Logistics around the meat supply chain in Kruger National Park: the African savanna buffalo (*Syncerus caffer caffer*) as model

by

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Thesis presented in partial fulfilment of the requirements for the degree of

Master of Science

at

Stellenbosch University

Food Science, Faculty of AgriSciences

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April 2019

DECLARATION

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SUMMARY

To facilitate a better relationship with adjacent communities, the Kruger National park (KNP) is investigating the possibility of sustainable offtakes of buffalo and using some of the meat as cooked stew as part of targeted environmental education engagement with local schools. Many of such schools form part of the government feeding scheme, which currently does not include any animal protein, except for canned fish occasionally. However, to help finance this scheme, an analysis of the whole supply meat value chain is required to see whether more expensive meat products can be derived from buffalo carcasses that could be sold to the public; the income from this would then be used to subsidise the school engagements. Therefore, the objective of this study was to investigate the meat characteristics, composition and overall meat quality of male and female African savanna buffalo (*Syncerus caffer caffer*) muscles [*Longissimus thoracis et lumborum* (LTL), *Biceps femoris* (BF), *Semimembranosus* (SM), *Semitendinosus* (ST), *Infraspinatus* (IS) *and Supraspinatus* (SS)] from animals in the Kruger National Park, South Africa. The meat quality was quantified on the physical characteristics (pH, colour, drip and cooking loss, water holding capacity and tenderness), proximate composition (moisture, protein, fat and ash content) and ageing of the selected muscles.

For the first trial thirty buffalo were harvested in KNP and divided into adult and sub-adult categories according to sex (male and female). Males (n=17) had a mean "live" weight of 478.6 kg and females (n=13) 451.7 kg. Dressing percentages was very similar 58.3% and 58.9% for males and females, respectively. Of the six muscles, the three heaviest muscles were the BF (5.3-5.7 kg), SM (4.4-4.6 kg) and LTL (3.0 kg). The muscle weights of the selected muscles increased between 24 and 50 percent between sub-adult and adults.

Sex did not influence the physical and chemical characteristics. However, muscle type had an influence, with highest tenderness observed for the SS muscle (31.0 N), BF muscle was toughest (45.9 N) and LTL muscle had highest amount of protein (22.7%). Age also had an influence; Sub-adults had a lower muscle ultimate pH, shear force and protein content, with a higher moisture content ($p \leq 0.05$) than the adult category. Thus, sub-adult meat samples displayed more desirable physical characteristics. Furthermore, the mean CIELab colour measurements were in accordance with what is expected for game meat (L*=38.54, a*=15.94 an b*=11.75).

An ageing trial was conducted to determine a standard protocol for ageing time to achieve optimal tenderness for the LTL, SM and BF muscles. A significant increase in tenderness was noted for both the LTL and SM muscle by 25 days post-mortem, however, a decrease in tenderness was noted for the BF muscle over the ageing period of 32 days. Furthermore,

cumulative purge loss increased over the 32 days post-mortem from 4.0% to 9.3%. Cooking loss decreased significantly from day one PM to day five post-mortem and then plateaued over the ageing period with a slight increase from day 13 PM onwards. Furthermore, all the mean colour measurements changed significant over the ageing period. The mean muscle (BF, SM and LTL) surface colour turned lighter (L*=41.3), less red (a*=13.2), and more yellow (b*=12.4) over the 32 days post-mortem. The study found that ageing the LTL and SM muscles up to day 25 gave optimum tenderness, and the BF should be utilised in different value-added products, such as biltong.

A biltong production trial was conducted to determine the effect of freezing of measles infected buffalo carcasses on the physico-chemical and textural properties of biltong. Fifteen frozen and fifteen chilled carcasses were utilised and five selected muscles (BF= *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; LTL: *Longissimus thoracic et lumborum*; RF: *Rectus femoris*) were removed. Biltong from the frozen-thawed muscles had a higher ($p \leq 0.05$) salt, protein and ash content with a lower ($p \leq 0.05$) moisture, water activity (a_w), pH and fat content. The BF muscle had the lowest salt content as well as the highest pH and fat content. Overall, frozen-thawed biltong had a higher hardness as well as lower springiness compared to fresh muscle tissue. Nonetheless, the study confirms that frozen carcasses detained due to low-level measles infection can therefore be utilised in value added products such as biltong.

For the last trial, a standard operating procedure (SOP) was developed, for the management of African savanna buffalo carcasses in Kruger National Park. Grade A and AB (sub-adult) buffalo carcasses should be utilised for aged primal cuts and value-added products. Whereas grade B, C (adult) and detained (frozen) buffalo carcasses are more suited for processed meats and value-added products. The primal cuts, LTL and SM of grade A and AB carcasses should be aged at 0-5^{o}C for 25 days in vacuum bags and sold to restaurants and lodges. The BF is ideal for the production of biltong due to the lack of decrease in shear force over an extended period. The trimming and off-cuts could be utilised for value added products (mince, boerewors and patties). Hides, trophy heads and bone meal could be processed further locally and sold at auctions and local shops.

OPSOMMING

Om ‘n beter verhouding met die aangrensende gemeenskappe te fasiliteer, ondersoek die Nasionale Krugerwildtuin die moontlikheid om buffels te oes en om dan die vleis te gebruik as stowe vleis in ‘n skoolvoedingsprogram. Om hierdie skema te finansier, word ‘n ontleding van die hele vleis voorraad waardeketting vereis om te kan sien of duurder vleis produkte geproduseer kan word van buffelkarkasse wat dan aan die publiek verkoop kan word. Hierdie inkomste sal dan gebruik word om die skoolvoedingsprogram te subsideer. Daarom is die doel van die studie om die vleis eienskappe, samestelling en algehele kwaliteit van manlike en vroulike African savanna buffel (*Syncerus caffer caffer*) spiere [*Longissimus thoracis et lumborum* (LTL)*, Biceps femoris* (BF)*, Semimembranosus* (SM)*, Semitendinosus* (ST)*, Infraspinatus* (IS) *and Supraspinatus* (SS)] te ondersoek, van diere in die Nationale Kruger Wildtuin, Suid Afrika. Die vleiskwaliteit is gekwantifiseer op die fisiese eienskappe (pH, drup- en kookverlies, kleur en taaiheid), chemiese samestelling (vog, proteïen, vet en as) en veroudering van geselekteerde spiere.

Vir die eerste proef was dertig buffels geoes in die Nasionale Krugerwildtuin en verdeel in twee ouderdomsgroepe, naamlik volwasse en subvolwasse, en volgens geslag (manlik en vroulik). Manlik (n=17) se gemiddelde “lewendige” gewig was 478.6 kg en vroulik (n=13) was 451.7 kg. Uitslagpersentasie was omtrent dieselfde 58.3% en 58.9% vir manlik en vroulik onderskeidelik. Van die ses spiere, is die drie swaarste spiere die BF (5.3-5.7 kg), SM (4.4-4.6 kg) en LTL (3.0 kg). Die gewigte van die geselekteerde spiere het met 24 tot 50 persent vermeerder tussen subvolwasse en volwasse buffels.

Die geslag het geen invloed op die fisiese en chemiese eienskappe gehad nie. Spiertipe het egter ‘n invloed gehad, met die hoogste sagtheid opgemerk vir die SS spier (31.0 N), BF spier was die taaiste (45.9 N) en die LTL spier het die hoogste proteïen inhoud (22.7%). Ouderdom het ook ‘n invloed getoon; subvolwasse buffels het die laagste ultimate pH, taaiheid en proteïen inhoud vertoon, met ‘n hoër voginhoud ($p \leq 0.05$) as die volwasse buffels. Dus het subvolwasse buffels meer wenslike fisiese eienskappe. Verder, was die gemiddelede CIELab kleur metings ook in ooreenstemming met vorige studies op wildsvleis (L*=38.54, a*=15.94 an b*=11.75).

