 1999) after determining that the data was normally distributed. Differences between treatments were tested for by means of the Bonferroni t-test. The objective of this investigation was not to compare species, but rather differences within species, therefore no statistical comparisons were made with species as main effect.

3. Results and discussion

3.1. Moisture and Ash content

Generally meat has a moisture content of 70-77%, depending on the fat content of the meat. As the fat content increases, the moisture content decreases (Young, Frost, West and Braggins, 2001). The moisture contents of untreated springbok and blesbok muscles (Table 1) in this study were slightly lower (73.4% and 74.4%, respectively) than the average of 75.5% shown by Von la Chevallerie (1972).

Of the five springbok muscles investigated, the *M. biceps femoris* and *M. supraspinatus* did not differ significantly from each other or from any of the other muscles in terms of moisture content. However, while the *M. rectus femoris* and *M. semitendinosus* did not differ significantly from each other, it did differ significantly ($P<0.05$) from the *M. longissimus et lumborum*. The blesbok *M. longissimus et lumborum* was the only muscle of the five that differed significantly ($P<0.05$) from the other muscles in its moisture content. There were no significant differences detected in the moisture contents of the *M. biceps femoris*, *M. rectus femoris*, *M. semitendinosus* or *M. supraspinatus*.

Of the untreated springbok muscles, the *M. rectus femoris* had the highest, and the *M. longissimus et lumborum* the lowest, moisture content (74.16 ± 1.10% vs. 72.16 ± 1.68%). For the untreated blesbok muscles, the *M. biceps femoris* showed the highest moisture content (75.05 ± 1.86%) and the *M. longissimus et lumborum* the lowest (73.47 ± 1.30%). Although the literature is limited, Jeremiah, Smith and Carpenter (1971) reported that out of five sheep muscles investigated, *M. biceps femoris* and *M. rectus femoris* were the two muscles that were rated the juiciest, with *M. semitendinosus* and *M. vastus lateralis* rated least juicy. It seems that there is a general harmony between the findings of this research and the results reported in the literature where the muscles with the highest moisture contents are concerned. Although it was not the same muscle in both species, it was in accordance with the findings of Jeremiah *et al*. (1971). In both species the *M. longissimus et lumborum* was found to be the muscle with the lowest moisture content, not the *M. semitendinosus* as

Jeremiah *et al*. (1971) reported. The *M. semitendinosus* of both species had intermediate moisture levels, with the *M. biceps femoris* (in the case of the springbok) and the *M. rectus femoris* (in the case of the blesbok) showing even lower moisture contents.

When the moisture levels of the enhanced muscles are considered, there are marked improvements in the moisture content of most of the five muscles investigated (Table 1). Although the average value of the enhanced springbok muscles was, at 75.3%, slightly lower than the average provided by Von la Chevallerie (1972), it was higher than the moisture value that the reported for springbok meat, which was 74.7%. The average moisture value for springbok was also higher than the 74.2% reported by Kroucamp (2004) and corresponds well with the 75.3% reported (for the whole carcass) by Van Zyl and Ferreira (2004). An average moisture value of 76.5% was found for the enhanced blesbok muscles. This value is slightly higher than the 75.1% reported by Smit (2004) and much higher than the 71.1% Van Zyl and Ferreira (2004) reported for whole blesbok carcasses.

Table 1 Least squared means of moisture and ash analysis of five springbok and blesbok muscles either enhanced with an inorganic salt solution or left untreated.

	Springbok		Blesbok	
Muscles	Moisture (%)	Ash (%)	Moisture (%)	Ash (%)
Biceps femoris				
Enhanced	75.268 ± 1.145	2.136 ± 0.125	76.146 ± 1.209	2.164 ± 0.299
Untreated	72.613 ± 1.212[a, b]	1.192 ± 0.080	75.046 ± 1.864 [a]	1.205 ± 0.123
P-value	0.0003	<0.0001	0.1206	<0.0001
Longissimus et lumborum				
Enhanced	74.745 ± 1.609	2.167 ± 0.154	74.353 ± 1.406	1.837 ± 0.390
Untreated	72.157 ± 1.682 [b]	1.324 ± 0.237	73.470 ± 1.300 [b]	1.382 ± 0.229
P-value	<0.0001	<0.0001	0.1226	0.0222
Rectus femoris				
Enhanced	75.817 ± 1.346	2.230 ± 0.537	77.300 ± 1.074	2.245 ± 0.486
Untreated	74.157 ± 1.102 [a]	1.370 ± 0.299	73.962 ± 0.538 [a]	1.250 ± 0.197
P-value	0.0008	0.0039	<0.0001	0.0003
Semitendinosus				
Enhanced	75.779 ± 0.894	2.095 ± 0.229	77.884 ± 1.001	2.376 ± 0.375
Untreated	73.857 ± 0.969 [a]	1.465 ± 0.306	74.547 ± 1.607 [a]	1.293 ± 0.131
P-value	0.0002	0.0002	<0.0001	<0.0001
Supraspinatus				
Enhanced	75.075 ± 1.971	1.967 ± 0.443	76.962 ± 1.136	2.316 ± 0.183
Untreated	74.087 ± 0.810 [a, b]	1.171 ± 0.132	74.869 ± 0.936 [a]	1.274 ± 0.228
P-value	0.1701	<0.0001	<0.0001	<0.0001

[a, b] Untreated (control) muscles with different superscripts differ significantly (P<0.05).

Sales (1995) reported an inverse correlation between intramuscular fat and moisture content of meat and it is therefore expected that game meat may have higher moisture values than domesticated species. When comparing the moisture contents of the meat from several game species with that of several domesticated meat species, the moisture content of the game species, varying between 74.7 and 77.0% (Von la Chevallerie, 1972) compared very favourably with that of mutton, 60.7%, pork, 55.0%, and beef, 65.4% (Sayed, Frans and Schönfeldt, 1999).

For all the springbok muscles, except the *M. supraspinatus*, the enhanced muscles differed highly significantly ($P< 0.001$) from the untreated muscles. Of the five blesbok muscles investigated, only the *M. biceps femoris* and *M. longissimus et lumborum* did not show highly significant ($P<0.0001$) improvements in the enhanced samples. This marked increase in the moisture levels of treated muscles can be ascribed to the improved water holding capacity (WHC) caused by the injection of the inorganic salts present in the enhancing solution. A change in the ion-protein relationship can lead to increased WHC because of the changes brought on through the K^+-absorption and Ca^{2+}-release, which is particularly visible in comminuted meats when the salts of weak acids (particularly phosphates and polyphosphates) are added (Lawrie, 1998). Offer and Trinick (1983) reported an increased water up-take by myofibrils in strong salt solutions mainly because of a disruption in the forces determining the arrangement of the filaments at the Z- and M-lines and between the myosin heads and the actin filaments. This transpires when the lattice of thick and thin filaments expand when the increasingly negatively charged components repel one another.

In fact, several authors have shown that injecting meat with inorganic salts can improve the juiciness of meat (Scanga *et al*., 2000; Baublits *et al*., 2005). Prestat, Jensen, McKeith and Brewer (2002) found added phosphate improved juiciness and postulated that it was because of the added moisture (the water included in the enhancement solution) and the increased moisture retention due to the increased pH levels caused by the added phosphate. Phosphate addition also caused increased water retention, although untreated samples had greater levels of free water, the phosphate-treated samples contained a higher total moisture percentage (Baublits *et al.*, 2005). Injecting 1-4% sodium lactate into top rounds increased the juiciness during storage, while injecting top rounds with only 1% sodium lactate caused significant decreased in the juiciness (Papadopoulos, Miller, Ringer and Cross, 1991).

The moisture content for all the springbok and blesbok muscles investigated were much higher than those values reported by Sayed *et al*. (1999) for mutton (60.7%), pork (55.0%) and beef (65.4%), although the moisture values of ostrich meat was higher (76.3%) than all of these species. The addition of the inorganic salt mixture definitely increased the moisture content of enhanced game muscles and will have positive ramifications where the eating quality of the meat is concerned, since juiciness will be improved by the increased moisture content of the enhanced muscles.

Usually the ash content of meat is very small, but Van Schalkwyk (2004) declared the ash content of game meat to be higher than that of domesticated animals. No differences in the ash contents could be found amongst the untreated muscles of either blesbok or springbok. The average ash content reported for male game animals has been in the vicinity of 1.23-1.29g/100 g (Kroucamp, 2004; Smit, 2004; Van Schalkwyk, 2004). The ash content of meat represents its mineral contents and therefore, in this study, the expectation was that the enhanced samples would have higher ash percentages than untreated samples (Table 1). That was definitely the case with the enhanced springbok samples having a mean of 2.12% and the blesbok samples a mean of 2.19%. The ash values of the enhanced samples were significantly higher ($P<0.01$) than the untreated samples for all five muscles in both species.

3.2. Fat and protein content

The intramuscular fat of meat has a very important role in its eating quality, with intramuscular fat directly affected juiciness and flavour and indirectly affected tenderness (Jeremiah, Dugan, Aalhus and Gibson, 2003). Of the five springbok muscles investigated (Table 2), the *M. biceps femoris*, *M. longissimus et lumborum* and *M. rectus femoris* did not differ significantly from each other or from the *M. semitendinosus* or the *M. supraspinatus* in fat contents. The *M. semitendinosus* and *M. supraspinatus* did, however, differ significantly ($P<0.05$) from each other. No significant differences occurred amongst the investigated blesbok muscles where fat content was considered.

In this study, the fat content of springbok muscles averaged 1.80% (enhanced) and 2.14% (untreated) and the blesbok fat content averaged 1.86% (enhanced) and 2.22% (untreated), which is well under the value of 2-3% reported by Schönfeldt (1993) and Hoffman (2000) (Table 2). The fat content of the untreated muscles were higher than the enhanced muscles throughout all investigated muscles.

The untreated springbok *M. longissimus et lumborum*, *M. rectus femoris* and *M. semitendinosus* had significantly higher ($P<0.05$) fat values than the enhanced muscles, with *M. biceps femoris* and *M. supraspinatus* showing no significant treatment differences. Of the five blesbok muscles investigated, the untreated *M. rectus femoris*, *M. semitendinosus* and *M. supraspinatus* had significantly ($P<0.01$) higher fat contents, while *M. biceps femoris* and *M. longissimus et lumborum* did not differ significantly although, the untreated muscles definitely had higher fat values than the enhanced samples.

The fat content of most game species have been reported as averaging less than 3% (Von la Chevallerie, 1972; Schönfeldt, 1993; Pauw, 1993; Hoffman, 2000). Von la Chevallerie (1972) reported game fat contents of between 1.4 and 2.4g/100g, with springbok having a fat content of 1.7g/100g, while the fat contents of the buttocks of beef (14.2g/100g), mutton (21.6g/100g) and pork (17.6g/100g) were much higher (Sayed *et al*., 1999).

The lower fat content of the enhanced muscles could be ascribed to the fact that the moisture content of these muscles were increased due to the enhancement effects and therefore, the fat content would be lower than it would have before enhancement. Thomas,

Gondoza, Hoffman, Oosthuizen and Naudè (2004) postulated that this was due to a diluting effect the bound water had on the muscle fibres – when more water is bound (in a fixed area), a smaller amount of muscle fibres will be found.

Meat protein has a very high biological value (Higgs, 2000) and the nutritive value of animal protein is higher in terms of protein efficiency ratio and in terms of biological value than protein from plant origin (MacRae, O'Reilly and Morgan, 2005). In terms of protein content, no significant differences could be detected amongst the investigated untreated springbok muscles (Table 2). In the blesbok, however, only the *M. longissimus et lumborum* differed significantly (P<0.05) from the other four muscles, while the *M. biceps femoris*, *M. rectus femoris*, *M. semitendinosus* and *M. supraspinatus* did not differ significantly in its protein contents.

Table 2 Least squared means of fat and protein analysis of five springbok and blesbok muscles either enhanced with an inorganic salt solution or left untreated.

	Springbok		Blesbok	
Muscles	Fat (%)	Protein (%)	Fat (%)	Protein (%)
Biceps femoris				
Enhanced	1.954 ± 0.537	20.816 ± 1.212	1.898 ± 0.525	19.719 ± 1.251
Untreated	2.241 ± 0.718 [a, b]	23.681 ± 1.411	2.056 ± 0.331	20.810 ± 1.694 [b]
P-value	0.1699	0.0035	0.2708	0.0837
Longissimus et lumborum				
Enhanced	1.722 ± 0.621	21.783 ± 1.520	1.965 ± 0.567	21.923 ± 1.323
Untreated	2.273 ± 0.579 [a, b]	24.184 ± 1.476	2.089 ± 0.364	22.678 ± 1.446 [a]
P-value	0.0127	0.0008	0.5041	0.1886
Rectus femoris				
Enhanced	1.558 ± 0.299	20.737 ± 1.291	1.856 ± 0.380	19.207 ± 1.620
Untreated	2.140 ± 0.168 [a, b]	22.581 ± 1.450	2.434 ± 0.561	21.898 ± 0.939 [b]
P-value	0.0006	0.0123	0.0062	0.0003
Semitendinosus				
Enhanced	1.639 ± 0.312	21.577 ± 3.166	1.657 ± 0.624	18.444 ± 0.820
Untreated	1.814 ± 0.346 [b]	23.409 ± 0.569	1.886 ± 0.401	22.143 ± 1.562 [b]
P-value	0.0448	0.1156	0.1432	<0.0001
Supraspinatus				
Enhanced	2.144 ± 0.485	21.215 ± 1.832	1.906 ± 1.039	18.731 ± 1.363
Untreated	2.213 ± 0.491 [a]	22.422 ± 1.258	2.653 ± 0.853	20.799 ± 1.602 [b]
P-value	0.7955	0.2506	0.0756	0.0019

[a, b] Untreated (control) muscles with different superscripts differ significantly (P<0.05).

The protein content of the inorganic salt-treated springbok muscles in this study was lower than the untreated muscles, with *M. biceps femoris*, *M. longissimus et lumborum* and *M. rectus femoris* differing significantly ($P<0.05$) between treatments, although *M. semitendinosus* and *M. supraspinatus* did not differ significantly between treatments, the untreated muscles did have higher protein contents than the untreated muscles (Table 2). The enhanced *M. biceps femoris*, *M. longissimus et lumborum* and *M. rectus femoris* were significantly ($P<0.01$) higher in terms of protein levels, but even though the *M. supraspinatus* and *M. semitendinosus* technically did not show significant P-values, there were big differences between the treated and untreated muscle protein values, with control muscles having higher protein percentages than the enhanced samples.

The reason for this could be that, as the moisture content increased in a particular area of the muscle or carcass, it had a diluent effect on the number of muscle fibres and, thus, the protein content found in a particular area (Thomas *et al*., 2004), or it could be due to the solubilisation of myofibrillar proteins caused by similar mechanism as the non-enzymatic salting-in of calcium ions (Takahashi, Kim and Yano, 1987). Deatherage (1963) commented on the use of phosphates to cause improved protein solubility in meat processing and enhancing meat with phosphates did increase meat tenderness (Scanga *et al*., 2000).

Game meat has fairly high protein contents and Smit (2004) found male blesbok *M. longissimus et lumborum* to have an average protein content of 22.4%, while Van Zyl and Ferreira (2004) reported the protein value of male springbok carcasses to be 23.7% on average. McCane and Widdowson (1991, as cited by Elliot, 1993) reported the following protein values for several domesticated meat species: beef topside roast, 26.6 g/100g; lamb leg roast, 26.1 g/100g; pork leg roast, 19.8 g/100g; chicken roast, skin-on, 22.6 g/100g. The protein contents of game meat found in this study, compares favourably with that of the above mentioned meat species.

The general tendency in enhanced springbok and blesbok muscles was that, as the moisture content became higher than that of the untreated muscle, the fat and protein contents became decreased.

3.3. Mineral content

Meat provides several minerals that are vital to human health (Higgs, 2000) and especially the iron content of meat is very important. Lawrie (1998) reported potassium and phosphorus to be the two minerals present in the highest quantities in meat. Game meat contains higher levels of the macro-minerals calcium, magnesium and potassium, as well as the trace elements iron, copper and selenium, than the meat from domesticated animals (Niemenin, 1992). The mineral values observed in the current study (Table 4) were in general all higher than those reported by Smit (2004), except for iron and copper, which were lower. Kroucamp (2004) reported lower mineral values for male springbok than the values found for untreated springbok muscles in the present study (Table 3), except for calcium, which Kroucamp (2004) found to be much higher.