‘n Verouderingsproef is uitgevoer om ‘n standaardprotokol vir die verouderingperiode te bepaal om die optimum sagtheid te bepaal vir die LTL, SM en BF spiere. ‘n Beduidende toename in sagtheid is opgemerk vir die LTL en SM spiere 25 dae post-mortem, alhoewel ‘n toename in taaiheid opgemerk is vir die BF spier oor die 32 dae verouderingsperiode. Verder het die kumulatiewe vogverlies vermeerder oor die verloop van die 32 dae post-mortem vanaf 4.0% tot

9.3%. Kookverlies het beduidend afgeneem vanaf dag een tot dag vyf post-mortem waarna ‘n plato oor die verouderingsperiode opgemerk is met ‘n effense toename vanaf dag 13 post-mortem. Verder het al die kleurmetings beduidend verander oor die verouderingsperiode. Die kleur van die vleisoppervlak het ligter geword (L*=41.3), minder rooi (a*=13.2), en meer geel (b*=12.4) oor die verloop van die 32 dae. Die studie het bevind dat die veroudering van die LTL en SM spiere tot 25 dae post-mortem optimale sagtheid gegee het en dat die BF spier in ander waarde toegevoegde produkte soos biltong gebruik moet word.

‘n Biltong produksieproef is gedoen om die effek van 15 gevriesde buffelkarkasse op die fisiese, chemiese en teksturele eienskappe van biltong te bepaal. Vyftien gevriesde en vyftien verkoelde karkasse is gebruik waarvan vyf spiere (BF= *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; LTL: *Longissimus thoracic et lumborum*; RF: *Rectus femoris*) uitgehaal is. Biltong van die ontdooïde spiere het ‘n ($p \leq 0.05$) hoër sout-, proteïen- en as-inhoud gehad ($p \leq 0.05$) met ‘n laer vog, wateraktiwiteit (a_w), pH en vetinhoud. Oor die algemeen, het ontdooïde biltong ‘n hoër hardheid sowel as ‘n laer veerkragtigheid in vergelyking met vars biltong gehad. Nietemin, gevriesde karkasse (karkasse met masels “detained”) kan dus gebruik word in waarde toegevoegde produkte soos biltong.

Vir die laaste proef is ‘n standaard bewerkings prosedure ontwikkel vir die bestuur van die African savanna buffelkarkasse in die Nasionale Krugerwildtuin. Graad A en AB (subvolwasse) buffelkarkasse moet gebruik word vir verouderde primale snitte en waarde toegevoegde produkte. Graad B en C (volwasse) en gevriesde buffelkarkasse is meer geskik vir geproseseerde vleise en waarde toegevoegde produkte. Die primale snitte, insluitende die LTL en SM, moet vir 25 dae verkoel, vakuumverpak, verouder word en aan restaurante en lodges verkoop word. Die BF is ideaal vir die vervaardiging van biltong as gevolg van die gebrek in afname in skeurkrag oor die verlengde verouderingsperiode. Die oortollige vleis snysels (trimmings) en lae gehalte oortollige vleis snysels (off-cuts) kan gebruik word vir waarde toegevoegde produkte (maalvleis, boerewors en patties). Huide, trofeekoppe en beenmeel kan verder geprosesseer word (deur plaaslike inwoners) en verkoop word by veilings en plaaslike winkels.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank and acknowledge my heavenly Farther without Whom nothing would be possible.

Furthermore, I would like to express my sincerest appreciation to the following people and institutions:

Prof. L.C. Hoffman (Supervisor) at the Department of Animal Sciences, Stellenbosch University. His friendship, guidance, support and encouragement given throughout the present study enabled me to grow as a researcher. Carpe diem!

Prof. P.A Gouws (Co-supervisor) at the Department of Food Science, Stellenbosch University, for his guidance in the completion of this thesis, for enabling me to further my studies and help me to reach my potential.

Dr D. Govender (Co-supervisor) disease ecologist at SANParks, for her input during this study and for an enjoyable visit to Kruger National Park.

The National Research Foundation (NRF), for the financial assistance (The opinions expressed, and conclusions arrived at in this study are those of the author and are not necessarily to be attributed to the NRF)

Freddie Viviers for his guidance, knowledge, friendship and patience throughout my study in Kruger National Park.

Prof M. Kidd, at the Centre for Statistical Consultation, Stellenbosch University, for analysing all the data.

SANParks and all the staff for giving me the opportunity to do research in Kruger National Park.

The staff members at the Department of Animal Sciences, for their friendly assistance during laboratory analysis and admin requirements throughout my thesis.

Fellow students whom I can now call my friends, for their support and assistance during the thesis.

My parents, N.J and Karen van As, as well as the rest of the family and friends for their support and encouragement enabling me to reach this point in my studies

NOTES

The language and style used in this thesis is in accordance with the requirements of the International Journal of Food Science and Technology. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between the chapters, especially in the Materials and Methods section, was therefore unavoidable.

TABLE OF CONTENT

CHAPTER 1

GENERAL INTRODUCTION

The Kruger National Park is one of the largest of its kind in Sub-Saharan Africa and is under increasing pressure to engage with the many impoverished and previously displaced communities situated along its border (Venter *et al*., 2008). Importantly, such efforts should extend beyond the mere provision of material goods and services to include emphasis on community involvement and education to support ecotourism opportunities and optimize biodiversity conservation efforts (Hoffman & Wiklund, 2006). Ultimately, improved community relations and benefit sharing may have a positive impact on future sustainability of the National Park through improved support for conservation.

Since local communities are faced with malnutrition and lack of viable protein sources (Pollock, 1969; Asibey, 1974; Hoffman & Cawthorn, 2013) there is specific interest for the sustainable resource programme in using wild animals (including Mopani worms) to supplement the diet of the poor and unemployed as a source of protein (Bender,1992; Swemmer & Mmethi, 2016). In particular, the supply of game meat to local schools in adjacent communities is seen as strategically important (building constituency for conservation in small but meaningful ways), given its high nutritional value, and limited provision of animal protein by local government programs. In this setting, the use of game meat is particularly advantageous, as it is considered a healthy, organic alternative to farmed sources of protein (Mancini, 2009; Troy & Kerry, 2010). In particular, local species including African savanna buffalo (*syncerus caffer caffer*) are rich in protein, low in saturated fat, and maintain tenderness as well as a pleasing taste associated with high-quality fresh produce (Van Zyl & Skead, 1964; Hoffman *et al*., 2004; Hoffman *et al*., 2018).

However, the creation of a sustainable market for the game meat industry is dependent on high and consistent quality of the products supplied (Hutchison *et al*., 2010). In this context, the distribution mechanisms need to be flexible and adaptive, yet strategically optimal to accommodate ad-hoc meat availability. Despite Southern Africa having a healthy buffalo population, this animal is rarely hunted for its meat and therefore little is known about the physical attributes, quality and expected yield of buffalo carcasses.

In this context, a successful meat supply needs a complex logistics system to apply the value chain analysis, since the red meat industry are determined by demand and supply forces (National Department of Agriculture, 2002). However, information on the quality, composition and characteristics of buffalo meat are lacking. Therefore, the purpose of the present study was to establish the carcass yield and composition and to determine the effects that age, sex and muscle type has on the physical characteristics, proximate composite and overall quality of buffalo meat. Insight gathered as a result of the proposed study was anticipated to ultimately help inform the logistical processes and marketing approaches that would hold the highest benefit for consumers, adjacent communities and the Kruger National Park itself.

The following approaches were followed to address this critical lack in existing knowledge concerning the ideal procedures for management of buffalo meat across different products and utilisation purposes.

1) Standard operating procedures (SOP) will be established from the carcass yield and composition, with focus on the age and sex of the animals, which assist with predicting the best utilization of the carcass. Hence utilizing the carcass for value-added products (biltong, mince) or for prime steaks are known beforehand thereby creating a more efficient supply chain.
2) Primarily block tests were conducted on carcasses to determine the quantity of meat available for different commercial products, including prime steaks, and processed meats as value-added products. Furthermore, the effect of age and sex was determined on the physical characteristics and proximate composition of selected skeletal muscle tissues to establish the quality of these different cuts.
3) Prime steaks were aged for ~32 days to evaluate at which day a tenderness level is attained that would be adequate for high-end restaurants so as to maximise the price for the product.
4) Another aspect that warranted further research was whether a measles-detained carcass can be used for the making of biltong after the mandatory 3-day freezing period required to kill the tapeworm cysts. Current practice is to put the entire carcasses into stewing meat productions (the product with the smallest profit margin). Given the high prevalence rates of measles in some areas (~40%), there is a need to find a way to maximise return from these carcasses to support financial viability.

The current thesis is outlined as follows. A concise review and synthesis of the academic literature is provided (Chapter 2) followed by results for the different sub-studies are presented in the form of manuscripts (Chapters 3, 4, 5 and 6) followed by a preliminary logistics plan with an overall conclusion and recommendations (Chapter 7).

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CHAPTER 2

LITERATURE REVIEW

2.1 Kruger National Park

2.1.1 Biophysical characteristics

The Kruger National Park (KNP) is the largest nature reserve in South Africa and one of the largest protected areas in the world, covering an area of approximately 20000 km^2 of woodland, savanna, riverine forest and mountain ranges (Fig. 2.1). The park borders Mozambique in the East and Zimbabwe in the North, while its rivers create natural boundaries to the North and South, the Lebombo hills to the East, while high-density communal areas as well as private and provincial nature reserves constitute the western boundaries (SANParks, 2016).

The biological environment consists of almost 2000 plant species, including 220 grasses and approximately 400 types of trees and shrubs. Furthermore, the fauna consists of about 150 species of mammals and more than 500 birds, 34 amphibian, 116 reptile species, in addition to more than 370 alien species (Mabunda, 2008). The climate is tropical to subtropical with mild, generally frost-free winters and high mean summer temperatures. Convective thunderstorms are responsible for high precipitation rates in the summer months between October and April. The park is host to 16 different ecosystems, featuring nearly 130 rock art sites and more than 254 cultural heritage sites. Moreover,KNP is maintained by a highly developed management system (Braack, 2000).

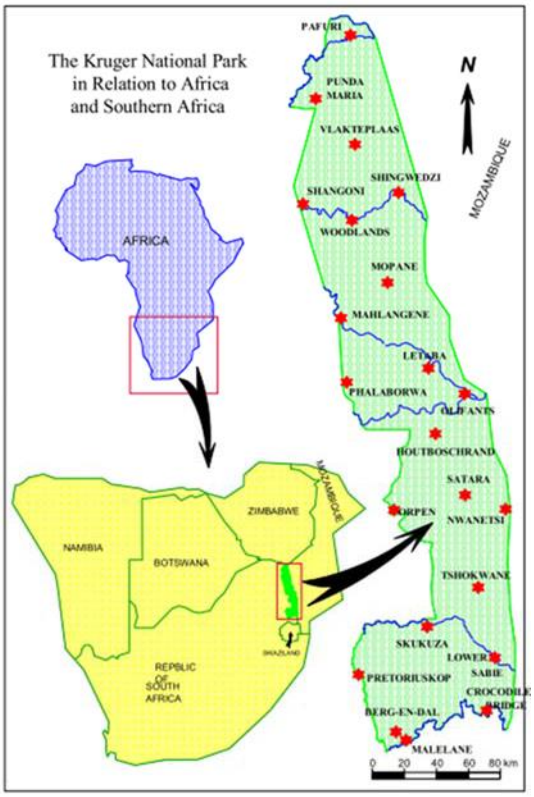

Figure 2.1 The Kruger National Park and its location in South Africa (stars represent ranger section outposts) (Anthony, 2006).

2.1.2 History

Paul Kruger, president of the Transvaal Republic, established the Sabie Game Reserve in March 1898 as a controlled hunting area (Mabunda, 2008). In 1926, the Sabie Game Reserve was merged with the neighbouring Shingwedzi Game Reserve and various private farms to form the KNP. Since the park opened to the public in 1927, KNP became a major global research and conservation institution, and remains one of Africa's foremost wildlife-watching destinations (Mabunda, 2008).

During the Apartheid era, large-scale land dispossession of indigenous populations with limited or no compensation was undertaken all over South Africa to make space for conservation reserves (Kepe *et al.*, 2005). In particular as pertaining to the KNP, marginalisation of Tsonga-speaking populations and the Makuleke clan of the Pafuri Triangle (constitutes the northernmost section of KNP) contributed to familial discord and increased rates of impoverishment during establishment of the KNP. In this context, Carruthers (1995) argued that the establishment of the KNP instilled a sense of pride in Afrikaner residents and was engineered to serve reigning nationalist policies. Indeed, racist housing and employment practices were rampant, and directly contradicted alternative approaches towards nation building for all citizens. A “fences and fines” approach to park management further aggravated disempowerment and poverty in the adjacent communities, where conflict was rampant. In addition, marginalization fuelled opposition to wildlife protection among local indigenous population groups (Hopkins, 1999). The strained relationship between the park and large adjacent communities continues to this day, fuelling hostility against the backdrop of pressing social issues including economic benefit, land claims and utilization of natural resources (Mabunda, 2004). Thus, there is increasing political pressure on the KNP to provide noticeable benefits and development opportunities for adjacent communities, with emphasis on benefits sharing, promotion of access to rural populations, and socio-economic development. Therefore, forums such as the Hlanganani Forum were created to support park-community engagement.

2.1.3 Establishment of Protected Areas with different approaches

Socio-economic pressures among communities who depend on protected areas for their livelihood contribute to these institutions being increasingly threatened (World Bank 1996; Balmford *et al.,* 2001). There is a need for optimal nature conservation strategies to effectively manage protected areas with the goals of matching conservation with human development and welfare, which were largely ignored in the past (Ghai, 1992; Songorwa, 1999).

The conservation ‘against’ the people was a traditional approach implemented by post-colonial African governments, in which policies excluded native communities as potential collaborators for park management (Gibson, 1999). Use of force, legal prosecution and fines contributed to tension and social conflict between indigenous populations and park managers (Cumming, 1993; Ghimire, 1994; McNeely, 1989).

In the developing world, integrated conservation and development projects (ICDP) have emerged as a novel approach towards harmonizing human development and biological conservation as part of a parsimonious model (Wells & Brandon, 1993; Alpert, 1996). In particular, emphasis is placed on promoting small and medium enterprise businesses as well as fair access to local natural resources. A criticism of this approach is that benefits received were often interpreted as bribes aimed at ensuring future cooperation between stakeholders (Uphoff, 1998). In more recent years, community-based conservation (CBC) projects were developed to involve rural communities in wildlife conservation. Local residents are not viewed as opponents but rather essential partners in assessing challenges and opportunities for natural resource allocation and conservation protection (Little, 1994; Murphree, 1996). An inclusive philosophy is considered an improvement over previous models to create long-standing and beneficial partnerships between rural communities and conservation initiatives (Adams & McShane, 1992; Wells, Brandon *et al*., 1992; Pimbert & Pretty, 1997; Hackal, 1999).