Table 3 Least squared means of the mineral (mg/100g) analyses of two treatments of five springbok muscles.

	Phosporus	Potassium	Calcium	Magnesium	Sodium	Iron	Copper	Zinc	Manganese
Biceps femoris									
Enhanced	230.07	256.56 [a, b]	9.06	23.16	38.04	2.55 [a, b]	0.16	2.15 [b, c]	0.03 [a, b, c]
Untreated	220.56	163.65	9.58	28.46 [a]	15.14	2.92 [a, b]	0.09	2.56 [b]	0.04
SEM	20.05	9.60	0.66	1.33	2.24	0.11	0.02	0.12	0.01
P-value	0.7343	<0.0001	0.5828	0.0184	<0.0001	0.0431	0.0643	0.0394	0.6586
Longissimus et lumborum									
Enhanced	268.59	277.35 [a]	11.73	24.43	40.21	3.08 [a]	0.18	1.51 [c]	0.05 [a]
Untreated	222.01	160.90	11.48	27.30 [a, b]	12.82	3.27 [a]	0.08	1.77 [b]	0.04
SEM	23.54	7.48	0.37	0.46	1.83	0.10	0.03	0.06	0.00
P-value	0.1951	<0.0001	0.6408	0.0017	<0.0001	0.2049	0.0648	0.0142	0.8923
Rectus femoris									
Enhanced	222.45	266.56 [a, b]	9.00	20.77	38.53	2.17 [b]	0.14	4.31 [a]	0.04 [a, b]
Untreated	191.35	173.77	9.74	24.90 [a, b]	13.45	2.20 [d]	0.07	4.89 [a]	0.03
SEM	14.56	16.59	0.77	0.52	2.72	0.09	0.02	0.24	0.01
P-value	0.1652	0.0033	0.5140	0.0003	0.0001	0.8237	0.0621	0.1188	0.0934
Semitendinosus									
Enhanced	233.76	260.53 [a, b]	9.73	23.93	32.66	2.30 [b]	0.13	2.91 [b]	0.03 [b, c]
Untreated	207.23	169.79	8.82	26.81 [a, b]	12.59	2.30 [c, d]	0.04	2.87 [b]	0.03
SEM	19.05	10.80	1.10	0.88	3.00	0.12	0.02	0.16	0.01
P-value	0.3506	0.0002	0.5772	0.0453	0.0011	0.9993	0.0048	0.8564	0.5362
Supraspinatus									
Enhanced	201.47	205.97 [b]	8.48	20.10	29.15	2.48 [a, b]	0.10	4.49 [a]	0.02 [c]
Untreated	171.68	155.03	11.32	23.47 [b]	14.48	2.69 [b, c]	0.06	5.58 [a]	0.03
SEM	23.04	13.01	0.95	1.70	2.40	0.31	0.02	0.38	0.01
P-value	0.3500	0.0190	0.0535	0.1694	0.0021	0.6221	0.2194	0.0611	0.1227

[a, b, c] Muscles within a treatment group with different superscripts differ significantly (P<0.05) for the specified mineral.

Table 4 Least squared means of the mineral (mg/100g) analyses of two treatments of five blesbok muscles.

	Phosporus	Potassium	Calcium	Magnesium	Sodium	Iron	Copper	Zinc	Manganese
Biceps femoris									
Enhanced	251.61	279.26	9.19	20.50	37.51	2.91[a]	0.19	2.08[c]	0.05
Untreated	161.21	153.39	7.74[b]	24.46[a, b]	12.77	2.78	0.05	2.04[b]	0.04
SEM	11.59	12.14	0.50	1.96	1.73	0.20	0.02	0.14	0.00
P-value	<0.0001	<0.0001	0.0548	0.1918	<0.0001	0.6628	<0.0001	0.8383	0.2043
Longissimus et lumborum									
Enhanced	221.57	248.25	9.05	21.60	31.00	3.05[a]	0.14	1.33[c]	0.04
Untreated	190.37	179.91	10.75[a]	27.65[a]	13.28	3.30	0.06	1.67[b]	0.05
SEM	9.71	10.39	0.72	1.14	1.51	0.20	0.03	0.11	0.01
P-value	0.0356	0.0002	0.1100	0.0015	<0.0001	0.3835	0.0542	0.0424	0.6003
Rectus femoris									
Enhanced	233.34	272.03	7.83	19.40	43.04	2.42[a, b]	0.09	3.58[b]	0.04
Untreated	180.03	164.00	7.90[b]	25.79[a, b]	12.07	3.09	0.06	5.29[a]	0.05
SEM	9.36	11.19	0.50	0.73	4.93	0.17	0.01	0.26	0.00
P-value	0.0007	<0.0001	0.3606	<0.0001	0.0003	0.0121	0.1318	0.0002	0.0389
Semitendinosus									
Enhanced	259.41	299.72	7.54	17.25	41.15	2.18[a]	0.10	1.78[c]	0.04
Untreated	193.74	183.34	8.24[b]	27.57[a]	13.79	2.58	0.07	2.33[b]	0.04
SEM	13.21	16.99	0.49	1.53	3.20	0.13	0.02	0.11	0.01
P-value	0.0025	0.0001	0.3248	0.0002	<0.0001	0.0388	0.3350	0.0030	0.7035
Supraspinatus									
Enhanced	237.54	296.54	7.47	17.36	42.92	2.51[a, b]	0.10	5.03[a]	0.36
Untreated	164.46	171.47	8.22[b]	22.93[c]	15.47	3.09	0.06	6.03[a]	0.41
SEM	16.06	18.70	0.38	0.83	3.38	0.16	0.02	0.34	0.00
P-value	0.0054	0.0002	0.1834	0.0002	<0.0001	0.0244	0.2703	0.0572	0.4499

[a, b, c] Muscles within a treatment group with different superscripts differ significantly (P<0.05) for the specified mineral.

Since the inorganic salt solution used to enhance the meat contained additional sodium (5.21%), potassium (2.53%), di- and triphosphates (3.45%) and lactate (12.40%), the expected results would be an increase in these particular mineral values in the enhanced samples. In the springbok muscles, potassium and sodium were significantly ($P<0.01$) higher in the enhanced muscles compared with the untreated muscles, except in the case of the *M. supraspinatus* where the difference in potassium was slightly less significant ($P<0.05$). Although phosphorus was present at a higher concentration in the enhanced springbok muscles, there was no significant difference between treatments. All blesbok muscles showed highly significant differences ($P<0.01$) between treatment in phosphorus, potassium and sodium (except *M. longissimus et lumborum,* which had a significance of $P<0.05$ in the case of phosphorus, thus differing slightly less significantly than the other muscles), with the enhanced samples having much higher values of these three minerals than the untreated samples. All the enhanced springbok and blesbok muscles had higher copper quantities than the untreated muscles, but only that of the *M. semitendinosus* (springbok, $P<0.01$) and *M. biceps femoris* (blesbok, $P<0.0001$) differed significantly.

There was a significant difference ($P<0.05$) in the magnesium content of all springbok muscles, with the exception of the *M. supraspinatus*), as well as a highly significant ($P<0.01$) difference in all blesbok muscles (with the exception of the *M. biceps femoris*) with the untreated samples having higher magnesium values than the enhanced samples. The same trend was seen for the zinc content of the springbok *M. biceps femoris* and *M. longissimus et lumborum* and blesbok *M. longissimus et lumborum*, *M. rectus femoris* and *M. semitendinosus*, where the untreated samples had significantly ($P<0.05$) higher mineral values than the enhanced samples.

The untreated muscles also showed higher iron values, but only the difference in the springbok *M. biceps femoris* and blesbok *M. rectus femoris*, *M. semitendinosus* and *M. supraspinatus* were significantly higher ($P<0.05$). For the most part, the calcium and manganese contents of all five muscles remained fairly unchanged, with no significant ($P>0.05$) differences between treatments, although significant differences amongst control muscles were detected for calcium in the blesbok.

In the springbok, muscle differences (within treatments) were observed for potassium and manganese, with significant differences occurring within the enhanced muscles. The untreated muscles differed significantly for magnesium and when iron and zinc were considered, there were significant muscle differences within both the enhanced and untreated muscle groups. In blesbok, there were significant muscle differences within the untreated calcium-, magnesium- and zinc-groups, while there were significant differences within the muscles of the treated iron- and zinc groups.

3.4. Fatty acid content

Various authors have reported the higher levels of PUFA found in game meat as opposed to that of beef (Schönfeldt, 1993; Viljoen, 1999; Hoffman, 2000). In this study the

total amount of PUFA in springbok meat averaged 3.71mg/g^{-1} (Table 5), with the *M. biceps femoris* containing the highest amount, while the *M. rectus femoris* had the lowest amount of PUFA. This correlates very well with the values (3.849 ± 0.44mg/g^{-1}) reported by Kroucamp (2004). The total PUFA level in blesbok meat averaged 2.81mg/g^{-1} (Table 6), with the highest (*M. longissimus et lumborum*) and lowest (*M. supraspinatus*) amounts contributed by the same muscles as in the springbok. According to Kroucamp (2004) springbok meat has a PUFA value of 36.34 ± 3.37% (*M. longissimus dorsi*) and Smit (2004) reported a PUFA value of 2.89mg/100 g of total fatty acids for blesbok *M. longissimus dorsi*. P:S values of 1.11 ± 0.13 (Kroucamp, 2004) and 1.00 ± 0.39 (Smit, 2004) have been reported for springbok and blesbok, respectively. The same authors reported n-6:n-3 values of 3.28 ± 0.12 for springbok and 3.62 ± 0.75 for blesbok meat.

When the PUFA as a percentage of the total fatty acids were considered (Table 7), the springbok *M. semitendinosus* had the highest value (36.937 ± 8.516%), while the *M. supraspinatus* had the lowest value (30.714 ± 3.707%) – these values tie in well with the PUFA percentage reported by Kroucamp (2004). The PUFA as a percentage of the total fatty acids of blesbok (Table 8) is in the same vicinity, but slightly higher than those reported for springbok, with a higher value of 40.515 ± 13.954% (*M. biceps femoris*) and a lower value of 34.125 ± 11.909% (*M. supraspinatus*).

It has been suggested that a higher dietary intake of polyunsaturated fatty acids (PUFA), in comparison to the saturated fatty acids (SFA), is more beneficial. Wood *et al*. (2004) reported a recommended P:S value of no less than 0.4, and furthermore noted that the normal P:S ratio for meat is around 0.1. However, Gibney and Hunter (1993) found that high levels of the omega-6 (n-6) PUFA could, in fact, have a detrimental impact on health. Inflammatory eicosanoids are produced during the post-absorptive metabolism of n-6 PUFA and inflammatory responses are important factors in the development of cardiovascular heart disease and cancer. The omega-3 (n-3) PUFA can act as modulators to this inflammation and that is why the ratio of n-6:n-3 PUFA is so important. The most important n-6 PUFA is linoleic acid (C18:2) and linolenic acid (C18:3) is the most important n-3 PUFA. The British Department of Health (1994) recommends a n-6:n-3 ratio of less than 4.0. It was reported that ruminant meat has very low n-6:n-3 ratios, especially if the animals primarily graze, because of the higher levels of linolenic acid (C18:3) found in grass (Wood *et al*., 2004). This study showed that game meat can definitely compete well with domesticated meat where the fatty acid profile is concerned, since both springbok and blesbok meat contains high levels of PUFA, yet has high P:S and low n-6:n-3 ratios.

The mean P:S ratio of the five springbok muscles was 0.78 (*M. supraspinatus* lowest and *M. biceps femoris* highest value), while the mean blesbok P:S ratio was 0.92 (*M. supraspinatus* lowest and *M. biceps femoris* highest value). The springbok values are lower than those previously reported by Kroucamp (2004), while the blesbok values are just slightly higher than what Smit (2004) reported, however, both are much higher than the average value reported by Wood *et al*. (2004) and is also higher than the recommended value of 0.4.

Table 5 Mean fatty acid composition (mg/g^{-1} lipid) (± Std. deviation) of five springbok muscles.

Fatty acid	*Biceps femoris*	*Longissimus et lumborum*	*Rectus femoris*	*Semitendinosus*	Supraspinatus
C14:0 (Myristic)	0.160 ± 0.181	0.170 ± 0.170	0.026 ± 0.029	0.134 ± 0.076	0.079 ± 0.076
C16:0 (Palmitic)	2.098 ± 1.013	2.523 ± 1.213	1.847 ± 0.923	2.292 ± 0.538	1.797 ± 0.532
C16:1 (Palmitoleic)	0.124 ± 0.078	0.134 ± 0.084	0.103 ± 0.059	0.152 ± 0.053	0.096 ± 0.056
C18:0 (Stearic)	2.528 ± 1.027	2.728 ± 1.211	2.184 ± 1.079	2.926 ± 0.765	2.053 ± 0.448
C18:1 (Oleic)	2.328 ± 1.278	2.484 ± 2.083	1.854 ± 1.199	2.528 ± 0.622	1.522 ± 1.251
C18:2 (Linolelaidic)	0.043 ± 0.020	0.039 ± 0.016	0.037 ± 0.020	0.052 ± 0.030	0.024 ± 0.010
C18:2 (Linoleic)	2.086 ± 0.484	2.340 ± 0.452	1.653 ± 0.636	1.901 ± 0.335	1.797 ± 0.405
C18:3 (g-Linolenic)	0.016 ± 0.003	0.025 ± 0.014	0.026 ± 0.019	0.019 ± 0.004	0.020 ± 0.009
C18:3 (a-Linolenic)	0.351 ± 0.117	0.388 ± 0.115	0.303 ± 0.119	0.383 ± 0.080	0.306 ± 0.059
C20:0 (Arachidic)	0.041 ± 0.025	0.040 ± 0.016	0.038 ± 0.021	0.046 ± 0.019	0.027 ± 0.010
C20:1 (Gondoic)	0.031 ± 0.033	0.026 ± 0.018	0.024 ± 0.013	0.018 ± 0.007	0.022 ± 0.011
C20:2	0.036 ± 0.015	0.042 ± 0.018	0.030 ± 0.017	0.034 ± 0.014	0.038 ± 0.027
C20:3 (Homo-g-Linolenic)	0.130 ± 0.055	0.013 ± 0.038	0.123 ± 0.069	0.131 ± 0.059	0.201 ± 0.215
C20:3	0.867 ± 0.127	0.545 ± 0.381	0.516 ± 0.410	0.626 ± 0.490	0.562 ± 0.458
C20:4 (Arachidonic)	0.042 ± 0.028	0.025 ± 0.012	0.180 ± 0.351	0.312 ± 0.396	0.029 ± 0.033
C20:5 (EPA)	0.223 ± 0.091	0.140 ± 0.076	0.171 ± 0.090	0.175 ± 0.051	0.197 ± 0.123
C22:0 (Behenic)	0.033 ± 0.019	0.027 ± 0.016	0.028 ± 0.024	0.031 ± 0.011	0.123 ± 0.301
C22:1 (Erucic)	0.022 ± 0.006	0.018 ± 0.007	0.028 ± 0.022	0.020 ± 0.004	0.037 ±0.052
C22:2	0.039 ± 0.040	0.031 ± 0.025	0.025 ± 0.018	0.038 ± 0.031	0.030 ± 0.029
C24:0 (Lignoceric)	0.080 ± 0.037	0.072 ± 0.039	0.074 ± 0.033	0.071 ±0.020	0.049 ± 0.019
C22:5 (DPA)	0.138 ± 0.127	0.105 ± 0.112	0.141 ± 0.236	0.092 ± 0.114	0.222 ± 0.216
C22:6 (DHA)	0.070 ± 0.062	0.072 ± 0.078	0.061 ± 0.043	0.052 ± 0.024	0.106 ± 0.152
SFA	5.147 ± 2.225	5.789 ± 2.668	4.534 ± 2.180	5.821 ± 1.289	4.349 ± 1.031
MUFA	2.681 ± 1.378	2.825 ± 2.260	2.184 ± 1.341	2.924 ± 0.726	1.854 ± 1.404
PUFA	4.041 ± 0.745	3.880 ± 0.576	3.266 ± 1.355	3.812 ± 0.621	3.532 ± 0.986
TUFA	6.722 ± 1.872	6.705 ± 2.630	5.451 ± 2.497	6.737 ± 1.226	5.386 ± 1.873
P:S	0.852 ± 0.207	0.766 ± 0.280	0.739 ± 0.169	0.669 ± 0.111	0.841 ± 0.293
PUFA n6	2.317 ± 0.508	2.557 ± 0.506	2.020 ± 0.915	2.414 ± 0.365	2.071 ± 0.431
PUFA n3	1.649 ± 0.276	1.249 ± 0.368	1.191 ± 0.674	1.327 ± 0.575	1.393 ± 0.716
n6:n3	1.406 ± 0.191	2.282 ± 1.130	2.078 ± 1.366	2.276 ± 1.364	1.873 ± 1.114

[a, b, c] Muscles with different superscripts differ significantly (P<0.05) for the specified fatty acids.

Table 6 Mean fatty acid composition (mg/g^{-1} lipid) (± Std. Deviation) of five blesbok muscles.

Fatty acid	*Biceps femoris*	*Longissimus et lumborum*	*Rectus femoris*	*Semitendinosus*	*Supraspinatus*
C14:0 (Myristic)	0.036 ± 0.026	0.060 ± 0.042	0.061 ± 0.041	0.036 ± 0.033	0.103 ± 0.097
C16:0 (Palmitic)	1.201 ± 0.464	1.164 ± 0.625	1.482 ± 0.562	1.291 ± 0.719	1.689 ± 1.145
C16:1 (Palmitoleic)	0.056 ± 0.027	0.061 ± 0.027	0.066 ± 0.034	0.070 ± 0.039	0.083 ± 0.064
C18:0 (Stearic)	1.557 ± 0.511[b]	1.775 ± 0.541[a, b]	1.793 ± 0.625[a, b]	1.599 ± 0.514[b]	2.310 ± 1.345[a]
C18:1 (Oleic)	1.588 ± 1.310	1.834 ± 1.050	1.912 ± 1.080	2.063 ± 1.350	1.928 ± 2.400
C18:2 (Linolelaidic)	0.128 ± 0.329	0.019 ± 0.027	0.012 ± 0.004	0.012 ± 0.004	0.015 ± 0.009
C18:2 (Linoleic)	1.431 ± 0.284	1.524 ± 0.271	1.340 ± 0.172	1.312 ± 0.300	1.423 ± 0.256
C18:3 (g-Linolenic)	0.016 ± 0.009	0.017 ± 0.002	0.014 ± 0.003	0.014 ± 0.005	0.015 ± 0.005
C18:3 (a-Linolenic)	0.486 ± 0.177	0.523 ± 0.113	0.445 ± 0.113	0.440 ± 0.196	0.482 ± 0.145
C20:0 (Arachidic)	0.022 ± 0.005	0.021 ± 0.004	0.022 ± 0.006	0.020 ± 0.005	0.026 ± 0.006
C20:1 (Gondoic)	0.012 ± 0.005	0.010 ± 0.003	0.011 ± 0.003	0.012 ± 0.005	0.011 ± 0.006
C20:2	0.018 ± 0.011	0.014 ± 0.009	0.013 ± 0.007	0.014 ± 0.014	0.015 ± 0.006
C20:3 (Homo-g-Linolenic)	0.062 ± 0.016	0.057 ± 0.013	0.063 ± 0.010	0.058 ± 0.010	0.064 ± 0.007
C20:3	0.371 ± 0.331	0.395 ± 0.284	0.584 ± 0.107	0.450 ± 0.264	0.306 ± 0.279
C20:4 (Arachidonic)	0.193 ± 0.337	0.221 ± 0.350	0.011 ± 0.002	0.071 ± 0.181	0.113 ± 0.264
C20:5 (EPA)	0.164 ± 0.067	0.168 ± 0.044	0.135 ± 0.042	0.148 ± 0.070	0.121 ± 0.035
C22:0 (Behenic)	0.012 ± 0.004	0.011 ± 0.003	0.009 ± 0.007	0.010 ± 0.004	0.097 ± 0.221
C22:1 (Erucic)	0.013 ± 0.004	0.012 ± 0.006	0.012 ± 0.003	0.011 ± 0.006	0.013 ± 0.005
C22:2	0.017 ± 0.010	0.014 ± 0.009	0.010 ± 0.004	0.012 ± 0.006	0.020 ± 0.012
C24:0 (Lignoceric)	0.039 ± 0.010	0.046 ± 0.014	0.043 ± 0.014	0.039 ± 0.010	0.053 ± 0.022
C22:5 (DPA)	0.082 ± 0.082	0.088 ± 0.081	0.030 ± 0.042	0.085 ± 0.078	0.053 ± 0.066
C22:6 (DHA)	0.029 ± 0.017	0.042 ± 0.024	0.034 ± 0.024	0.036 ± 0.031	0.018 ± 0.009
SFA	3.066 ± 1.013	3.231 ± 1.045	3.612 ± 1.267	3.177 ± 1.117	4.420 ± 2.588
MUFA	1.774 ± 1.346	2.011 ± 1.093	2.098 ± 1.138	2.240 ± 1.406	2.163 ± 2.474
PUFA	2.997 ± 0.848	3.083 ± 0.564	2.690 ± 0.435	2.651 ± 0.744	2.644 ± 0.488
TUFA	4.774 ± 1.282	5.094 ± 1.250	4.788 ± 1.173	4.891 ± 1.839	4.807 ± 2.780
P:S	1.074 ± 0.420[a]	1.047 ± 0.363[a, b]	0.827 ± 0.298[a, b]	0.901 ± 0.309[a, b]	0.754 ± 0.341[b]
PUFA n6	1.829 ± 0.794	1.839 ± 0.588	1.440 ± 0.177	1.466 ± 0.371	1.630 ± 0.504
PUFA n3	1.132 ± 0.447	1.217 ± 0.352	1.227 ± 0.269	1.159 ± 0.455	0.979 ± 0.147
n6:n3	1.870 ± 1.206	1.683 ± 0.898	1.205 ± 0.198	1.379 ± 0.501	1.717 ± 0.639

[a, b, c] *Muscles with different superscripts differ significantly (P<0.05) for the specified fatty acids.*

The n-6:n-3 ratio averaged 1.98 (M. biceps femoris lowest and M. longissimus et lumborum highest value) in springbok, and 1.57 (M. rectus femoris lowest and M. biceps femoris highest value) in blesbok, which is much lower than the upper limit of 4.0 of the recommended intake value. Since the n-6:n-3 ratio is calculated by dividing the sum of all the n-6 PUFA by the sum of all the n-3 PUFA present in the sample, these relatively low n-6:n-3 ratios may be explained by the low linoleic acid content observed in all five muscles.

Kroucamp (2004) reported a linoleic acid value of 21.62 ± 1.33% in springbok, while the values found in the present study were lower and lay between 15.30 ± 2.33% (*M. supraspinatus*) and 20.17 ± 4.67% (*M. longissimus et lumborum*). The α-linolenic acid values found in this study (3.01 ± 0.63% - 3.24 ± 0.62%, found in *M. biceps femoris* and *M. semitendinosus* muscles respectively) were very similar to that (3.37 ± 0.29%) reported by Kroucamp (2004). The linoleic acid of blesbok meat ranged from 17.01 ± 4.78% (*M. rectus femoris*) to 19.14 ± 4.78% (*M. biceps femoris*), while the α-linolenic acid values varied between 5.61 ± 1.66% (*M. rectus femoris*) and 6.49 ± 1.49% (*M. longissimus et lumborum*).

In this study, arachidonic acid in springbok meat was observed to be 1.10% (*M. longissimus et lumborum* and *M. supraspinatus*, respectively lowest and highest value), which was much lower than previously reported for springbok meat, while blesbok had an arachidonic acid value of 1.27% (*M. rectus femoris* and *M. longissimus et lumborum*, respectively lowest and highest value). The palmitoleic acid varied from 0.92 ± 0.31% (*M. semitendinosus*) to 1.20 ± 0.31% (*M. supraspinatus*) in springbok, and between 0.69 ± 0.19% (*M. biceps femoris*) and 0.82 ± 0.31% (*M. supraspinatus*), and was higher than previously reported for springbok meat. However, the arachidonic acid percentages observed in this study was still competitive to those reported for other domesticated species and the palmitoleic acid values presented here were much lower than those reported for beef, lamb and pork.

Viljoen (1999) reported that springbok meat contained high levels of arachidonic acid (C20:4), a PUFA capable of lowering serum cholesterol, and that it contained lower palmitoleic acid (C16:1) levels, a PUFA with cholesterol-increasing properties. These claims were confirmed by Kroucamp (2004) who reported an arachidonic acid level of 9.30 ± 0.73% and a palmitoleic acid level of 0.067 ± 0.03% for springbok meat, which was respectively higher and lower than the arachidonic and palmitoleic acid percentages reported by Enser *et al*. (1998) for beef (0.63 ±0.21%; 4.54 ± 0.81%), lamb (0.64 ± 0.23%; 2.20 ± 0.26%) and pork (2.21 ± 0.73%; 2.71 ± 0.45%). This alone may establish game meat as a 'healthier' meat alternative.

The SFA present in the highest quantities were palmitic (1.80 ± 0.53 – 2.52 ± 1.21mg/g^{-1} in springbok, and 1.16 ± 0.63 – 1.69 ± 1.15mg/g^{-1} in blesbok) and stearic (2.05 ± 0.45 – 2.93 ± 0.77mg/g^{-1} in springbok and 1.56 ± 0.51 – 2.31 ± 1.35mg/g^{-1} n blesbok) acids, which was consistent with the findings of other authors (Schönfeldt, 1993; Melanson, Gootman, Myrdal, Kline and Rippe, 2003). The PUFA present in the highest quantities were oleic (C18:1) (1.52 ± 1.25 – 2.53 – 0.62mg/g^{-1} in springbok, and 1.59 ± 1.31 – 2.06 ± 1.35mg/g^{-1} in blesbok)

Table 7 Mean fatty acid composition as a percentage (%) of total fatty acids (± Std. Deviation) of five springbok muscles.

Fatty acid	*Biceps femoris*	*Longissimus et lumborum*	*Rectus femoris*	*Semitendinosus*	*Supraspinatus*
C14:0 (Myristic)	1.148 ± 0.779	1.126 ± 0.731	1.331 ± 0.525	0.776 ± 0.590	1.092 ± 0.537
C16:0 (Palmitic)	17.152 ± 2.065	19.822 ± 2.701	18.388 ± 1.789	18.586 ± 3.309	18.166 ± 1.560
C16:1 (Palmitoleic)	1.008 ± 0.305	0.986 ± 0.296	1.044 ± 0.288	0.918 ± 0.314	1.204 ± 0.312
C18:0 (Stearic)	21.022 ± 2.375	21.865 ± 3.928	21.815 ± 2.002	21.598 ± 3.909	23.107 ± 2.672
C18:1 (Elaidic)	0.549 ± 0.378	0.613 ± 0.446	0.782 ± 0.461	0.522 ± 0.456	0.888 ± 0.597
C18:1 (Oleic)	18.951 ± 4.370	17.506 ± 8.821	18.397 ± 4.075	14.252 ± 10.799	19.961 ± 1.407
C18:2 (Linoleic)	18.156 ± 2.978 [a, b]	20.169 ± 4.670 [a]	17.150 ± 3.131 [a, b]	19.009 ± 4.192 [a]	15.303 ± 2.327 [b]
C18:3 (g-Linolenic)	0.145 ± 0.050	0.211 ± 0.125	0.269 ± 0.180	0.209 ± 0.095	0.150 ± 0.039
C18:3 (a-Linolenic)	3.007 ± 0.634	3.235 ± 0.544	3.146 ± 0.499	3.239 ± 0.622	3.101 ± 0.653
C20:0 (Arachidic)	0.338 ± 0.135	0.352 ± 0.159	0.398 ± 0.141	0.277 ± 0.053	0.351 ± 0.085
C20:1 (Gondoic)	0.295 ± 0.361	0.204 ± 0.099	0.237 ± 0.097	0.223 ± 0.087	0.142 ± 0.042
C20:2	0.326 ± 0.167	0.348 ± 0.095	0.298 ± 0.105	0.368 ± 0.199	0.259 ± 0.072
C20:3 (Homo-g-Linolenic)	1.201 ± 0.658	1.097 ± 0.358	1.211 ± 0.530	1.937 ± 1.588	1.041 ± 0.370
C20:3	7.693 ± 1.478	4.985 ± 3.425	5.329 ± 3.401	5.620 ± 4.201	4.525 ± 3.508
C20:4 (Arachidonic)	0.362 ± 0.261	0.203 ± 0.075	1.549 ± 2.727	0.326 ± 0.418	3.058 ± 4.113
C20:5 (EPA)	2.031 ± 0.980	1.316 ± 0.796	1.658 ± 0.652	2.115 ± 1.365	1.464 ± 0.589
C22:0 (Behenic)	0.302 ± 0.217	0.223 ± 0.137	0.280 ± 0.191	1.539 ± 3.883	0.245 ± 0.073
C22:1 (Erucic)	0.199 ± 0.072	0.150 ± 0.050	0.260 ± 0.143	0.355 ± 0.400	0.160 ± 0.041
C22:2	0.357 ± 0.375	0.258 ± 0.189	0.256 ± 0.092	0.285 ± 0.207	0.295 ± 0.210
C24:0 (Lignoceric)	0.729 ± 0.390	0.589 ± 0.243	0.745 ± 0.226	0.529 ± 0.220	0.571 ± 0.132
C22:5 (DPA)	1.286 ± 1.208	1.137 ± 1.398	1.262 ± 2.233	2.487 ± 2.468	0.665 ± 0.806
C22:6 (DHA)	0.683 ± 0.749	0.808 ± 1.213	0.585 ± 0.402	1.091 ± 1.640	0.449 ± 0.298
SFA	42.451 ± 3.434	45.816 ± 6.137	45.278 ± 2.808	45.564 ± 8.133	46.208 ± 2.387
MUFA	21.945 ± 4.146	20.099 ± 8.904	21.650 ± 4.008	17.499 ± 11.110	23.079 ± 1.823
PUFA	35.604 ± 6.650	34.086 ± 9.302	33.072 ± 5.905	36.937 ± 8.516	30.714 ± 3.707
TUFA	57.549 ± 3.434	54.184 ± 6.137	54.722 ± 2.808	54.436 ± 8.133	53.793 ± 2.387
P:S	0.852 ± 0.207	0.766 ± 0.280	0.739 ± 0.169	0.841 ± 0.293	0.669 ± 0.111
PUFA n6	20.221 ± 3.365	22.000 ± 4.988	20.538 ± 4.757	21.731 ± 3.930	19.955 ± 5.439
PUFA n3	14.700 ± 3.351	11.481 ± 5.105	11.980 ± 4.457	14.553 ± 6.754	10.204 ± 3.191
N6:n3	1.406 ± 0.191	2.282 ± 1.130	2.078 ± 1.366	1.873 ± 1.114	2.276 ± 1.364

[a, b, c] Muscles with different superscripts differ significantly (P<0.05) for the specified fatty acid.

Table 8 Mean fatty acid composition (%) (± Std. Deviation) of five blesbok muscles.