2.1.4 Social Ecology and political context at Kruger National Park

There is increasing political pressure on the KNP to provide noticeable benefits and development opportunities for adjacent communities, with emphasis on benefits sharing, promotion of access to rural populations, and socio-economic development.

There has been a gradual practical and philosophical shift towards understanding conservation as a process that occurs within wider social, economic and political realities within the management of KNP. However, the KNP still experiences external social problems with adjacent communities in keeping with an increasing demand for natural resources and recreation (Venter *et al.*, 2008). The KNP is situated at the centre of a three- country (South Africa, Zimbabwe and Mozambique) mosaic with sharply contrasting views on the usage of land for human development and biological conservation. In this context, several co-existing bodies have been founded to systematically address the social, political, economic and ecological issues relevant to overall KNP management (Table 2.1). Key among these issues are the need for community facilitation, environmental education, research and monitoring, as well as economic empowerment (SANParks, 2000).

Table 2.1 The crucial associates in the political, social and economic planning realm of the Kruger National Park (adapted from Mabunda, 2008)

1	The Great Limpopo Transfrontier Park and wider Great Limpopo Transfrontier Conservation Area
2	The National Department of Environmental Affairs and Tourism (DEAT)
3	The Provincial Environmental and Tourism Departments
4	The municipalities adjacent to the KNP, particularly their planning departments responsible for integrated development plans (IDPs)
5	The Road Infrastructure Strategic Framework for South Africa that aims to establish Mbombela municipal area as intellectual capital of environmental management and tourism
6	The north-eastern escarpment bioregion - which strives to link ecosystem services and livelihoods
7	The various clusters of private and provincial parks which straddle the KNP

The Social Ecology Program, now called People and Conservation, founded in 1995, facilitates effective communication with adjacent communities within 15 km of the park border, as well as dealing with issues underlying resentment and barriers to access. This program started engagement with 88 adjacent communities, and by March 2000, 24 permanent social ecology staff were appointed. Monthly meetings are organized to discuss pertinent community issues, including illegal wildlife use, land claims, and wild animal diseases/zoonosis (H. Mmethi, personal communication, August 29, 2003). In addition, community property associations (CPA) that negotiate land claims in collaboration with the private sector have been formed. Furthermore, 1998 saw the first successful land claim: in 1995, the Makuleke Tribe applied for repossession of land (23 700 ha) under the restitution of Land Rights Act (1994) and the Communal Property Associations Act (1996). The portion of land was known as the 'Pafuri Triangle' at the northern tip of the park from which the tribe was evicted in 1969. A procedure was negotiated to keep management of the Makuleke Contractual Park under the KNP as defined by the CITES (Convention on the International Trade in Endangered Species) treaty (Carruthers, 1995; Steenkamp & Urh, 2000; Reid, 2001).

Social Ecology programs were initiated to help benefit the KNP and the adjacent communities. At the end of 2015 in the Kruger benefit report with reference to the managing relationships and restoring rights: 108 196 people entered KNP for free in 2014 and 181 half price permits are supplied yearly to native communities. Furthermore, R1 452 258 was paid to plaintiffs for livestock loss due to predators and 175 people work in the Makuleke and Nkambeni contractual parks while a 10% turnover fee is also paid to the Makuleke Tribe from concessions and R47 300 is contributed to the Nkambeni community projects per month (SANParks, 2016).

2.1.5 Socio-economic development of adjacent communities

Multiple programs have been implemented over the years in order to drive socio-economic development for adjacent communities, including Park Forums, Environmental Education, Kids in Parks (KiP), The National Parks Week, Imbewu (seed), Kudu Green School Initiative (KGSI), Kids in Kruger, Junior Ranger Programme and Sustainable Resource Use Programmes.

The Sustainable Resource Use Programmes are implemented to help contribute to the socio-economic well-being of adjacent communities, including access to ecological resources for subsistent use. Examples of these include the expanded Public Works Programme (EPWP), Social Investment Programme and SMME (small, medium and micro-sized enterprises) development (Swemmer & Mmethi, 2016). Several initiatives have been explored to protect medicinal plants and build relationships with traditional healers. Efforts have also been made towards sustainable offtakes of wild animals including buffalo, a process managed by the

Wildlife Products Section (WPS) in Skukuza.

The Expanded Public Works Programme (EPWP) is a government initiative which seeks to create temporary working opportunities towards poverty relief in adjacent communities (Swemmer & Mmethi, 2016). Furthermore, community-based economic development opportunities have been developed to assist SMMEs (Eliffe & Manning, 1996). There are several SMME currently registered with SANParks, providing a variety of products and services (catering, entertainment, equipment and transport) to Kruger business.

2.1.6 Hlanganani Forum

The Hlanganani Forum (HF), one of 7 community forums active throughout the area bordering the Park, was introduced in 1994 following a meeting between the KNP and impoverished adjacent communities inhabiting an area approximately 15 km within the park borders observed by H.P Chauke (personal communication, August 22, 2003). The HF included representation of communities subjected to forcible removal during the Apartheid era (Shikolokolo, 2010). Discussions focused on damage-causing animals and absence of compensation for such damage. Emphasis was further placed on 1) building trust between communities and the park, 2) resolving mutual problems, 3) facilitating business development and support, 4) promoting environmental education, and 5) enhancing capacity-building within the region. The HF is considered the most active KNP forum (Anthony, 2006), and in 2000 established a new constitution focused on establishing working relationships between different stakeholders. Primary and secondary objectives identified in the new constitution are summarized in Table 2.2.

Table 2.2 Primary and secondary objectives identified in the new constitution for establishing working relationships in KNP (adapted from Anthony, 2006)

	Primary objective	Secondary objective
1	Strengthen a healthy relationship between the Forum, KNP and the Government.	Managing different conservation and environmental related projects that are beneficial to the community members. Intended at community development and empowering the community socially and economically.
2	To strive toward development of the previously disadvantage communities.	Creating employment opportunities.
3	To generate employment opportunities either in KNP, the Government, or even the Forum.	Establishing a support centre that will look at training of professional hunters, compensation of people who have lost their livestock and also giving information to the relevant law enforcement officers in the Park and the Government about people who transgress the law according to the Nature Conservation Act.
4	Help educate communities about conservation and further environmental matters.	
5	To help take care of problem animals, either by the tendering process or by employing professionals.	
6	To compensate members who lost their livestock.	

2.2 Management and justification

2.2.1 Threshold for potential concern (TPC)

The KNP is a large national park, which requires complex, adaptive strategies to effectively manage internal needs in the context of external socio-economic and political factors. The relevance of such an approach is further supported by the many adjacent communities which influence, and are influenced by, issues of biodiversity, resource allocation and socially conscious development (Pienaar, 1983). The concept of a threshold for potential concern (TPC) provides a useful basis to forecast management outcomes. Biophysical TPCs include real transitions beyond a desired limit, including the pending danger of loss of species (Grant *et al*., 2011). A benchmark or threshold should be acquired for each situation to measure the impact and guide the management of individual TPCs. For most indicators, such information is however not accessible. Therefore, historic data may be used as an initial benchmark, and accustomed with the improvement of the system. The historical framework that was used for TPCs seeks to guarantee that the future generations still have possibilities of diverse outcomes. Originally, the TPCs were developed to try and detect unacceptable or homogenisation change, as shown in Table 2.3.

Table 2.3 Development of TPCs to try and detect unacceptable or homogenisation changes in the KNP (adapted from Grant, Peel, & Bezuidenhout, 2011)

1	Structural diversity in the woody and herbaceous component
2	Patchiness in the woody and herbaceous component
3	Dominant and subdominant tree species
4	Basal herbaceous cover
5	Herbivore species composition
6	Herbivore distribution
7	Landscape function (nutrient cycling, infiltration and soil stability)

The TPCs established for the KNP attempted to address the outcomes of this intricate system according to vegetation composition and structure, as well as herbivore populations' distribution. Herbivory is a natural disturbance, which enables compensatory growth, pollination and seed dispersal, among others. Thus, herbivores act as disturbance agents implying that biodiversity may be maximised with intermediate levels of disturbance. Furthermore, it is important that the gradient of disturbance intensity of herbivory is spatially heterogeneous. In particular, some places should have low levels of herbivory, while others should have intense levels of herbivory as a disturbance agent. These gradients help create different combinations of species to exits in response to herbivory disturbances. Mega-herbivores induce mechanical and structural changes and act as ecosystem engineers (SANParks, 2018).

The management of mega-herbivores become important after they pass the desired threshold. In the past, KNP had low mammalian herbivore numbers, given the rinderpest epidemic and uncontrolled hunting (Mabunda *et al*., 2003). Between 1959 and 1980, the park was fenced to control the spread of diseases, keep predators and other dangerous game from leaving the park, and to simplify patrolling the boundaries for poachers. This change resulted in less water access for the animals and artificial water was provided. The alteration in water provision created several unanticipated consequences, including a decrease in rare antelope numbers, indirectly affected by higher competition from water-dependent species as well as an increase in predators. Elephants benefited the most from the artificial water and grew to approximately 7000 towards the end of the 1960s. Numbers were kept in check through harvesting, and between 1966 and 1994, nearly 16000 elephants were removed from the park. A moratorium on the harvesting of animals instituted in 1994 caused the number of elephants in KNP to increase to 19000 by 2017 (SANParks, 2018). This increase in mega-herbivores, together with the residency imposed by the artificial water provision, concentrates space use and foraging by elephants and can deteriorate the vegetation, thereby negatively affecting biodiversity. The management of elephants and their ecological impact is fixed in the overall SANParks objective of providing assistance to people, restoring or sustaining the ecosystem integrity, as well as taking cognisance of aesthetic and wilderness qualities (Ferreira *et al*., 2012).

2.2.2 Damage-causing animals (DCA)

Problems caused by damage-causing animals (DCA) in KNP is a primary reason for negative attitudes towards KNP. This issue was also raised at the HF meeting, with discussions centred around the absence of compensation to the damage caused by these animals. Farmers were not being financially compensated for losses until 2012, despite promises that compensations would be forthcoming. The KNP was perceived by many adjacent communities as contributing to present wrongs by harbouring dangerous animals that causes extensive damage and threatening livelihoods of the very communities it seeks to empower with socioeconomics and resources (Anthony, 2007). Moreover, DCAs can also create misunderstanding and distrust with respect to the purpose of KNP and its assumed commitment to improve relationships with its adjacent communities.

Damage-causing animals outside KNP that leave KNP in South Africa, particularly into areas owned by adjacent local traditional communities, falls under the jurisdiction of the Local Provincial Nature Conservation Authority. The complaint will be investigated by the provincial authority involved with wildlife management. These officers will assess the scene based on a set of criteria. The selected officials will be issued with a permit, usually the relevant Section Ranger, of SANParks with the required skill and experience. Even though the decision must be sanctioned by the Head of Department: Conservation Management, the officials must contemplate the following options, in sequence (Ferreira *et al.,* 2012).

1) Chase offending animals back to KNP and repair the fence;
2) Capture and translocation if viable;
3) If the above options are not viable, harvesting the individual will be the last resort.

In SANPark's case, the compensation is mainly through making available the carcass to the owner of the land on which the individual was harvested (no meat inspection is done; thus, the consumption of the carcass is left at own risk). The meat will remain the property of the owner of the land on which the individual was harvested. When harvested in a tribal area, the meat will be used by the local community (Ferreira *et al.,* 2012).

The DCAs inside Kruger such as elephants entering rest camps and staff villages will be chased out using numerous resources and is the responsibility of the local section ranger. Repeat offenders that regularly enter staff villages and rest camps throughout the day and pose a threat to human life will be harvested following approval by the Head of Department: Conservation Management (Ferreira *et al.,* 2012). The carcass will then be processed at the WPS and the meat will be sold and/or donated to local schools.

2.2.3 Management options

There are three primary management options for the increase in the mega-herbivores species, namely translocation, contraception and harvesting. Translocation holds the benefit of establishing another animal population elsewhere, while contraception via hormonal control may also assist in managing the population of mega-herbivores. Harvesting is considered the only suitable long-term alternative. While the use of anaesthetic drugs offers an ideal approach to harvesting, meat from animals harvested in this manner cannot be used for human consumption, while leaving the contaminated carcass in the field for scavengers is also non-viable. In the past, the use of succinyldicholine chloride (SDC) for harvesting of mega-herbivores had the advantage of preventing wounds and providing a greater safety margin for staff and scientists. Furthermore, SDC has been approved for human consumption of the meat since component compounds of SDC occur naturally in mammalian bodies. Moreover, SDC is a neuro/muscular blocking agent and therefore paralyse the animal by preventing brain impulses from reaching the muscles. The use of SDC on elephant is however now considered inhumane since the animals die from suffocation while fully conscious and paralyzed; marksmen with live ammunition from a helicopter is now currently preferred. In contrast, the use of SDC for harvesting of buffalo has not yet been discontinued and is still practiced today (Whyte, 2001). It was decided to use the meat and animal by-products from harvesting, leading to the establishment of a certified abattoir in the KNP. Techniques for harvesting were further refined to align with ethical standards for animal welfare (Pienaar, 1983). Furthermore, animals need to be harvested for various reasons, including disease monitoring, research, DCA and sustainable use and the best method, that allows for maximum use of those carcasses needs to be sought.

In 1967, the first complete aerial census on buffalo and elephant was carried out, with 15758 buffalo and 6586 elephants counted. Furthermore, an adequate lower and upper population parameter were set for elephants and buffalo, and an annual sustainable harvesting program put in place. However, this signalled the start of the "management era" during which the policy was to hold the elephant population at a level around 7000 (Whyte, 2004), about 16000 elephants were harvested between 1966 and 1994. A moratorium on harvesting was introduced in 1994 and elephant numbers has risen to around 19000 in 2017 (SANParks, 2018). These days KNP will be pursuing the elephant population through minimizing the distribution of additional water points and dams, removing restrictions such as fences where appropriate and mimicking the effect of natural water distribution. Although the Kruger Elephant Management Plan does not involve harvesting in the long run, nonetheless it may include harvesting as a short-term measure to deal with the impact of historical elephant management strategies on current elephant numbers and behaviour (SANParks, 2012). Presently, harvesting is not an option: even disturbance harvesting at this stage are against the norms and standards for elephant management.

2.2.4 Justification for the "sustainable off-take" of buffalo

The scientific justification for the "sustainable off-take" of buffalo is found in the Constitution of the Republic of South Africa. Section 24(b) of Act 108 of 1996 states that everyone has the right to have the environment protected for the benefit of present and future generations through reasonable legislative measures. Subheadings (i) and (iii) emphasize preventing pollution and ecological degradation, securing ecologically sustainable expansion, and using natural resources to encourage reasonable economic and social development. These principles accord with the main goals of the Convention on Biological Diversity (CBD), i.e. 1) sustainable use of natural resources, 2) conservation of biological diversity, and 3) fair and unbiased sharing of benefits from the use of genetic resources (Republic of South Africa, 2008).