Fatty acid	*Biceps femoris*	*Longissimus et lumborum*	*Rectus femoris*	*Semitendinosus*	*Supraspinatus*
C14:0 (Myristic)	0.440 ± 0.258	0.732 ± 0.462	0.686 ± 0.355	0.447 ± 0.265	0.983 ± 0.776
C16:0 (Palmitic)	15.061 ± 2.642	13.602 ± 6.101	17.315 ± 2.204	15.819 ± 5.616	17.393 ± 3.736
C16:1 (Palmitoleic)	0.692 ± 0.187	0.712 ± 0.214	0.745 ± 0.210	0.813 ± 0.242	0.818 ± 0.307
C18:0 (Stearic)	19.709 ± 2.338 [b]	21.142 ± 2.017 [b]	21.230 ± 2.806 [b]	20.092 ± 2.029 [b]	25.013 ± 4.218 [a]
C18:1 (Elaidic)	0.691 ± 0.502	0.623 ± 0.543	0.496 ± 0.524	0.433 ± 0.380	1.003 ± 0.996
C18:1 (Oleic)	18.429 ± 11.658	20.766 ± 8.205	21.194 ± 7.014	23.230 ± 8.934	15.806 ± 12.936
C18:2 (Linolelaidic)	1.706 ± 4.405	0.267 ± 0.428	0.138 ± 0.034	0.156 ± 0.064	0.182 ± 0.075
C18:2 (Linoleic)	19.138 ± 4.782	19.004 ± 4.307	17.006 ± 4.776	17.431 ± 4.776	18.362 ± 6.419
C18:3 (g-Linolenic)	0.201 ± 0.096	0.215 ± 0.040	0.174 ± 0.037	0.182 ± 0.049	0.186 ± 0.055
C18:3 (a-Linolenic)	6.447 ± 2.214	6.494 ± 1.488	5.606 ± 1.663	5.574 ± 1.990	5.962 ± 1.811
C20:0 (Arachidic)	0.284 ± 0.057	0.268 ± 0.089	0.280 ± 0.094	0.260 ± 0.059	0.321 ± 0.101
C20:1 (Gondoic)	0.158 ± 0.038	0.127 ± 0.031	0.135 ± 0.026	0.149 ± 0.032	0.125 ± 0.059
C20:2	0.233 ± 0.136	0.157 ± 0.068	0.151 ± 0.058	0.187 ± 0.169	0.197 ± 0.102
C20:3 (Homo-g-Linolenic)	0.841 ± 0.284	0.717 ± 0.223	0.816 ± 0.284	0.785 ± 0.252	0.869 ± 0.371
C20:3	5.673 ± 5.517	5.235 ± 4.301	7.465 ± 2.270	6.305 ± 3.931	4.797 ± 5.423
C20:4 (Arachidonic)	2.103 ± 3.743	2.527 ± 3.872	0.136 ± 0.045	0.756 ± 1.822	0.827 ± 1.725
C20:5 (EPA)	2.251 ± 1.013	2.128 ± 0.702	1.721 ± 0.662	1.897 ± 0.829	1.577 ± 0.597
C22:0 (Behenic)	0.163 ± 0.052	0.138 ± 0.040	0.105 ± 0.087	0.130 ± 0.060	1.232 ± 2.810
C22:1 (Erucic)	0.176 ± 0.049	0.154 ± 0.095	0.151 ± 0.062	0.129 ± 0.067	0.167 ± 0.076
C22:2	0.234 ± 0.146	1.180 ± 0.116	0.127 ± 0.042	0.149 ± 0.060	0.252 ± 0.146
C24:0 (Lignoceric)	0.524 ± 0.170	0.552 ± 0.101	0.532 ± 0.148	0.527 ± 0.214	0.665 ± 0.323
C22:5 (DPA)	1.254 ± 1.261	1.188 ± 1.128	0.454 ± 0.765	1.021 ± 0.936	0.684 ± 0.861
C22:6 (DHA)	0.433 ± 0.351	0.538 ± 0.308	0.418 ± 0.309	0.452 ± 0.366	0.230 ± 0.134
SFA	38.698 ± 3.501 [b]	38.453 ± 5.815 [b]	42.413 ± 3.693 [a, b]	39.704 ± 4.359 [b]	47.466 ± 8.845 [a]
MUFA	20.787 ± 11.461	22.897 ± 8.276	23.375 ± 7.087	25.404 ± 8.966	18.409 ± 12.264
PUFA	40.515 ± 13.954	38.650 ± 9.718	34.212 ± 10.092	34.892 ± 9.665	34.125 ± 11.909
TUFA	61.302 ± 3.501 [a]	61.547 ± 5.815 [a]	57.587 ± 3.693 [a, b]	60.296 ± 4.359 [a]	52.534 ± 8.845 [b]
P:S	1.074 ± 0.420 [a]	1.047 ± 0.362 [a, b]	0.827 ± 0.298 [a, b]	0.901 ± 0.309 [a, b]	0.754 ± 0.341 [b]
PUFA n6	23.990 ± 9.787	22.730 ± 6.926	18.269 ± 5.083	19.309 ± 4.929	20.426 ± 6.403
PUFA n3	16.058 ± 8.545	15.583 ± 6.054	15.665 ± 5.141	15.248 ± 5.602	13.250 ± 6.322
n6:n3	1.870 ± 1.206	1.683 ± 0.898	1.205 ± 0.198	1.379 ± 0.501	1.717 ± 0.639

[a, b, c] Muscles with different superscripts differ significantly (P<0.05) for the specified fatty acids.

and linoleic (1.65 ± 0.64 – 2.34 ± 0.45 mg/g^{-1} in springbok, and 1.31 ± 0.30 – 1.52 ± 0.27 mg/g^{-1} in blesbok) acids.

Schönfeldt (1993) reported that a decrease in cardiovascular disease risk could be manipulated by decreasing the dietary intake of saturated fatty acids (SFA), especially myristic (C14:0) and palmitic (C16:0) acid, as this results in lower blood serum cholesterol levels. These two SFA are usually responsible for increasing cholesterol levels, with myristic acid having four times the cholesterol-raising potential of palmitic acid (Higgs, 2000). Only minor amounts of myristic acid are present in meat (Higgs, 2000). The main SFA found in meat are palmitic and stearic (C18:0) acid (Schönfeldt, 1993; Melanson *et al*., 2003), but stearic acid is viewed as a neutral fatty acid and does not display any cholesterol elevating effects.

Muscle types also differ in fatty acid composition, with red oxidative muscles (e.g. *M. semitendinosus*) having higher levels of PUFA than muscles with predominantly white muscle fibres, such as the *M. longissimus dorsi* (Lengyel *et al*., 2003). Enser *et al.* (1998) explain these differences by pointing out the differences in the phospholipid concentration between the two muscle types; red oxidative muscles have higher phospholipid concentrations.

Although the five muscles investigated did differ slightly in terms of its fatty acid profile, there were no significant differences found between any of the springbok muscles when the fatty acid content (in mg/g^{-1}) was examined, but for blesbok muscles significant ($P<0.05$) differences were found between the muscles for stearic acid content and the P:S ratio. However, significant differences between springbok muscles were found when the fatty acids were investigated as a percentage of the total fatty acids, but only where linoleic acid (C18:2) was concerned. When the blesbok fatty acid profile was investigated as a percentage of the total fatty acids, differences between muscles were found for stearic acid, total SFA content, total unsaturated fatty acid (TUFA) content and P:S ratio.

As far as the fatty acid profile is concerned, the five springbok and blesbok muscles investigated in this study are pretty much equally matched.

4. Conclusion

Enhancing springbok and blesbok muscles with an inorganic salt solution significantly improved the moisture content of most muscles, except for the springbok *M. supraspinatus* and blesbok *M. biceps femoris* and *M. longissimus et lumborum*. This will probably lead to improved juiciness at consumption, which is exactly what the consumer desires. Ash percentage was significantly affected in all muscles, mainly due to the additional minerals the injected solution delivered to the enhanced muscles. Fat and protein percentages were lower in the enhanced muscles, but that might be due to a dilution-effect caused by the higher amount of moisture present in those muscles.

Potassium and sodium were significantly higher in the enhanced springbok muscles, while phosphorus, as well as potassium and sodium, were significantly higher in the enhanced blesbok muscles. Magnesium was significantly lower in most of the untreated

muscles as compared to the enhanced muscles in both species. The mineral differences between treatments were directly caused by the addition of the inorganic salt solution used to enhance the meat.

Overall, the fatty acid profile for the five muscles investigated in this study, correlates well with the results found in previous studies conducted on game species and compares favourably with the fatty acid profiles of other (domesticated) meat species.

5. References

AOAC. (1997). *Official Methods of Analysis*. 15th ed. Arlington, VA. USA: Association of Official Analytical Chemists.

Baublits, R.T., Pohlman, F.W., Brown Jr., A.H. & Johnson, Z.B. (2005). Effects of sodium chloride, phosphate type and concentration, and pump rate on beef *biceps femoris* quality and sensory characteristics. *Meat Science* 70, 205-214.

Chizzolini, R., Zanardi, E., Dorigoni, V. & Ghidini, S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. *Trends in Food Science and Technology* 10, 119-128.

Committee on Medical Aspects of Food Policy (1984). 'Diet and Cardiovascular Disease. *Report on Health and social subjects*, Department of Health and Social Security, No. 28, HMSO, London.

Conroy, A.M. & Gaigher, I.G. (1982). Venison, Aquaculture and ostrich meat production: Action 2003. *South African Journal of Animal Science* 2, 219-233.

Deatherage, F.E. (1963). The effect of water and inorganic salts on tenderness. In *Proceedings meat tenderness symposium* (pp. 45-68). Camden: Campbell Soup Company.

Department of Health. (1994). Department of Health, Nutritional Aspects of Cardiovascular Disease. In: *Report on Health and Social Subjects no. 46*, HMSO, London.

Elliot, J. (1993). Farmed Venison, the new meat comes of age. *Nutrition and Food Science* 26-29.

Enser, M., Hallett, K., Hewett, B., Fursey, G.A.J., Wood, J.D. & Harrington, G. (1998). Fatty acid composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. *Meat Science* 49, 329-341.

Folch, J., Lees, M. & Sloane-Stanley, G.H. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry* 226, 495-509.

Gibney, M.J. & Hunter, B. (1993). The effects of short- and long-term supplementation with fish oil on incorporation of n-3 polyunsaturated fatty acids into cells of the immune system in health volunteers. *European Journal of Clinical Nutrition* 47, 255-259.

Higgs, J.D. (2000). The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science and Technology* 11, 85-95.

Hoffman, L.C. (2000). Meat quality attributes of night-cropped impala (*Aepyceros melampus*). *SA Journal of Animal Science* 30, 133-137.

Hoffman, L.C., Muller, M., Schutte, De W., Calitz, F.J. & Crafford, K. (2005). Consumer expectations, perceptions and purchasing of South African game meat. *South African Journal of Wildlife Research* 35, 33-42.

Hoffman, L.C., Muller, M., Schutte, De W. & Crafford, K. (2004). Retail of South African game meat: current trade and marketing trends. *South African Journal of Wildlife Research* 34, 123-134.

Jeremiah, L.E., Dugan, M.E.R., Aalhus, J.L. & Gibson, L.L. (2003). Assessment of the relationship between chemical and components and palatability of major beef muscles and muscle groups. *Meat Science* 65 1013-1019.

Jeremiah, L.E., Smith, G.C. & Carpenter, Z.L. (1971). Palatability of individual muscles from ovine leg steaks as related to chronological age and marbling. *Journal of Food Science* 35, 45-47.

Kroucamp, M. (2004). Meat quality characteristics of the springbok (*Antidorcas marsupialis*). M. Sc. (Foods). Department of Food Science. University of Stellenbosch, Stellenbosch.

Lawrie, R.A. (1998). *Lawrie's Meat Science* (6th ed.). Cambridge, England: Woodhead Publishing Ltd.

Lee, C.M., Trevino, B. & Chaiyawat, M. (1996). A simple and rapid solvent extraction method for determining total lipids in fish tissue. *Journal of AOAC International* 79, 487-492.

Lengyel, Z., Husvèth, F., Polgar, P., Szabo, F. & Magyar, L. (2003). Fatty acid composition of intramuscular lipids in various muscles of Holstein-Friesian bulls slaughtered at different ages. *Meat Science* 65, 593-598.

Lewis, A.R., Pinchin, A.M. & Kestin, S.C. (1997). Welfare implications of the night shooting of wild impala (*Aepyceros melampus*). *Animal Welfare* 6, 123-131.

MacRae, J., O'Reilly, L. & Morgan, P. (2005). Desirable characteristics of animal products from a human health perspective. *Livestock Production Science* 94, 95-103.

Melanson, K., Gootman, J., Myrdal, A., Kline, G. & Rippe, J. (2003). Weight loss and total lipid profile changes in overweight women consuming beef or chicken as the primary protein source. *Nutrition* 19, 409-414.

Nelson, G.J., Schmidt, P.C. & Kelley, D.S. (1995). Low-fat diets do not lower plasma cholesterol levels in healthy men compared to high-fat diets with similar fatty acid composition and constant caloric intake. *Lipids* 30, 969-976.

Niemenin, M. (1992). Meat production and chemical composition of reindeer meat. *Proceedings of the 3rd International Wildlife Ranching Symposium*, Pretoria, South Africa.

Offer, G. & Trinick, J. (1983). On the mechanism of water holding in meat: The swelling and shrinking of myofibrils. *Meat Science* 4, 245-281.

Olsson, U., Hertzman, C. & Tornberg, E. (1994). The influence of low temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. *Meat Science* 37, 115-131.

Papadopoulos, L.S., Miller, R.K., Ringer, L.J. & Cross, H.R. (1991). Sodium lactate effect on sensory characteristics, cooked meat colour and chemical composition. *Journal of Food Science* 56, 621-626.

Pauw, J. (1993). The development of venison marketing. In *Forum: The venison industry. Research requirements and possibilities* (pp.3-5). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Pinta, M. (1982). Modern methods for trace element analysis (3rd ed.). Ann Arbor, MI, USA: Ann Arbor Science.

Prestat, C., Jensen, J., McKeith, F.K. & Brewer, M.S. (2002). Cooking methods and endpoint temperature effects on sensory and colour characteristics of pumped pork loin chops. *Meat Science* 60, 395-400.

Sales, J. (1995). Nutritional quality of meat from some alternative species. *World review of Animal Production* 30, 47-56.

SAS (1999). *SAS/STAT User's Guide*, Version 8 (Volume II). SAS Institute Inc., North Carolina.

Sayed, N., Frans, Y. & Schönfeldt, H.C. (1999). *Composition of South African foods*. Parow: Medical Research Council.

Scanga, J.A., Delmore Jr., R.J., Ames, R.P., Belk, K.E., Tatum, J.D. & Smith, G.C. (2000). Palatability of beef steaks marinated with solutions of calcium chloride, phosphate, and (or) beef-flavouring. *Meat Science* 55, 397-401.

Schönfeldt, H. (1993). Nutritional content of venison. In *Forum: The venison industry. Research requirements and possibilities* (pp. 51-60). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Shackelford, S.D., Wheeler, T.L. & Koohmaraie, M. (1995). Relationship between shear force and trained sensory panel tenderness ratings of 10 major muscles from *Bos indicus* and *Bos taurus* cattle. *Journal of Animal Science* 73, 3333-3340.

Smit, K. (2004). Meat quality characteristics of blesbok (*Damaliscus dorcas phillipsi*) and red hartebeest (*Alcelaphus buselaphus caama*) meat. M. Consumer Sc. (Food) thesis. Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Takahashi, K., Kim, O.H. & Yano, K. (1987). Calcium-induced weakening of Z-discs in post mortem skeletal muscle. *Journal of Biochemistry* 101, 767-773.

Thomas, A.R., Gondoza, H., Hoffman, L.C., Oosthuizen, V. & Naudè, R.J. (2004). The roles of the proteasome, and cathepsins B,L,H and D, in ostrich meat tenderisation. *Meat Science* 67, 113-120.

Van Schalkwyk, S. (2004). Meat quality characteristics of three South African game species: Black wildebeest (*Connochaetes gnou*), Blue wildebeest (*Connochaetes taurinus*) and Mountain reedbuck (*Redunca fulvorufula*). M. Sc. Cons. (Foods). Department of Consumer Science. University of Stellenbosch, Stellenbosch.

Van Zyl, L. & Ferreira, A.V. (2004). Physical and chemical carcass composition of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*). *Small Ruminant Research* 53, 103-109.

Varnam, A.H. & Sutherland, J.P. (1995). *Meat and meat products, technology, chemistry and microbiology*. London: Chapman & Hall. Pp. 57-76.

Viljoen, J.J. (1999). 'n Vergelyking van die lipiedkomponente van springbokvleis met die van beesvleis en die verwante belangrikheid vir aspekte van die menslike gesondheid. *SA Tydskrif vir Natuurwetenskap enTegnologie* 18, 51-53.

Von la Chevallerie, M. (1972). Meat quality of seven wild ungulate species. *South African Journal of Animal Science* 2, 101-103.