According to the *National Environmental Management: Protected Areas Act, 57 of 2003,* the purpose of the declaration of protected areas lies in guaranteeing a constant supply of environmental goods and services, providing for the sustainable use of biological and natural resources, to produce or increase destinations for nature-based tourism; to manage the interrelationship amongst human settlement, natural environmental biodiversity and economic development; largely, to contribute to human, cultural, social, spiritual and economic development; or to restore and rehabilitate degraded ecosystems and promote the recovery of endangered and vulnerable species (National Environmental

Management, 2004).

Even a large park like KNP struggles with the application of the principles of keeping all their ecological processes and system drivers intact. The historical influence humans had on the system through hunting, setting fires and creating 'landscapes of fear' for certain animal species is no longer effective, necessitating management actions to understand the role of animal-borne diseases and zoonosis which drive buffalo sustainable off takes. The number of animals to be harvested was calculated so as to not have a detectable influence on the buffalo population number. SANParks achieved this by removing fractions that are smaller than the Coefficient of Variance (CV) measured for r_{max} (expected growth rate in a population if there are no limitations on that population) of the proposed range of removals using the normal park models also giving the trends in EVI (enhanced vegetation index). SANParks uses theoretical growth, derived from life history parameters to predict r_{max}. Currently the r_{max} for buffalo is 0.226 and thus the CV is 0.026, furthermore the buffalo population estimate was 48560 in September 2015. Moreover, removing the approved 400 buffalo for 2017 is far less than the CV of 0.026 that equals to the amount of 1263 (0.026 x 48 560 = 1263). Thus, there is no risk to a detectable buffalo population decline. However, in KNP, due to its size and relative intactness, removals are done so that they do not impose on or negatively affect ecological processes, instead of mimicking them (SANParks, 2017).

The rationale for the sustainable buffalo off-takes in 2016 was due to the drought experienced during the 2015/2016 climatic year and the subsequent impact on the biodiversity inside the park as well as the subsistence agriculture (livestock and crops) outside the park. Buffalo are very sensitive to droughts, (the numbers decline in drought due to low food availability), and therefore less than 0.5% (105 buffalo) of the population was harvested. This opportunity opened options for sharing biodiversity benefits and in the longer term, building local conservation constituency. In the case of the 2016 offtakes, the feasibility and logistics were explored in the distribution of the buffalo meat outside the park and to start learning about the potential to increase positive influences on biodiversity conservation, by sharing benefits in this manner.

2.3 Importance of buffalo in the Kruger National Park

2.3.1 Buffalo in Africa

The African buffalo can be traced back as far as 1553, when French physician and naturalist Pierre Belon made notes of a creature which he described as a "little ox" (Mloszewski, 1983) corresponding to that of the smaller northern buffalo (*Syncerus caffer aequinoctialis*). Over the next two centuries, very little was published about the African buffalo (Mloszewski, 1983). Throughout the mid- and late-1800s, the quantity and depictions of the African buffalo increased due to increased travel in the African continent (Mloszewski, 1983; Prins, 1996). Early mammologists recognized 43 sub-species after the African buffalo was renamed from *Bos caffer* to *Bos syncerus* in 1847, making it the African mammal with the largest morphological variation (Du Toit, 2005). However, the number of sub-species has been narrowed down to between two and four, contingent upon the classification system utilised.

2.3.2 Physical characteristics of African savanna buffalo

The African savanna buffalo has a barrel-shaped, wide-chested body, with stocky legs, a short thick neck, and large head. The most noticeable character on the head apart from the horns are the large, droopy ears fringed with long hairs (Nowak, 1991; Alden *et al*., 1995). Its body weight ranges between 650-850 kg for bulls and 520-750 kg for cows, with a mean shoulder height of 1.5 m in adults (Bengis, 1996). Juvenile buffalo may undergo a change of colour from yellow-brown to dark brown before reaching adulthood. Adults are dark brown or black, with males naturally darker compared to females (Buchholtz, 1990; Nowak, 1991; Alden *et al.,* 1995). Both sexes of African savanna buffalo have horns, although their shape and size are variable (Alden *et al.,* 1995). The horns curve downwards from their source in the skull, before curling inwards and upwards (Buchholtz, 1990). In males, the horns expand into a heavy shield over the forehead, termed the "boss" (Nowak, 1991; Alden *et al.,* 1995) which does not develop until the age of three to five years. In large males, the length of the horn along the outer curve can reach 160 cm, with a horizontal spread exceeding 90 cm (Buchholtz, 1990; Alden *et al.,* 1995). On average the horns of the female are thinner and shorter with the boss absent or incomplete (Alden *et al.,* 1995).

2.3.3 Ecology of African savanna buffalo

African savanna buffalo occupy an extensive range of habitats across Africa, including coastal savanna, montane grasslands, lowland rainforest, semi-arid bushlands and the Miombo brachystegia woodland (Nowak, 1991). However, they do not inhabit deserts and sub-desert regions such as the Namib and Saharan/Sahelian transition zone (Prins & Sinclair, 2013). Buffalo are absent in the Karoo and grassland plains of the Highveld, given their need for adequate vegetation, shade and water access. Indeed, forage availability, cover for protection against predators, proximity to water and herd mobility all influence habitat selection (Funston *et al*., 1994). Buffalo drink water frequently, and often graze and take shelter in thick, riverine vegetation (Skinner & Chimimba, 2005). African savanna buffalo prefer riverine habitats throughout the dry seasons, since these areas provide a supply of water and vegetation, as well as protection from environmental extremes and predators (Sinclair, 1977; Redfern *et al*., 2003; Ryan, 2006; Cornelis *et al.,* 2011). Buffalo will persevere in semi-arid areas, provided that surface water is available 20-40 km year-round (Naidoo *et al*., 2012; Prins & Sinclair, 2013).

2.3.4 Social behaviour of African savanna buffalo

Buffalo are sociable ungulates and occur in mixed herds with herd numbers in the KNP averaging between 3000 and 5000 (Whyte, 2004). The size of the herd correlates well with the proportion of juveniles in the group (Tambling *et al*., 2013). Small home ranges are generally observed in forested or high-rainfall ranges, and large home ranges are generally observed in open, drier habitats. The young bulls will leave the herd and continue to form smaller bachelor herds that have the tendency to inhabit smaller ranges than the female-dominated herds. These smaller bachelor herds have higher levels of risk associated with predation, given smaller average herd sizes, and also tend to inhabit riskier environments (Tambling *et al.,* 2013). Normally, the herds will move in the morning and again in the early evening towards a water source. Buffalo are most active when feeding early in the morning and late afternoon. Moreover, they are also known for feeding bouts at night, and given a high predation risk, buffalo might decrease their early morning movement and increase their midday movement (Tambling *et al.,* 2015).

2.3.5 Social structure of African savanna buffalo

The essential family structure of a Buffalo herd comprises adult females and males, infants, juveniles, and sub-adults (Mloszewski, 1983). This is a very simplistic classification; however, various authors have used more complex classification systems which consider age, status, and grouping. Rank and hierarchy are applicable within a group or herd and any buffalo joining the herd that already have a place in a different herd or group will not be challenged or dominated when entering a new herd. However, the new entrant does not hold the rights associated with status or rank in the entered herd (Sinclair, 1977; Mloszewski, 1983; Prins, 1996). Consequently, the primarily groups found in a herd can be limited down to bulls (adult and sub-adult), cows (adult and sub-adult), calves and juveniles (Winnie *et al*., 2008).

2.3.6 Reproduction and sexual development of African savanna buffalo

In the KNP, calves are typically born between January and April, with a peak in January/February, correlating with the peak in grass growth and protein content (Skinner & Chimimba, 2005). Males reach sexual maturity between the age of 3.5 and 5.5 years; however, older dominant bulls prevent the younger bulls breeding till they reach an age of seven to eight years (Skinner & Chimimba, 2005). In addition, bulls ten years and older are no longer found in the breeding herds (Skinner & Chimimba, 2005). At the age of four to five years, females typically give birth to their first calf (Carmichael *et al*., 1977; Taylor, 1985; Mizutani, 1987). The gestation period is ~340 days (Ryan *et al*., 2007) which results in a single born calf with a weight approximately 31.1 kg for males and 31.2 kg for females. Calves may continue to stay with their mother for two years following approximately nine months of suckling. The inter-calving period ranges between 13 and 29 months, contingent on the accessibility of high-quality forage and grazing (Sinclair, 1977; Prins, 1996).

2.3.7 Diseases affecting African savanna buffalo

The four main diseases that infect African savanna buffalo are Corridor disease (CD), bovine tuberculosis (BTB), bovine brucellosis and foot-and-mouth disease (FMD) (Bartels *et al*., 1996; Laubscher & Hoffman, 2012). Buffalo are required to test negative for all four diseases to be considered 'disease free' to enable movement within the country. The other diseases that affect the carcass of the buffalo and has a direct impact on its use as a meat source are sarcocystis and beef measles (*Cysticercosis*).

2.3.7.1 Corridor disease (CD)

Corridor disease is a serious protozoal disease caused by *Theileria parva lawerence*, which is usually transmitted by the brown ear tick (*Rhipicephalus appendiculatus)* (Du Toit, 2003)*. Rhipicephalus appendiculatus* is a three-host tick since it has to feed on three different hosts during its three different life cycles (Berry, 1996). The parasite can only be contracted during the larval stage when the larvae feed on an infected buffalo and can then only be transmitted during the adult stage (Meltzer, 1996). The symptoms of CD appear after an incubation period of nine to 20 days and include swelling of lymphadenopathy, fatigue, nasal discharge, emaciation and diarrhoea. The ticks can be regarded as free from CD two years after the infected buffalo have been removed from the veld (Du Toit, 2003).

2.3.7.2 Bovine tuberculosis (BTB)

Bovine tuberculosis is a bacterial disease caused by *Mycobacterium bovis,* which is also responsible for tuberculosis in cattle. During the 1950s, the disease spread from cattle to buffalo in the southern region of the KNP (Du Toit, 2003). When a buffalo is infected, *Mycobacterium bovis* will spread naturally within the herd. When infected, buffalo survive several years before showing signs of BTB infection. Furthermore, buffalo remain infected until they die, since they are the maintenance host (Cross *et al.,* 2004). The transmission of the mycobacterium can be spread through cough droplets in the atmosphere and through mediums such as contaminated food and water; lions can also become infected through eating a contaminated buffalo. The clinical symptoms include coughing, emaciation and swollen lymph nodes which may rupture (Du Toit, 2003).

2.3.7.3 Bovine brucellosis

Bovine brucellosis is caused by the bacterium *Brucella abortus.* Transmission usually occurs orally, but bacteria can also be transmitted via the semen of infected males or via the milk of infected cows (Du Toit, 2003). The infection is believed to cause abortion of the first calf after infection, which is maintained in buffalo. However, after the first calf, the cows develop antibodies towards the infection, and are usually asymptomatic (Madsen & Anderson, 1995). Once the infection becomes chronic, symptoms are simpler to identify: bulls will show testicular inflammation (orchitis) and buffalo will develop swelling of the knee or other joints known as hygroma and bursitis (Oberem & Oberem, 2011).

2.3.7.4 Foot-and-mouth disease (FMD)

Foot-and-mouth disease (FMD) is caused by *Picornavirus* and leads to the formation of vesicles and lesions of the mucosa in the mouth and interdigital skin (Du Toit, 2003). Furthermore, FMD is a highly contagious notifiable disease, which is maintained in buffalo and can spread to domestic livestock where it results in huge losses in production. While mortality in cattle is usually less than one percent (<1%), morbidity is often high. Transmission of the virus usually occurs via air or through direct contact with animals (van Schalkwyk & Hoffman, 2010). There are three strains of FMD in the South African Territories (SAT), i.e. 1, 2 and 3. Infection with FMD lowers the productive capacity of animals and has a drastic negative effect on meat exports as no meat can be exported from a country that has FMD (Grubman & Baxt, 2004). The veterinary red-line was therefore created to keep control of the FMD-infected areas and the FMD-free areas with a buffer zone in between, thereby allowing a country to export meat from the free zone (Thomson, 1996). No raw meat may leave either the red or buffer zone.

Due to buffalo in the KNP being infected has resulted in the Park being zoned infected, making the adjacent communal rangelands within the buffer zone. This has created its own socio-economic problems with the cattle owned by the communities having little economic value as the meat cannot be sold easily into the rest of South Africa. As a result, there are few registered cattle abattoirs in the communal areas adjacent to the KNP. Also, with the development of larger shopping malls within these communities, more structured meat selling facilities (butcheries/supermarkets) have been developed who typically “import” their fresh and processed meat from other regions in South Africa, thereby removing the demand for local beef (Nkosi, 2015).

2.3.7.5 Sarcocystis

Sarcocystis have been reported from the African savanna buffalo, but the species have not been named, the name *Sarcocystis cafferi* has been proposed (Dubey *et al.,* 2014). It appears as light grey oblong dots. Moreover, it is diagnosed on the abattoir floor by making four incisions in the shoulder muscles for secondary inspection as well as the majority of cuts surfaces (i.e. 19+). When one or more cysts are observed on cut surfaces it shows excessive infestation of the carcass, which must then be condemned. Treatment (freezing) of conditionally passed carcasses affected by parasitic intermediate stages (measles) will kill the parasite. Thus, the carcass should be split and frozen for a minimum of 72 h with an air temperature of at least -18°C (National Department of Agriculture, 2007).

2.3.8 The wildlife product section in Skukuza

The Wildlife Product Section (WPS) is an abattoir and processing plant located between the Skukuza Airport and Sand River in the KNP. Legally, it is a low-throughput abattoir, registered to only slaughter less than 30 units per day, although the provincial executive officer (PEO) may determine a lower maximum throughput for the abattoir. Category A game does not apply to slaughter facilities registered under the game meat scheme, except in special cases under a protocol approved by the PEO (Department of Agriculture, Forestry and Fisheries, 2012). The abattoir was built in the early 1970's and expanded over time. Construction was concluded in 1981 with a canning factory as well as a biltong factory. The abattoir was planned and constructed to cater for the harvesting operations in the KNP that eventually came to an end in 1995. In 2010, the abattoir facility was upgraded to cater for the proper management of 'Damage Causing Animals' as well as to serve a research purpose. In early 2016, the abattoir was re-registered and met the food and safety regulations requirements. The abattoir performs ad-hoc operations on a regular basis and contributes to community beneficiation programmes including the buffalo project. Furthermore, the abattoir is equipped to produce fresh meat products (goulash, steaks, sausages, stewing meat) for local consumption. At this stage, the WPS slaughters on average 30 buffalo a week ("Conservation Management Services – KNP")