Wheeler, T.L., Koohmaraie, M. & Shackelford, S.D. (1997). Effect of post-mortem injection time and post-injection ageing time on the calcium-activated tenderisation process in beef. *Journal of Animal Science* 75, 2652-2660.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R. & Enser, M. (2004). Effects of fatty acids on meat quality: a review. *Meat Science* 66, 21-32.

Young, O.A., Frost, D.A., West, J. & Braggins, T. (2001). Analytical methods. In: Hui, Nip, Rogers & Young (Eds). *Meat Science and applications* (pp. 103-126). Marcel Dekker, New York.

Chapter 5

Analytical sensory evaluation of two springbok (*Antidorcas marsupialis*) and blesbok (*Damaliscus dorcas phillipsi*) muscles after injection with an inorganic salt mixture

Abstract

The effect of inorganic salt enhancement on the sensory quality of springbok and blesbok *M. biceps femoris* and *M. longissimus et lumborum* were investigated. The springbok (n=10) and blesbok (n=10) originated from the Gariep Nature Reserve in South Africa. The sensory characteristics evaluated by the experienced analytical panel (n=7) were aroma intensity, initial juiciness, sustained juiciness, tenderness at first bite, residue, overall flavour, and saltiness. In both species and both muscles, intensity of aroma was not significantly different between treatments. The overall flavour of the springbok samples did not differ significantly between treatments, although the overall flavour of the enhanced samples were lower than the untreated samples. The overall flavour of enhanced blesbok muscles was significantly lower than the untreated samples. Furthermore, the characteristics valued most by consumers, namely tenderness (tenderness at first bite and residue) and juiciness (initial and sustained juiciness) were positively influenced by inorganic salt enhancement. In most cases the enhanced samples were more tender and juicy than the untreated samples, with exceptions being initial juiciness and residue of the springbok *M. biceps femoris*, and initial juiciness of the blesbok *M. longissimus et lumborum* and *M. biceps femoris*. The characteristic 'saltiness' was added to the list of attributes evaluated because of the addition of various salts caused by the enhancement solution. Although there was a highly significant difference between treatments concerning salty taste, the enhanced samples were still well within the acceptable range, with values ranging between 2 (practically no salt) and 4 (very little salt). Enhancing game meat holds definite advantages in regards to improving its eating quality.

Key words: Springbok, Blesbok, Game meat, Meat enhancement, Injected meat, Eating quality, Sensory characteristics

1. Introduction

Since the 1980's red meat has been vilified in terms of its impact on human health. The British Government's Committee on Medical Aspects of Food and Nutrition (COMA, 1984) linked meat, a major source of saturated fatty acids according to their report, to coronary heart disease. Many consumers believe that red meat is unsuited for a balanced, weight-loss diet because of its association with obesity (Melanson, Gootman, Myrdal, Kline and Rippe, 2003). This view has been fuelled by reports that dietary fat and saturated fat intake were primarily responsible for obesity and therefore, it has been recommend that red

meat intake should be limited or completely eliminated. Another nail in the red meat consumption coffin was its cholesterol content. No matter what scientific evidence suggests, consumers associate meat with cholesterol and because serum cholesterol has been erroneously associated with chronic heart disease, most consumers still link red meat intake with increased cholesterol consumption and increased heart disease risk (Higgs, 2000). Since the surfacing of all these different reports, there has been a general decline in red meat consumption in favour of "safer" food sources such as chicken and plant proteins.

In their survey of 300 South African consumers, Hoffman, Muller, Schutte and Crafford (2004) found fat content to be the most important quality considered by consumers when purchasing meat. According to Chizzolini, Zanardi, Dorigoni and Ghidini (1999) nutritional guidelines dictate that dietary fat should provide 15-30% of the total calorie-intake and saturated fats should be limited to less than 10% of the caloric intake. It is also suggested that cholesterol-intake should not be in excess of 300mg per day. However, fatty acid composition, especially the ratio of polyunsaturated to saturated fatty acids, has been shown to be more important for health reasons than total fat content (Higgs, 2000; Chizzolini *et al*., 2003).

It was found that the springbok meat had a total fat content of 1.80% (enhanced) and 2.14% (untreated), and blesbok meat had a total fat content of 1.86% (enhanced) and 2.21% (untreated) (Chapter 4). These results compare very well with the fat contents of several meat species. For example, McCane and Widdowson (1991, as referenced by Elliot, 1993) reported the following fat values: Venison roast, 6.4g/100g; Beef roast, 12.0g/100g; Lamb roast, 17.9g/100g; Pork roast, 26.9g/100g; Skin-on chicken roast, 14.0g/100g, and Chicken meat (skinless), 5.4g/100g. From this data it is clear that venison can definitely compete with chicken when fat content is considered. Several South African game species have been found to have even lower fat contents than the 5.4g/100g that McCane and Widdowson (1991, as cited by Elliot, 1993) contributed to European venison. Several authors have reported game species to have fat contents less than 3.0g/100g (Kroon, Van Rensburg and Hofmeyr, 1972; Von la Chevallerie, 1972; Schönfeldt, 1993; Pauw, 1993; Hoffman, 2000). Schönfeldt (1993) stated that game meat had higher levels of polyunsaturated fatty acids and lower saturated fat contents than beef and this view has been confirmed by other authors (Viljoen, 1999; Hoffman, 2000). Therefore, game meat can be considered a "healthier" red meat because of its low fat and cholesterol contents and its beneficial fatty acid composition.

Game meat image has suffered in the past because of ignorance. Consumers are ill informed about the potential health benefits of game meat and are left in the dark as to proper preparation methods (Webb, 2001; Hoffman *et al*., 2004). Consumers often end up with "tough, dry and chewy" meat because of incorrect preparation and cooking techniques (Webb, 2001) and in addition, game meat quality is generally perceived as irregular (Bronkhorst, 2005).

Sensory analysis is a valuable tool in testing the different characteristics of a product (Lawless and Heymann, 1998). Moskowitz (1984) stated the following about trained taste

panellists: "…experts, by their very nature can better communicate nuances of the products that might totally escape the consumer". However, this author cautioned the exclusive use of analytical sensory panels by stating: "…consumers represent the target population. If a consumer does not perceive differences between products where an expert does, this simply means that the perceived difference do not amount to a relevant distinction." Analytical sensory evaluation of products is very important, but there is a difference between the findings of the trained taste panel and the preferences of the consumer. There is almost no data available on the sensory analysis of game meat, therefore, the data gathered in this study, may fill a part of the hole left in the game meat information currently available.

The aim of this study was to investigate the possible improvements to the eating quality of springbok and blesbok meat after enhancement with an inorganic salt mixture. Springbok and blesbok were chosen because these are two of the most common game species favoured by game farmers in South Africa (Conroy and Gaigher, 1982). Springbok was found to be the game species most often consumed by South African consumers (Hoffman, Muller, Schutte, Calitz and Crafford, 2005) and springbok was one of the three game meat species regularly available in South African supermarkets and restaurants (Hoffman *et al*., 2004).

2. Materials and Methods

2.1. Animals and sampling

Ten springbok (*Antidorcas marsupialis*) and ten blesbok (*Damaliscus dorcas phillipsi*) were randomly harvested at the Gariep Nature Reserve in the Free State Province. All animals were male and carcass weight varied between 17.4 kg and 30.4 kg for springbok, and 16.4 kg and 42.2 kg for blesbok. Animals were harvested at night by a professional cull team, using similar culling methods to those described by Lewis, Pinchin and Kestin (1997), and only head or neck shots were taken. Animals were exsanguinated within 5 minutes of harvesting and together with the culling methods used, this resulted in animals being exposed to minimal stress conditions. Carcasses were hung by the Achilles tendon. Bled and eviscerated skin-on carcasses were transported to Stellenbosch, in a temperature-controlled vehicle, where they were skinned and processed further approximately 24 h after harvesting.

The left halves of the springbok carcasses were injected with an inorganic salt solution (Freddy Hirsch Tenderbite #802539; P.O. Box 2554, Cape Town, 8000) with a chemical composition of sodium (5.21%) and potassium (2.53%) di- and triphosphates (3.45%), lactate (12.40%) and water (75.75%) to give a pumped gain of 20%, with a retention level of approximately 15%. Injection was performed at a pressure of 2.4 bar at 30 strokes per minute on a Rühle Curing Centre IR56 (Rühl GmbH, D-79865, Grafenhausen, Germany). After injection, the right and left side *M. biceps femoris* and *M. longissimus et lumborum* of each springbok carcass were removed. For the blesbok this procedure differed slightly because the blesbok carcass halves were too large to fit into the curing centre: the *M. biceps femoris* and *M. longissimus et lumborum* of each carcass were removed first and the whole

left hand muscles were injected with the same solution in the same manner as the halved springbok carcasses. Although these game species seldom have any visible fat, all visible carcass fat and connective tissue were removed from the muscles. The right hand samples served as the controls. All samples were individually vacuum-packed and frozen at -20 ºC until analysed further.

2.2. Descriptive sensory analysis

Seven panellists made up the descriptive analytical sensory panel. Five of the seven panellists had been part of a regular meat analysis group for over two years, while the other two were fairly new to meat analysis, having only been involved for approximately a month. The two new panellists were properly screened and tested for their sensitivity in the taste panel environment before they were included in the taste panel. The panel received two hours of training on treated (injected) and untreated *M. biceps femoris* and *M. longissimus et lumborum* on the first two days of the tasting programme of each species. Thereafter, a test-retest-session was held at the first session of the tasting programme to test each panellist's sensitivity and repeatability and to confirm that the panel understood the parameters set for each characteristic tested. There was a rest period of a week after the conclusion of the springbok tasting programme before the blesbok tasting programme started.

Left and right *M. biceps femoris* and *M. longissimus et lumborum* were defrosted at 3ºC for 24 h prior to the sensory evaluation. Whole muscles were roasted in two conventional electric Defy 835 ovens connected to a computerised electronic temperature control system (Viljoen, Muller, de Swart, Sadie and Vosloo, 2001) by means of high velocity, forced-air convection. Samples were placed on foil-wrapped roasting pans inside individual cooking bags. The American Meat Science Association (AMSA, 1995) recommends that samples be removed at about 5ºC below the desired internal temperature, which is 71ºC. After removal, the samples were allowed to cool for 5 minutes before being cut into 2 cm cubes. Cubed samples were individually wrapped in aluminium foil squares and coded. All surface areas of the meat exposed to the cooking environment were removed before the samples were cubed. The samples were reheated at 100ºC 10 minutes prior to the start of evaluation.

Panellists were seated in individual cubicles in a temperature-light-controlled room. Each panellist received crackers, apple slices and distilled water to use as palate cleansers between samples. For each species, panellists received two sets of four randomised samples over five days. The basic 8-point hedonic questionnaire ascribed by AMSA (1995) was used, but was changed slightly to better suit the purpose of the investigation and the characteristic "salty taste" was added (Table 1). For blesbok evaluation, 'Springbok' was just substituted with 'Blesbok'.

Table 1 Questionnaire used during analytical sensory evaluation of Springbok *M. biceps femoris* and *M. longissimus et lumborum* samples.

Sensory attribute	Explanation of attribute	Scale used
Springbok aroma intensity	Take a few short sniffs as soon as you remove the foil	8 Extremely intense 1 Extremely bland
Initial impression of juiciness	The amount of fluid exuded on the cut surface when pressed between your thumb and forefinger	8 Extremely juicy 1 Extremely dry
Sustained juiciness	The impression that you form after the first two to three chews between the molar teeth	8 Extremely juicy 1 Extremely dry
First bite	The impression of tenderness after the first two to three chews between the molar teeth	8 Extremely tender 1 Extremely tough
Residue	The amount of residue left in the mouth after the first twenty to thirty chews.	8 None 1 Abundant
Overall springbok flavour	This is a combination of taste and swallowing.	8 Extremely typical 1 Extremely untypical
Salty taste	Taste on the tongue associated with sodium ions.	8 Extremely salty 1 No salty taste

2.3. Statistical analysis

The standard GLM Procedure was not used when sensory data was analysed because the data was not normally distributed (SAS, 1999). Large proportions of the variation in the data could be attributed to panellist and animal effects. Therefore, the Mixed Procedure (SAS, 1999) was used for data analysis and both judge and animal were included in the model as random variables, which effectively removed their contributions to total variation.

3. Results and discussion

For all characteristics analysed, except saltiness, a higher value depicts a better score. For saltiness the opposite is true, with higher values indicating a saltier taste, which can be a detrimental factor in overall acceptability of the meat. Overall it was found that enhancing the meat of both species improved the eating quality of the meat and the quality characteristics most valued by consumers (tenderness and juiciness) were definitely improved by enhancement with the inorganic salt solution.

The results of the analytical sensory panels of the springbok *M. longissimus et lumborum* (Table 2) indicated significant differences ($P<0.05$) between treatments for the

majority of characteristics analysed, with only aroma intensity and overall flavour not differing significantly. The results of the *M. biceps femoris* showed that initial juiciness and residue, along with aroma intensity and overall flavour were not significantly different (P>0.05) between treatments. Overall flavour tended towards differing significantly (P=0.0988). The fact that springbok aroma intensity and overall flavour did not differ much between treatments is encouraging since it suggests that the inorganic salts used to enhance the meat did not alter the aroma or flavour properties of the meat. The enhanced samples received slightly lower scores for overall flavour, but it was given a slightly higher aroma intensity rating than the control samples. This is in direct opposition with results presented by Hoffman (2006) where the author found inorganic salt enhancement significantly affected the aroma of *M. longissimus et lumborum* and *M. semitendinosus* of mature cows, lowering the aroma intensity of enhanced samples. The contradicting results may be ascribed to the fact that game meat naturally has a stronger aroma than beef.

Table 2 Least squared means for the sensory characteristics of the springbok *M. biceps femoris* and *M. longissimus et lumborum* as evaluated by an analytical sensory panel.

Characteristic	Enhanced	Not enhanced	SEM	P-value
Longissimus et lumborum				
Aroma intensity	6.543	6.386	0.285	0.2082
Initial juiciness	7.114	6.771	0.170	0.0016
Sustained juiciness	6.800	5.586	0.271	<0.0001
Tenderness at first bite	7.643	6.857	0.186	<0.0001
Residue	7.729	7.271	0.203	<0.0001
Overall flavour	6.314	6.457	0.237	0.2039
Saltiness	3.129	1.514	0.188	<0.0001
Biceps femoris				
Aroma intensity	6.214	6.157	0.289	0.6205
Initial juiciness	6.629	6.543	0.160	0.4335
Sustained juiciness	6.443	5.843	0.220	<0.0001
Tenderness at first bite	6.829	6.457	0.258	0.0019
Residue	7.229	7.186	0.236	0.6546
Overall flavour	6.400	6.543	0.153	0.0988
Saltiness	2.729	1.429	0.189	<0.0001

The results of the analytical evaluation for blesbok *M. longissimus et lumborum* and *M. biceps femoris* showed that only aroma intensity and initial juiciness, although higher in the enhanced samples, did not differ significantly (P>0.05) between treatments (Table 3). The overall flavour of blesbok meat was significantly (P>0.05) higher in the untreated samples, showing that enhancement may adversely affect some flavour properties. Lawrence, Dikeman, Hunt, Kastner and Johnson (2003) found that adding phosphates to meat lowered

the flavour intensity and Scanga, Delmore Jr., Ames, Belk, Tatum and Smith (2000) reported that calcium chloride- or lactic acid-injection could cause sour and bitter flavours in meat.

Game meat is generally perceived as being less succulent than beef because of its low fat content (Von la Chevallerie, 1972). Warriss (2000) explained that the water remaining after cooking is responsible for the juiciness of meat and that lipids have only a small role in juiciness, mainly acting as lubrication. The highly significant (P<0.0001) differences found for sustained juiciness for all springbok and blesbok muscles is very encouraging. It shows that inorganic salt enhancement has the propensity to ensure juicier game meat. Sustained juiciness refers to the amount of moisture remaining in meat after cooking and is thus more important than initial juiciness in terms of the overall perception the consumer will form of the juiciness of the meat. The reason behind the improved juiciness of the enhanced samples lie in its moisture contents. The moisture contents of the enhanced samples of both muscles were significantly higher (P>0.01) than the untreated samples in both species (Chapter 4), with moisture values of 74.75 ± 1.61% vs. 72.16 ± 1.68%, for enhanced vs. untreated *M. longissimus et lumborum*; and 75.27 ± 1.15% vs. 74.75 ± 1.61%, for enhanced vs. untreated *M. biceps femoris*. Although the differences between treatments in both blesbok muscles were not significantly different, the moisture values of the enhanced muscles were still higher than the untreated sample (*M. longissimus et lumborum*: 74.35 ± 1.41% vs. 73.48 ± 1.30%; and *M. biceps femoris*: 76.15 ± 1.21% vs. 75.05 ± 1.86%).

Table 3 Least squared means for the sensory characteristics of the blesbok *M. longissimus et lumborum* and *M. biceps femoris* as evaluated by an analytical sensory panel.

Characteristic	Enhanced	Not enhanced	SEM	P-value
Longissimus et lumborum				
Aroma intensity	5.843	5.971	0.109	0.2059
Initial juiciness	6.900	6.714	0.201	0.1179
Sustained juiciness	6.943	5.786	0.193	<0.0001
Tenderness at first bite	7.529	6.414	0.188	<0.0001
Residue	7.571	6.786	0.168	<0.0001
Overall flavour	5.914	6.129	0.113	0.0049
Saltiness	2.729	1.286	0.104	<0.0001
Biceps femoris				
Aroma intensity	5.929	5.914	0.129	0.8733
Initial juiciness	6.657	6.457	0.193	0.0576
Sustained juiciness	6.600	5.743	0.246	<0.0001
Tenderness at first bite	6.886	6.243	0.235	<0.0001
Residue	7.043	6.543	0.218	<0.0001
Overall flavour	5.871	6.043	0.086	0.0228
Saltiness	2.600	1.143	0.084	<0.0001

Improved juiciness because of inorganic salt enhancement of meat has been reported by several authors (Papadopoulos, Miller, Ringer, and Cross, 1991; Scanga *et al*., 2000; Baublits, Pohlman, Brown Jr. and Johnson, 2005). Pork and beef juiciness was increased when the meat was injected with sodium tripolyphosphate (Smith, Simmons, McKeith, Betchel and Brady, 1984) and according to Deatherage (1963) sodium phosphate increases the water holding capacity of meat. Dhanda, Pegg, Janz, Aalhus and Shand (2001, as cited by Robbins, Jensen, Ryan, Homco-Ryan, McKeith and Brewer, 2003) found bison steaks injected with sodium tripolyphosphate and sodium chloride to be juicier than untreated steaks. Phosphate addition improves juiciness due to the added moisture because of the improved moisture retention due to the increased pH levels caused by the added phosphate (Prestat, Jensen, McKeith and Brewer, 2002). This reasoning was confirmed by Baublits *et al.* (2005) who found that, while untreated samples had larger amounts of free water, phosphate-treated samples contained a higher level of total moisture due to the increased water retention caused by phosphate treatment.

Tenderness is the most important eating quality characteristic according to consumers (Dransfield, Zamora and Bayle, 1998; Pietrasik and Shand, 2004) and because of its very low fat content, game meat is often perceived as being tougher than other meat, although Von la Chevallerie (1972) found that Warner-Bratzler shear force values did not correspond with this perception. In this investigation, tenderness at first bite was significantly ($P<0.05$) improved for all treated samples, while residue for all samples except springbok *M. biceps femoris* (though the enhanced sample was still rated higher) was also significantly ($P<0.05$) improved. During the physical analyses of the springbok and blesbok muscles (Chapter 3), the Warner-Bratzler shear force values of both muscles in both species showed highly significant ($P<0.0001$) treatment differences. The enhanced muscles produced shear force values much lower than the untreated samples and since lower shear force values indicate more tender meat, both enhanced muscles of both species were more tender than the untreated samples. The Warner-Bratzler shear force values (Chapter 4) for the enhanced and untreated *M. longissimus et lumborum* were 16.08 vs. 26.60 N/1.27cm Ø (springbok) and 18.86 vs. 41.20 N/1.27cm Ø (blesbok) while that of the *M. biceps femoris* were 23.32 vs. 32.74 N/1.27cm Ø (springbok) and 25.41 vs. 40.08 N/1.27cm Ø (blesbok). It was therefore expected that the two sensory tenderness characteristics (tenderness at first bite and residue) would be better scored in the enhanced samples as opposed to the untreated samples.

Papadopoulos *et al*. (1991) found improved tenderness when top round roasts were treated with sodium lactate of up to 2.0%. Sodium phosphates are often used to improve protein solubility in meat processing (Deatherage, 1963) and several authors have reported increased tenderness when meat was enhanced with phosphates (Smith *et al*., 1984; Scanga *et al*., 2000; Robbins *et al*., 2003). Baublits *et al*. (2005) reported that steaks treated with sodium hexametaphosphate, sodium tripolyphosphate or tetrasodium pyrophosphate scored higher in sensory analysis than sodium chloride-treated and untreated steaks, although there were no differences in Warner-Bratzler shear force values. When freshly slaughtered beef

was treated with sodium phosphate, rigor mortis was prevented and increased tenderness was achieved (Streitel, Ockerman and Cahill, 1977).

The increased saltiness of the enhanced samples is due to the increased levels of salt directly caused by the addition of the inorganic salt solution. Even though there are highly significant ($P<0.0001$) differences between the enhanced and untreated samples, the sensory panel ranked the saltiness of the enhanced samples as being between 2 (practically no salt) and 4 (very little salt) on the 8-point hedonic scale. These values are still well within the acceptability range and will therefore not detract from the overall acceptability of the enhanced product.

Overall flavour encompasses several other characteristics, such as aroma, mouthfeel and ease of swallowing, and is therefore a very good measurement of how well all the other characteristics interact to contribute to a well-rounded, well-liked product. Many of the substances used in enhancement solutions can have adverse effects on meat flavour. Most of these adverse flavour-effects can be attributed to the use of calcium salts (Scanga *et al*., 2000). Lawrence *et al*. (2003) reported that phosphate salts tended to lower flavour intensity, but did not report any other adverse effects associated with phosphates. Although the characteristics associated most with eating quality (tenderness and juiciness) were improved by enhancing the meat with an inorganic salt solution, the overall flavour of both muscles of both species were lower in the enhanced samples (not significant in springbok meat, but significant in blesbok). In the springbok, the overall flavour of both muscles and both treatments remained within the 6th scale point, which is "moderately typical" according to the sensory scale (Table 1) used, and is therefore still very acceptable. For the blesbok the overall flavour of both untreated muscles fell within the 6th scale point (a low 6), while that of the enhanced muscles fell within the 5th scale point (a high 5). This means that, while the enhanced meat flavour is still acceptable, it is closer to the more negatively perceived side of the scale and may not be liked as much by consumers.

However, acceptability is a composite and complex phenomenon which encompasses all eating quality aspects of meat, but in which some aspects may rank higher than others. Tenderness and juiciness are eating quality characteristics which are valued much more than, for example, aroma intensity or even overall flavour and the former two characteristics will therefore influence the consumer's overall acceptability much more than the latter two characteristics. Overall, the enhanced samples of both species performed better sensorically than the untreated samples.

4. Conclusion

Enhancing game meat with an inorganic salt solution holds definite benefits for the consumer as well as the game meat industry. By enhancing the meat, the two qualities most valued by consumers, i.e. tenderness and juiciness, are significantly increased. The overall flavour of the enhanced samples was lower and this may lead to consumers not accepting enhanced meat as well as they would if the overall flavour of enhanced meat was better than

the untreated meat. However, the differences were quite small if the sensory scale used to evaluate the characteristics is considered. No adverse flavour effects were encountered, which may be attributed to the fact that no calcium-based inorganic salts were used in the enhancing solution. Since consumers' overall acceptability of meat is influenced more by the characteristics more valued by them, in this case tenderness and juiciness, the enhanced springbok and blesbok meat will in all probability be found to be overall more acceptable to consumers than the untreated meat samples, although consumer sensory analysis would have to be performed to verify this.

5. References

AMSA (American Meat Science Association). (1995). *Research Guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat*. Chicago: National Livestock and Meat Board.

Baublits, R.T., Pohlman, F.W., Brown Jr., A.H. & Johnson, Z.B. (2005). Effects of sodium chloride, phosphate type and concentration, and pump rate on beef *biceps femoris* quality and sensory characteristics. *Meat Science* 70, 205-214.

Bronkhorst, N. (2005). Is koedoe en springbok op jou inkopielys? *Landbouweekblad* 24 Junie, 67

Chizzolini, R., Zanardi, E., Dorigoni, V. & Ghidini, S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. *Trends in Food Science and Technology* 10, 119-128.

Committee on Medical Aspects of Food Policy (1984). 'Diet and Cardiovascular Disease.' *Report on Health and social subjects*, Department of Health and Social Security, No. 28, HMSO, London.

Conroy, A.M. & Gaigher, I.G. (1982). Venison, Aquaculture and ostrich meat production: Action 2003. *South African Journal of Animal Science* 2, 219-233.

Deatherage, F.E. (1963). The effect of water and inorganic salts on tenderness. In: *Proceedings meat tenderness symposium* (pp. 45-68). Camden: Campbell Soup Company.

Dransfield, E., Zamora, F. & Bayle, M. (1998). Consumer selection of steaks as influenced by information and price index. *Food Quality and Preference* 9, 321-326.

Elliot, J. (1993). Farmed Venison, the new meat comes of age. *Nutrition and Food Science* 4, 26-29.

Higgs, J.D. (2000). The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science and Technology* 11, 85-95.

Hoffman, L.C. (2006). Sensory and physical characteristics of enhanced vs. non-enhanced meat from mature cows. *Meat Science* 72, 195-202.

Hoffman, L.C. (2000). Meat quality attributes of night-cropped impala (*Aepyceros melampus*). *SA Journal of Animal Science* 30, 133-137.

Hoffman, L.C., Muller, M., Schutte, De W., Calitz, F.J. & Crafford, K. (2005). Consumer expectations, perceptions and purchasing of South African game meat. *South African Journal of Wildlife Research* 35, 33-42.

Hoffman, L.C., Muller, M., Schutte, De W. & Crafford, K. (2004). Retail of South African game meat: current trade and marketing trends. *South African Journal of Wildlife Research* 34, 123-134.

Kroon, F.E., van Rensburg, W.J.J. & Hofmeyr, H.S. (1972). Seisoenale veranderinge in chemiese samestelling van volwasse blesbokramme (*Damaliscus dorcas phillipsi*) van die Van Riebeeck natuurreservaat. *Suid Afrikaanse Tydskrif van Veekunde* 2, 41-44.

Lawless, H.T. & Heymann, H. (1998). *Sensory evaluation of food: Principles and practices*. New York: Chapman & Hall.

Lawrence, T.E., Dikeman, M.E., Hunt, M.C., Kastner, C.L. & Johnson, D.E. (2003). Staged injection marination with calcium lactate, phosphate and salt may improve beef water-binding ability and palatability traits. *Meat Science* 65, 967-972.

Lewis, A.R., Pinchin, A.M. & Kestin, S.C. (1997). Welfare implications of the night shooting of wild impala (*Aepyceros melampus*). *Animal Welfare* 6, 123-131.

Melanson, K., Gootman, J., Myrdal, A., Kline, G. & Rippe, J. (2003). Weight loss and total lipid profile changes in overweight women consuming beef or chicken as the primary protein source. *Nutrition* 19, 409-414.

Moskowitz, H.R. (1984). Sensory analysis, product modelling and product optimisation. In G. Charalambous (Ed.). *Analysis of foods and beverages. Modern techniques* (pp. 13-67). Orlando: Academic Press Inc.

Papadopoulos, L.S., Miller, R.K., Ringer, L.J. & Cross, H.R. (1991). Sodium lactate effect on sensory characteristics, cooked meat colour and chemical composition. *Journal of Food Science* 56, 621-626.

Pauw, J. (1993). The development of venison marketing. In *Forum: The venison industry. Research requirements and possibilities* (pp. 3-5). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Pietrasik, Z. & Shand, P.J. (2004). Effect of blade tenderisation and tumbling time on the processing characteristics and tenderness of injected cooked roast beef. *Meat Science* 66, 871-879.

Prestat, C., Jensen, J., McKeith, F.K. & Brewer, M.S. (2002). Cooking methods and endpoint temperature effects on sensory and colour characteristics of pumped pork loin chops. *Meat Science* 60, 395-400.

Robbins, K., Jensen, J., Ryan, K.J., Homco-Ryan, C., McKeith, F.K. & Brewer, M.S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Science* 65, 721-729.

SAS (1999). *SAS/STAT User's Guide*, Version 8 (Volume II). SAS Institute Inc., North Carolina.

Scanga, J.A., Delmore Jr., R.J., Ames, R.P., Belk, K.E., Tatum, J.D. & Smith, G.C. (2000). Palatability of beef steaks marinated with solutions of calcium chloride, phosphate, and (or) beef-flavouring. *Meat Science* 55, 397-401.

Schönfeldt, H. (1993). Nutritional content of venison. In *Forum: The venison industry. Research requirements and possibilities* (pp. 51-60). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Smith, L.A., Simmons, S.L., McKeith, F.K., Betchel, P.J. and Brady, P.L. (1984). Effects of sodium tripolyphosphate on physical and sensory properties of beef and pork roasts. *Journal of Food Science* 49, pp. 1636-1637.

Streitel, R.H., Ockerman, H.W. & Cahill, V.R. (1977). Maintenance of beef tenderness by inhibition of rigor mortis. *Journal of Food Science* 42, 583-585.

Viljoen, J.J. (1999). 'n Vergelyking van die lipiedkomponente van springbokvleis met die van beesvleis en die verwante belangrikheid vir aspekte van die menslike gesondheid. *SA Tydskrif vir Natuurwetenskap en Tegnologie* 18, 51-53.

Viljoen, D.L., Muller, M., de Swart, J.B., Sadie, A. & Vosloo, M.C. (2001). Computerised electronic temperature control system for thermal efficiency during baking in food research. International Journal of Consumer Studies 25, 30-42.

Von la Chevallerie, M. (1972). Meat quality of seven wild ungulate species. *South African Journal of Animal Science* 2, 101-103.

Warriss, P.D. (2000). *Meat Science: an introductory text*. CABI Publishing, Wallingford, Oxon.

Webb, R. (2001). It's all in the game. *Diabetes Forecast* 54, 30-33.

Chapter 6

Effect of enhancement with an inorganic salt solution on the eating quality of blesbok (*Damaliscus dorcas phillipsi*) and springbok (*Antidorcas marsupialis*) *longissimus et lumborum* muscle as shown by analytical and consumer sensory evaluation

Abstract

The effects of inorganic salt enhancement on the sensory quality of springbok and blesbok *M. longissimus et lumborum*, after cooking in a stock mixture, were investigated. The springbok (n=5) and blesbok (n=5) originated from the Rustfontein Nature Reserve in the Free State Province of South Africa. Sensory testing comprised an analytical sensory evaluation by a panel (n=7) and a consumer sensory evaluation. The sensory characteristics evaluated by the experienced analytical panel were aroma intensity, initial juiciness, sustained juiciness, tenderness at first bite, residue, overall flavour and saltiness. Tenderness (tenderness at first bite and residue) and juiciness (initial and sustained juiciness) were positively influenced by inorganic salt enhancement for both species. These are the two eating quality characteristics most valued by consumers. The characteristic 'salty taste' had to be added to the list of attributes evaluated because of the addition of various salts in the enhancement solution. Although there was a highly significant difference between treatments concerning salty taste, the enhanced samples were still well within the acceptable range, with values ranging between 2 (practically no salt) and 4 (very little salt). The consumer panel were asked to do a likeness test of two springbok and blesbok *M. longissimus et lumborum* samples differing in treatment. For both species the consumers liked the enhanced samples significantly more than the untreated samples. Enhancing game meat holds definite advantages as pertaining to its eating quality.

Key words: Springbok, Blesbok, Game meat, Meat enhancement, Injected meat, Eating quality, Sensory characteristics, Tenderness, Juiciness

1. Introduction

There has been a definite shift in people's perception of the healthfulness of food products. Red meat is associated with obesity and thus many consumers believe that it is unsuitable for a balanced health-promoting diet (Melanson, Grootman, Myrdal, Kline and Rippe, 2003). This view has been fuelled by reports that dietary fat and saturated fat intake were primarily responsible for obesity and therefore it has been recommend that red meat intake should be limited or completely eliminated. Higgs (2000) stated that consumers associate meat with cholesterol and because serum cholesterol has been associated with chronic heart disease, most consumers still link red meat intake with increased cholesterol consumption and increased heart disease risk despite the fact that scientific evidence

suggests otherwise. Worldwide red meat consumption has declined in favour of "safer" food sources such as chicken and plant-proteins. Because of their growing health concerns consumers are demanding food with lower kilojoule, cholesterol and fat contents (MacRae, O'Reilly and Morgan, 2005). In a survey of 300 South African consumers, Hoffman, Muller, Schutte and Crafford (2004) found that fat content was the most important quality considered when purchasing meat. Nutritional guidelines suggests that dietary fat should provide 15-30% of the total calorie-intake and saturated fats should be limited to less than 10% of the caloric intake (Chizzolini, Zanardi, Dorigoni and Ghidini, 1999). It is also suggested that cholesterol-intake should not be in excess of 300mg per day. However, fatty acid composition, especially the ratio of polyunsaturated to saturated fatty acids, has been shown to be more important for health reasons than total fat content (Higgs, 2000; Chizzolini *et al*., 2003; MacRae *et al*., 2005).

Several authors have reported that South African game species have fat contents less than 3.0g/100g (Kroon, van Rensburg and Hofmeyr, 1972, Schönfeldt, 1993; Pauw, 1993; Hoffman, 2000) and Von la Chevallerie (1972) reported the fat content of springbok and blesbok to be 1.7g/100g. Furthermore, game meat has higher levels of polyunsaturated fatty acids and lower saturated fat contents than beef (Schönfeldt, 1993; Viljoen, 1999; Hoffman, 2000). Game meat can thus be considered a healthier red meat because of its low fat and cholesterol and its beneficial fatty acid composition.

The image of game meat has suffered in the past because consumers are ill informed about the potential health benefits of game meat and proper preparation methods (Webb, 2001; Hoffman *et al*., 2004). Consumers often erroneously assume that game meat is "tough, dry and chewy", states Webb (2001) but the author chalks this up to incorrect preparation and cooking techniques. Bronkhorst (2005) reported that consumers often perceive game meat quality as unpredictable.

Animal welfare, along with animal and product safety and environmentally friendly production, have become hot topics with consumers in the past few years, mainly because of a growing concern for health, safety and ethics encouraged further by several concerned groups and the media (Bernues, Olaizola and Corcoran, 2003b). BSE, antibiotics, hormones and fat and cholesterol content were found to be the issues that meat consumers were mostly concerned about (Verbeke and Vackier, 2004). European beef and lamb consumers listed animal feeding, origin of meat, environmentally friendly production and animal welfare as the most important non-physical factors associated with meat (Bernues, Olaizola and Corcoran, 2003a). Issanchou (1996) reported that consumers would lower their meat consumption if they were convinced that animal welfare and animal treatment in the meat production system is not as good as it should be. In the research of McCarthy, de Boer, O'Reilly and Cotter (2003) European consumers also associated conventional farming systems with environmental damage and negligent treatment of animals. Hoffman, Muller, Schutte, Calitz and Crafford (2005) found consumers had less of a problem with consuming game meat if they knew that the animals were harvested in a humane manner.

In this regard game meat is the ideal red meat source for even the most concerned consumer since it can be viewed as a wholesome, untainted product. Game animals contain no added antibiotics, growth hormones or other chemicals readily used in conventional farming systems. South African game animals are generally farmed in extensive free range, farming systems with minimal contact with humans and therefore game meat can be considered an organic, or natural, product (Pauw, 1993; Hoffman and Bigalke, 1999, Jansen van Rensburg, 2001).

The aim of this study was to investigate the possible improvements to the eating quality of springbok and blesbok meat after enhancement with an inorganic salt mixture and to test consumers' reaction towards enhanced game meat. Two types of sensory testing, analytical and consumer taste panels, were used to determine how enhanced game meat would be influenced by 'regular' cooking methods as opposed to strict laboratory conditions where no extra ingredients are added to the meat. In general, there has been very little sensory research done on game meat, with more analytical evaluations have been performed than consumer evaluations (Chapter 5). Springbok and blesbok were chosen because these are two of the most common game species favoured by game farmers in South Africa (Conroy and Gaigher, 1982). Springbok was found to be the game species most often consumed by South African consumers (Hoffman *et al*., 2005) and one of the three game meat species regularly available in South African supermarkets, butcheries and restaurants (Hoffman *et al*., 2004).

2. Materials and Methods

2.1. Animals

Five Blesbok (*Damaliscus dorcas phillipsi*) and five Springbok (*Antidorcas marsupialis*) were randomly harvested at the Rustfontein Nature Reserve in the Free State Province. Although the animals were all male, they differed in weight within species, with blesbok carcass weight varying between 30.7 kg and 36.9 kg and springbok carcass weight varying between 15.5 kg and 22.9 kg. Animals were harvested at night by a professional cull team, using similar culling methods to those described by Lewis, Pinchin and Kestin (1997), and only head or neck shots were taken. This resulted in animals experiencing minimum stress conditions. Animals were exsanguinated within 5 minutes of harvesting and hung by the Achilles tendon. Bled and eviscerated carcasses, but still with the skin on, were transported to Stellenbosch, in a temperature-controlled vehicle, where they were skinned and processed further approximately 24 h after harvesting.

The right and left hand side *M. longissimus et lumborum* of each carcass was removed, trimmed of any carcass connective tissue and fat, although these game species seldom have any visible fat, and the left side samples were injected with an inorganic salt solution (Freddy Hirsch Tenderbite #802539; P.O. Box 2554, Cape Town, 8000) containing sodium (5.21%) and potassium (2.53%) di- and triphosphates (3.45%), lactate (12.40%) and water (75.75%) to give a pumped gain of 20%, with a retention level of approximately 15%.

Injection was performed at a pressure of 2.4 bar at 30 strokes per minute on a Rühle Curing Centre IR56 (Rühl GmbH, D-79865, Grafenhausen, Germany). Samples were individually vacuum packed and frozen at -20 ºC.

2.2. Analytical sensory analysis

The analytical sensory panel consisted of seven panellists of who five had been part of a regular meat analysis group for over two years, while the other two were fairly new to meat analysis, having only been involved for approximately two months prior to their inclusion in the meat tasting programme. This panel received only one hour of training on treated and untreated blesbok and springbok meat the day before the actual analysis because they all had been tasting blesbok and springbok meat for two months prior to this specific session and had received rigorous training on both species during those two months. Still, all seven characteristics evaluated were thoroughly discussed.

Left and right *M. longissimus et lumborum* of blesbok and springbok were defrosted at 3 ºC for 24 h prior to the sensory evaluation. Muscles were cooked in a stock mixture (Table 1) at 160ºC in a Hobart combi steamer to an internal temperature of 66ºC. The American Meat Science Association (AMSA, 1995) recommends that samples be removed at about 5ºC below the desired internal temperature, which is 71ºC. After removal, the samples were allowed to cool for 1 hour before being cut into 2 cm cubes. Cubed samples were individually wrapped in aluminium foil squares and coded. All surface areas of the meat exposed to the cooking environment were removed before the samples were cubed. The samples were reheated at 100ºC 15 minutes prior to the start of evaluation.

Table 1 Ingredients comprising the stock mixture used to prepare blesbok and springbok *M. longissimus et lumborum* for analytical and consumer sensory analysis.

	Treated samples	Untreated samples
Ingredients	Mass (g) per 500 g meat	Mass (g) per 500 g meat
Carrots (sliced)	120	120
Onions (sliced)	75	75
Celery (chopped)	30	30
Water	150	150
Salt	0.00	1.00
Pepper	0.50	0.50
Bay leaves	1.00	1.00

Panellists were seated in individual cubicles in a temperature-light-controlled room. Each panellist received crackers, apple slices and distilled water to use as palate cleansers between samples. Panellists received four randomised samples over five sessions with a 20-minute break between sessions three and four. The basic 8-point hedonic questionnaire ascribed by AMSA (1995) was used, but was changed slightly to better suit the purpose of the

investigation and the characteristic "salty taste" was added (Table 2). This was the same questionnaire used in all previous blesbok and springbok evaluations, except that it referred to the generic term "Game" as panellists were evaluating blesbok and springbok samples consecutively.

Table 2 Questionnaire used during analytical sensory evaluation of Blesbok and Springbok *M. longissimus et lumborum* muscle samples.

Sensory attribute	Explanation of attribute	Scale used
Game aroma intensity	Take a few short sniffs as soon as you remove the foil	8 Extremely intense 1 Extremely bland
Initial impression of juiciness	The amount of fluid exuded on the cut surface when pressed between your thumb and forefinger	8 Extremely juicy 1 Extremely dry
Sustained juiciness	The impression that you form after the first two to three chews between the molar teeth	8 Extremely juicy 1 Extremely dry
First bite	The impression of tenderness after the first two to three chews between the molar teeth	8 Extremely tender 1 Extremely tough
Residue	The amount of residue left in the mouth after the first twenty to thirty chews.	8 None 1 Abundant
Overall game flavour	This is a combination of taste and swallowing.	8 Extremely typical 1 Extremely untypical
Salty taste	Taste on the tongue associated with sodium ions.	8 Extremely salty 1 No salty taste

2.3. Consumer sensory analysis

Consumers were asked to rate their likeness of four game meat samples. Of the 91(all regular meat consumers) people participating in the consumer sensory analysis, the majority were students and employees of Stellenbosch University. Since the analysis venue was on campus, it was much easier to get students and university employees to commit to a tasting session than non-university consumers. Participants were asked to supply their demographic detail on age (18-24; 25-34; 35-44; 45-54, and 55+), game meat consumption (more than once a week; once a week; once a month; less than once a month, and never) and gender. Nearly twice as many participants were female (n=56) than male (n=35) and about two thirds were between the ages of 18 and 24 (n=60). Most consumers consumed game meat less than once a month (n=48), with the second largest consumption group being consumers who enjoyed game meat at least once a month (n=29).

Every participant was thoroughly instructed on tasting and scoring procedure by assistants and were encouraged to ask for help if needed, with the assistants being close by at all times. When questionnaires were handed back, it was checked to assure that all boxes were filled out (demographic detail and liking scores) to ensure that as much information as possible were gathered.

Exactly the same muscles (blesbok and springbok *M. longissimus et lumborum*) were used during the consumer analysis part of the study and sample preparation is therefore exactly the same as described for the analytical sensory analysis.

Every consumer received four samples, two treatment samples from a particular blesbok (e.g. left and right *M. longissimus et lumborum* sample from animal 1) and a particular springbok so as to minimise inter-animal variation. The two samples from the same species were always located right next to each other so consumers would evaluate treatment differences within species rather than species differences. Samples were still coded with random three digit codes and species placement on the questionnaires were randomised between consumers. Each consumer sat alone at a table and received distilled water as a palate cleanser. A 9-point likeness scale was used on the questionnaire and consumers were asked only to rate their likeness of a particular sample, no validation or comments were asked. The nine scale points used were: Like extremely; Like very much; Like moderately; Like slightly; Neither like nor dislike; Dislike slightly; Dislike moderately; Dislike very much; and, Dislike extremely. According to Lawless and Heymann (1998) the 9-point hedonic scale has ruler-like properties (psychologically) because of the equal interval spacing of the words chosen to represent each point and this will allow sensory scientists to assign numerical values to the consumers' choices.

2.4. Statistical analysis

In both analytical and consumer sensory data analyses, the standard GLM Procedure was not used (SAS, 1999). The data was not normally distributed and large proportions of the variation in the data could be attributed to judge (panellist or consumer) and animal effects. Therefore, the Mixed Procedure was used for data analysis and both judge and animal were included in the model as random variables, which effectively removed their contributions to total variation (SAS, 1999). In the consumer sensory study, the main effect studied was the possible differences in likeness between the two muscle treatments in both species, which is why only this effect was statistically analysed, though demographic detail was collected and may be used in future correlate these detail with the sensory results attained.

3. Results and discussion

3.1 Analytical sensory analysis

The characteristics analysed by the analytical panel were the same characteristics commonly referred to by the standard hedonic questionnaire for meat given by AMSA (1995),

with the addition of salty taste (Table 2). The analytical panel found that treatments differed significantly for most of the attributes analysed in both blesbok and springbok *M. longissimus et lumborum* (Table 3). Generally the inorganic salt-treated samples scored higher than the untreated samples (higher scores indicate better performance for an attribute, except in the case of salty taste where a higher score actually indicates a more negative performance, since 1 = No salty taste, while 8 = Extremely salty taste).

Table 3 Least squared means of the analytical sensory analyses of blesbok and springbok *M. longissimus et lumborum* differing in treatment.

	Blesbok				Springbok			
Sensory attribute	Treated	Untreated	SEM	P-value	Treated	Untreated	SEM	P-value
Aroma intensity	6.200	6.171	0.207	0.8279	5.743	5.800	0.159	0.7141
Initial juiciness	6.829	6.600	0.303	0.0894	6.371	5.971	0.246	0.0083
Sustained juiciness	6.171	5.686	0.438	0.0042	5.829	5.171	0.318	0.0002
Tenderness	7.229	6.543	0.278	0.0004	7.114	6.429	0.196	<0.0001
Residue	7.457	6.886	0.191	<0.0001	7.371	6.943	0.126	0.0038
Flavour	6.286	6.114	0.158	0.2173	5.971	5.857	0.198	0.2334
Salty taste	3.571	2.743	0.571	<0.0001	3.629	2.829	0.424	<0.0001

Aroma intensity did not differ between treatments for either blesbok or springbok samples. Since sulphur-containing compounds, present at fairly low levels in meat, chiefly causes meat aroma (Mottram, 1998) and species-specific aromas are related to the fat composition of the meat and since neither one is influenced by any of the inorganic salts added when the meat is enhanced, it is fairly reasonable to expect that there will be no differences in the aroma of enhanced vs. untreated samples.

The initial impression of juiciness of blesbok *M. longissimus et lumborum* tended to differ significantly (P=0.089) between treatments, while the initial juiciness of springbok samples differed significantly (P=0.008). Sustained juiciness was much higher (P<0.01) in the treated samples from both species. Consumers consider juiciness an important attribute in meat eating quality (Dransfield, Zamora and Bayle, 1998; Lawrie, 1998; Pietrasik and Shand, 2004). In sensory analysis on venison, Forss, Manley, Platt and Moore (1979) reported that all samples tested, tended to be dry. The springbok meat analysed by Jansen van Rensburg (1997) was reported to be dry. Hoffman (2001) suggested that the reason South African game meat is frequently perceived as dry is due to animals experiencing stress during harvesting because of improper harvesting and handling procedures. The fact that enhancing meat with an inorganic salt solution improves juiciness may have very positive consequences for the game meat industry.

There have been several reports of the improvement of juiciness by means of inorganic salt enhancement of meat (Papadopoulos, Miller, Ringer, and Cross, 1991; Scanga, Delmore Jr., Ames, Belk, Tatum and Smith, 2000; Baublits, Pohlman, Brown Jr. and Johnson, 2005). Sodium tripolyphosphate injections increased pork and beef juiciness (Smith,

Simmons, McKeith, Betchel and Brady, 1984). According to Deatherage (1963) sodium phosphate increased the water holding capacity of meat. Dhanda, Pegg, Janz, Aalhus and Shand (2001, as cited by Robbins, Jensen, Ryan, Homco-Ryan, McKeith and Brewer, 2003) found bison steaks injected with sodium tripolyphosphate and sodium chloride to be juicier than untreated steaks. Prestat, Jensen, McKeith and Brewer (2002) reported that phosphate addition improved juiciness due to the added moisture as well as the improved moisture retention because of the increased pH levels caused by the added phosphate. Baublits *et al.* (2005) confirmed the findings of Prestat *et al*. (2002) when they found that phosphate-treated samples contained a higher level of total moisture due to the increased water retention caused by phosphate treatment, while untreated samples had larger amounts of free water.

Game meat is often perceived as being tougher than other meat because of its very low fat content. However, Von la Chevallerie (1972) found that Warner-Bratzler shear force values did not correspond with this perception. Tenderness was shown to be the eating quality characteristic most revered by consumers (Dransfield *et al*., 1998; Pietrasik and Shand, 2004) and influences consumer purchase behaviour tremendously (Dransfield *et al*., 1998). Consumers would choose to buy a steak that is known to be more tender even if it is the most expensive steak on offer. The results from this study show that the improvement in tenderness at first bite caused by enhancing the meat was highly significant, with P=0.0004 and P<0.0001, for blesbok and springbok muscles respectively. There was a significant improvement in the residue of the enhanced samples. A high rating for residue points to meat that is more tender, since higher residue ratings means that there is smaller amounts of residue remaining in the mouth after the designated amount of chewing has been completed. The improved tenderness ratings of enhanced samples can be explained by the addition of certain chemical compounds present in the enhancement solution.

Papadopoulos *et al*. (1991) found improved tenderness in top round roasts after treatment with sodium lactate of up to 2.0%. Several authors have reported increased tenderness when meat was enhanced with phosphates (Smith *et al*., 1984; Scanga *et al*., 2000; Robbins *et al*., 2003). Sodium phosphates are often used to improve protein solubility in meat processing (Deatherage, 1963). Baublits *et al*. (2005) reported that steaks treated with sodium hexametaphosphate, sodium tripolyphosphate or tetrasodium pyrophosphate scored higher in sensory analysis than sodium chloride-treated and untreated steaks although there were no differences in Warner-Bratzler shear force values. Rigor mortis was prevented and increased tenderness was achieved when freshly slaughtered beef was treated with sodium phosphate (Streitel, Ockerman and Cahill, 1977). In this study, tenderness at first bite and residue were both rated particularly high in the treated samples of both species. Upon consumption, treated meat will most likely be perceived as more tender than untreated meat samples.

Although the treated samples had a significantly higher (P<0.0001) salty taste than untreated samples, it was still very acceptable as far as eating quality is concerned. The fact that treated samples was saltier than untreated samples can be ascribed to the inorganic salt

content of the treatment mixture injected into treated samples. During the preparation of the meat samples, no additional salt was added to the enhanced samples because it was already found to be saltier than the untreated samples (Chapter 5) and consumers discriminating against the enhanced samples purely because of a saltier taste had to be prevented. However, adding too much salt to the untreated meat may also cause a partiality to arise and therefore only 1.00 g salt was added to 500 g meat. Since the salt was added to the stock mixture (for untreated meat) and not injected directly into the muscle (as in the case of the enhanced samples), the salt only penetrated the surface of the untreated meat and thus, the enhanced samples were still perceived as saltier than the untreated samples.

Overall flavour is the impression that is created by the accumulation of different eating quality characteristics during consumption. Overall flavour did not differ between treatments in either species, which shows that inorganic salt treatment of meat does not change aroma and flavour properties. It is important for the overall flavour to remain the same regardless of the treatment.

In the end, however, it is not the acceptability of single characteristics that will determine a consumer's future purchasing behaviour, but the overall acceptability of the product, which is mostly influenced by the quality characteristics most valued by the consumer.

3.2 Consumer sensory analysis

The purpose of a consumer sensory evaluation is to establish consumer reaction to a product or specific treatment (de Kock, 1993). In this study it was imperative to know whether or not the enhancement of game meat would influence consumer perception and choice. Consumers were asked to rate their likeness of a particular sample on a 9-point likeness scale, where 1=Dislike extremely and 9=Like extremely. Consumers continuously rated the enhanced samples significantly higher ($P<0.05$) than the untreated samples, which meant that they liked the enhanced samples better than the untreated samples (Table 4).

Table 4 Consumer sensory analysis of inorganic salt-enhanced vs. untreated blesbok and springbok *M. longissimus et lumborum.*

Species	Enhanced	Untreated	SEM	P-value
Blesbok	6.562	5.936	0.178	0.0107
Springbok	7.023	6.276	0.167	0.0011

Consumers were not asked for comments or to validate their choices in any way – the choices they made were, therefore, made mostly on the inherent eating quality characteristics of the game meat. Consumer evaluation mainly focuses on the overall impression created on consumption of the product and cannot be used in the evaluation of individual characteristics of a product. Data from analytical analyses can be correlated to consumer

opinions, but discrepancies in the accuracy of the regression of consumer acceptance against descriptively analysed attributes often occur (Lawless, 1995).

Even though the analytical data cannot be accurately correlated with the consumer findings, it can, however, be postulated that the reason why consumers preferred the enhanced game meat to the untreated samples has a lot to do with the improved tenderness and juiciness as found by the analytical sensory panel. As previously stated, consumers value tenderness and juiciness very highly (Dransfield *et al*., 1998) and with the improved tenderness and juiciness of the enhanced samples, the overall acceptability also increased.

4. Conclusion

Enhancing game meat with an inorganic salt solution holds definite benefits for the consumer as well as the game meat industry. By enhancing the meat, the two qualities most valued by consumers, tenderness and juiciness, are significantly increased as was shown by the analytical sensory analysis. The acceptance of the enhanced meat was significantly improved as was clearly shown by consumers preferring enhanced game meat to untreated samples. By using enhancement as a processing method, the game meat industry may benefit tremendously. No adverse effects on meat eating quality characteristics were encountered, which may be attributed to the fact that no calcium salts were used in the enhancement solution as calcium salts may cause unacceptable flavour effects.

5. References

AMSA (American Meat Science Association). (1995). *Research Guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat*. Chicago: National Livestock and Meat Board.

Baublits, R.T., Pohlman, F.W., Brown Jr., A.H. & Johnson, Z.B. (2005). Effects of sodium chloride, phosphate type and concentration, and pump rate on beef *biceps femoris* quality and sensory characteristics. *Meat Science* 70, 205-214.

Bernues, A., Olaizola, A. & Corcoran, K. (2003a). Extrinsic attributes of red meat as indicators of quality in Europe: an application for market segmentation. *Food Quality and Preference* 14, 265-276.

Bernues, A., Olaizola, A. & Corcoran, K. (2003b). Labelling information demanded by European consumers and relationships with purchasing motives, quality and safety of meat. *Meat Science* 65, 1095-1106.

Bronkhorst, N. (2005). Is koedoe en springbok op jou inkopielys? *Landbouweekblad* 24 Junie, 67

Chizzolini, R., Zanardi, E., Dorigoni, V. & Ghidini, S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. *Trends in Food Science and Technology* 10, 119-128.

Conroy, A.M. & Gaigher, I.G. (1982). Venison, Aquaculture and ostrich meat production: Action 2003. *South African Journal of Animal Science* 2, 219-233.

Deatherage, F.E. (1963). The effect of water and inorganic salts on tenderness. In *Proceedings meat tenderness symposium* (pp. 45-68). Camden: Campbell Soup Company.

De Kock, R. (1993). Consumer sensory evaluation. In *Forum: The venison industry. Research requirements and possibilities* (pp. 61-64). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Dransfield, E., Zamora, F. & Bayle, M. (1998). Consumer selection of steaks as influenced by information and price index. *Food Quality and Preference* 9, 321- 326.

Forss, D.A., Manley, T.R., Platt, M.P. & Moore, V.J. (1979). Palatability of venison from farmed and feral red deer. *Journal of the Science of Food and Agriculture* 30, 932-935.

Higgs, J.D. (2000). The changing nature of red meat: 20 years of improving nutritional quality. *Trends in Food Science & Technology* 11, 85-95.

Hoffman, L.C. (2001). The effect of different culling methodologies on the physical meat quality attributes of various game species. In H. Ebedes, B. Reilly, W. van Hoven & B. Penzhorn (Ed.). *Sustainable utilisation - conservation in practice*. Proceedings of the 5th International Wildlife Ranching Symposium.

Hoffman, L.C. (2000). Meat quality attributes of night-cropped impala (*Aepyceros melampus*). *SA Journal of Animal Science* 30, 133-137.

Hoffman, L.C. & Bigalke, R.C. (1999). Utilizing wild ungulates from southern Africa for meat production: Potential research requirements for the new millennium. *Congress of the Wildlife Management Association of SA*. George, pp. 1-14.

Hoffman, L.C., Muller, M., Schutte, De W., Calitz, F.J. & Crafford, K. (2005). Consumer expectations, perceptions and purchasing of South African game meat. *South African Journal of Wildlife Research* 35, 33-42.

Hoffman, L.C., Muller, M., Schutte, De W. & Crafford, K. (2004). Retail of South African game meat: current trade and marketing trends. *South African Journal of Wildlife Research* 34, 123-134.

Issanchou, S. (1996). Consumer expectations and perceptions of meat and meat product quality. *Meat Science* 43, S5-S19.

Jansen van Rensburg, D.M. (2001). Venison as health food. In H. Ebedes, B. Reilly, W. van Hoven & B. Penzhorn (Ed.). *Sustainable utilisation - conservation in practice*. Proceedings of the 5th International Wildlife Ranching Symposium (pp. 196-198).

Jansen van Rensburg, D.M. (1997). The physical, chemical and sensory quality characteristics of Springbok (*Antidorcas marsupialis marsupialis*) meat. D. Tech. (Food and Nutrition). Department of Food and Nutrition. Technikon Pretoria, Pretoria.

Kroon, F.E., van Rensburg, W.J.J. & Hofmeyr, H.S. (1972). Seisoenale veranderinge in chemiese samestelling van volwasse blesbokramme (*Damaliscus dorcas phillipsi*) van die Van Riebeeck natuurreservaat. *Suid Afrikaanse Tydskrif van Veekunde* 2, 41-44.

Lawless, H. (1995). Dimensions of sensory quality: a critique. *Food Quality and Preference* 6, 191-199.

Lawless, H.T. & Heymann, H. (1998). *Sensory evaluation of food: principles and practices*. Gaithersburg, MD, USA:Aspen Publishers.

Lawrie, R.A. (1998). *Lawrie's Meat Science* (6th ed.). Cambridge, England: Woodhead Publishing Ltd.

Lewis, A.R., Pinchin, A.M. & Kestin, S.C. (1997). Welfare implications of the night shooting of wild impala (*Aepyceros melampus*). *Animal Welfare* 6, 123-131.

MacRae, J., O'Reilly, L. & Morgan, P. (2005). Desirable characteristics of animal products from a human health perspective. *Livestock Production Science*, 94, 95-103.

McCarthy, M., de Boer, M., O'Reilly, S. & Cotter, L. (2003). Factors influencing intention to purchase beef in the Irish market. *Meat Science* 65, 1071-1083.

Melanson, K., Gootman, J., Myrdal, A., Kline, G. & Rippe, J. (2003). Weight loss and total lipid profile changes in overweight women consuming beef or chicken as the primary protein source. *Nutrition* 19, 409-414.

Mottram, D.S. (1998). Flavour of muscle foods - an overview. In F. Shahidi (Ed.). *Flavour of meat, meat products and seafoods* (pp. 5-24). London: Blackie Academic and Professional.

Papadopoulos, L.S., Miller, R.K., Ringer, L.J. & Cross, H.R. (1991). Sodium lactate effect on sensory characteristics, cooked meat colour and chemical composition. *Journal of Food Science* 56, 621-626.

Pauw, J. (1993). The development of venison marketing. In *Forum: The venison industry. Research requirements and possibilities* (pp. 3-5). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Pietrasik, Z. & Shand, P.J. (2004). Effect of blade tenderisation and tumbling time on the processing characteristics and tenderness of injected cooked roast beef. *Meat Science* 66, 871-879.

Prestat, C., Jensen, J., McKeith, F.K. & Brewer, M.S. (2002). Cooking methods and endpoint temperature effects on sensory and colour characteristics of pumped pork loin chops. *Meat Science* 60, 395 - 400.

Robbins, K., Jensen, J., Ryan, K.J., Homco-Ryan, C., McKeith, F.K. & Brewer,M.S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Science* 65, 721-729.

SAS (1999). *SAS/STAT User's Guide*, Version 8 (Volume II). SAS Institute Inc., North Carolina.

Scanga, J.A., Delmore Jr., R.J., Ames, R.P., Belk, K.E., Tatum, J.D. & Smith, G.C. (2000). Palatability of beefsteaks marinated with solutions of calcium chloride, phosphate, and (or) beef flavouring. *Meat Science* 55, 397-401.

Schönfeldt, H. (1993). Nutritional content of venison. In *Forum: The venison industry. Research requirements and possibilities* (pp. 51-60). Meat industry centre, Irene Agricultural research Council, Pretoria, South Africa.

Smith, L.A., Simmons, S.L., McKeith, F.K., Betchel, P.J. and Brady, P.L. (1984). Effects of sodium tripolyphosphate on physical and sensory properties of beef and pork roasts. *Journal of Food Science* 49, pp. 1636-1637.

Streitel, R.H., Ockerman, H.W. & Cahill, V.R. (1977). Maintenance of beef tenderness by inhibition of rigor mortis. *Journal of Food Science* 42, 583-585.

Verbeke, W. & Vackier, I. (2004). Profile and effects of consumer involvement in fresh meat. *Meat Science* 67, 159-168.

Viljoen, J.J. (1999). 'n Vergelyking van die lipiedkomponente van springbokvleis met die van beesvleis en die verwante belangrikheid vir aspekte van die menslike gesondheid. *SA Tydskrif vir Natuurwetenskap en Tegnologie* 18, 51-53.

Von la Chevallerie, M. (1972). Meat quality of seven wild ungulate species. *South African Journal of Animal Science* 2, 101-103.

Webb, R. (2001). It's all in the game. *Diabetes Forecast* 54, 30-33.

Conclusion

In South Africa, game meat from wild ungulates is still considered as novel meat. Most tourists view it as a truly African delicacy, while most South African consumers have conflicting thoughts on game meat – most think it too expensive and others have only experienced it as meat with a dubious quality, often being dry and tough. However, game meat does not necessarily have to be tough and dry every time, depending on harvesting and preparation methods, game meat has the ability to be just as tender and juicy as any red meat. A unifying corporate body or institution, laying down regulations as to the proper harvesting and pre-slaughter handling procedures, may be able to make game meat quality more uniform and more acceptable to the consumer.

This study has highlighted differences in five muscles (*M. biceps femoris*, *M. longissimus et lumborum, M. rectus femoris, M. semitendinosus* and *M. supraspinatus*), of both blesbok and springbok, as pertaining to the physical (cooking loss, drip loss, tenderness and colour), as well as the chemical (moisture, ash, fat, protein, mineral composition and fatty acid composition) characteristics of meat. It was found that there were definite differences amongst muscles for most of these characteristics.

There is no information available on game muscles, except for the *M. longissimus dorsi* that is usually used in research studies. This study, therefore, may be able to fill some of the void that is presently found available in game meat information.

Furthermore, the aim was to make game meat even more acceptable and preferable by trying to improve its tenderness and juiciness by injecting an inorganic salt solution into the meat. This proved to be a very successful method of improving most of the eating quality characteristics of the meat, as was shown by the analytical and consumer sensory analyses performed on the *M. biceps femoris* and *M. longissimus et lumborum* of both springbok and blesbok.

Enhancing game meat with inorganic salts proved to improve the two quality characteristics most valued by consumers, i.e. tenderness and juiciness. This was also shown by the physical analyses, where the Warner-Bratzler shear force values of enhanced muscles were much lower (therefore more tender) than the untreated muscles. The chemical analyses showed that the moisture content of the enhanced samples were higher than that of the untreated samples. The only characteristic that may have a less positive effect on the overall acceptability of the enhanced meat was its salty taste – the enhanced samples had a slightly higher salty taste than untreated samples, but were still found to be very acceptable.

Consumers chose the enhanced game meat samples over the untreated samples of both springbok and blesbok, which shows that the overall acceptability of enhanced game meat was improved. This can probably be attributed to an improvement in the tenderness and juiciness of the enhanced meat, for these two characteristics are most valued by consumers and would therefore influence the overall acceptability of the product more.

Game meat should be more actively promoted as a healthy red meat, since it has a very low fat content and a very beneficial fatty acid profile. More information about the good qualities, as well as the correct preparation techniques should be provided to consumers. This should make consumers aware of the excellent benefits that game meat holds for human health and should definitely further the cause of South African game meat.