The WPS is also evaluating the expansion of its operations to service local livestock farmers, which could be mutually beneficial in terms of community benefits and meeting the veterinary regulations regarding animal slaughter and movement out of a Foot and Mouth (FMD) infection zone (Fig. 2.2). Firstly, the WPS could provide a slaughter, processing and retail service for local small-scale communal livestock farmers in the FMD buffer zone adjoining the KNP, which currently doesn't have such a facility/service easily accessible. The WPS could also stimulate the development of local small, medium and micro enterprises (SMMEs) in the buffer zone, in the form of livestock traders, livestock transporters, secondary-products value chain development, such as small-scale tanneries for hides, leather product manufacturing, bone/horn crafts (D. Govender, personal communication, June 20, 2017). Furthermore, the WPS could link local producers and KNP meat consumers in a meaningful way ensuring product safety and quality, and meeting the current disease regulations, which currently prevent raw meat from cloven hoofed animal leaving the buffer zone. However, there are also negative aspects to the expansion of the WPS operations to service local livestock farmers; bringing in live animals can result in diseases entering the KNP, Furthermore, the transport of live cattle to be slaughtered in KNP can be unpleasing for the tourist and "against" the purpose of a National Park. Also, the small-scale communal livestock farmers may not understand the reason for their cattle to be declared as condemned or detained if they did not meet National health guidelines and thus not receiving the money they were expecting, resulting in strained relationships. There is also the question around lairage of cattle at the WPS and the effect that it could have on the larger predators' behaviour patterns. Alternatively, meat and meat products from communal farmers could be brought into the Park (who currently purchase their meat from the larger supermarkets in the surrounding metros), but this would still require a medium throughput abattoir outside of the park (D. Govender, personal communication, June 20, 2017).

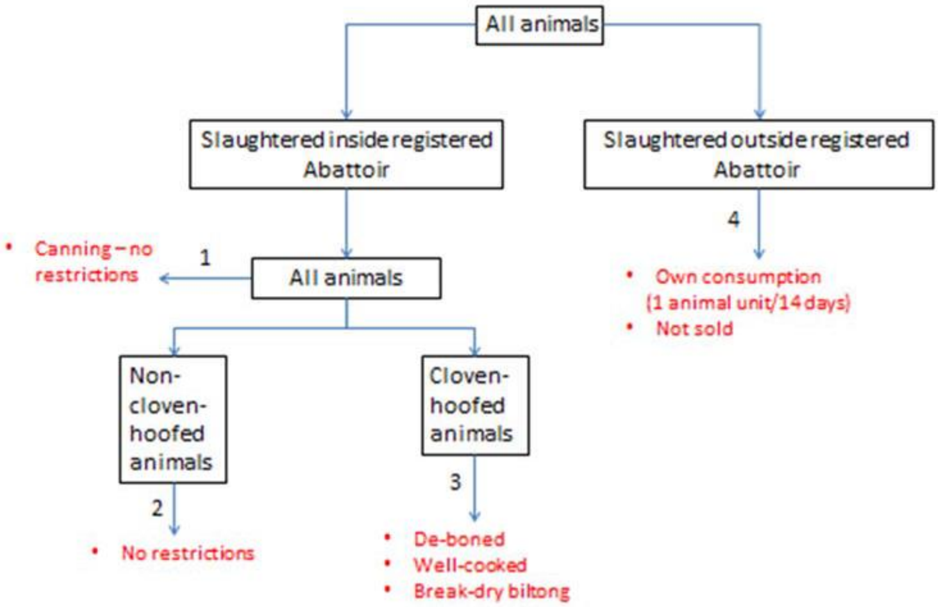

Figure 2.2 Veterinary regulations regarding animal slaughter and movement out of a Foot and Mouth (FMD) infection zone (Swemmer & Mmethi, 2016).

The meat of harvested buffalo and elephants is currently harvested for economic, ecological and social reasons (including human-wildlife conflict) and some of it is donated to adjacent schools (SANParks, 2018). In addition, the sustainable resource programme forms part of awareness and outreach raising in adjacent communities and helps to create a positive park-stakeholder relationship between the different stake holders (tourist, politicians and local communities). Importantly SANParks is very aware of managing trade-offs between stakeholder groups and stakeholder groups and the environment, understanding that benefits to one group sometimes come at a cost to another group for example Big Five game viewing from the safety of your car versus damage causing elephant in your crop field (Swemmer, 2012).

2.4 Logistics of the meat supply of buffalo in Kruger National Park (KNP)

2.4.1 Definitions and concept of value chain analysis theory (VCA)

It is important to excel in the management of both physical and technological resources to allow companies to compete in the global marketplace (Rayport & Sviokla, 1995). In this context, value chain analysis (VCA) theory has emerged as a useful tool for assessing the role of value in the relationship between supplier and customer (Schmitz, 2005). Supporting models, including lean approach theory, support VCA to remove non-value adding activities along the "value chain" (Hollingworth, 2002; Droste, 2007). Kaplinsky and Morris (2000) defined "value chain" as the full set of activities required to bring a service or product from raw material through different phases of production, transformation and delivery, for optimal social benefit and environmental sustainability. Kaplinsky & Morris (2000) expanded on the aforementioned definition to define “value chain” as *“the full range of farms, firms and their coordination in value-adding activities that produce particular raw agriculture materials and transforms them into particular food products that are sold to a final consumer and the disposal after use, in a manner that is profitable throughout, has broad-based benefits for society and does not permanently deplete natural resources”.*

In contrast to a “supply chain”, where emphasis is placed on provision of goods from the supplier to the customer, “value chain” focuses on value the customer may hold for the supplier (Feller *et al*., 2006). For this reason, value chains are also known as “demand chains”. The value chain is a very adaptive model, leading to many definitions and different tools of analysis (Womack & Jones, 1996). Furthermore, this model can be applied to different levels and approaches, such as at a particular chain actor, industry level or through more of a holistic approach.

2.4.2 Supply chain management (SCM)

In addition to VCA, supply chain management (SCM) is an important concept which originated in operational research focusing on logistics. The SCM is defined in three different categories; some define SCM in operational terms involving the flow of products, while others view it as a management philosophy, and some view it in terms of management processes (Tyndall *et al*., 1998). Driven by the rapid technological development and industrialisation of the 1980s, the SCM revolutionised the grocery and textile industries in the 1990s. This method was refined by Wal-Mart, one of the world largest firms with reference to their turnover and sales (Johnson, 2006).

Tyndall *et al.* (1998) acknowledged that “SCM logistics” include managing the flow of products and materials from source to user. The SCM or the logistics system comprises of the total flow of materials, from gaining all the raw material through processing to the finished product and the delivery thereof to the ultimate users. This process further relates to counter-flows of information such as the records and control of material movements. Thus, logistics is one of the functions contained within the SCM.

2.4.3 Limitations of the value chain

Value chains are complex, with inherent limitations and challenges; according to the type of product, the value chain analysis differs (Holweg & Helo, 2013). Furthermore, approaches struggle to resolve all the complications in the food system (FAO, 2014). The first limitation is how to implement the value chain method, since there is no agreed best method (FAO, 2007). Secondly, the development of value chains is primarily fixated on the economic aspects and less on environmental and social impacts. A sustainable firm is one that takes all the different aspects into account namely: environmental, social and economic. This can lead to a one-directional focus that can result in an unsustainable value chain, which will lower the chain's pursuit of sustainable competition (Fearne *et al*., 2012). Lastly, the development of a value chain is a timely process that requires time and resources when attempting proper implementation; this aspect is often overlooked which frequently leads to inadequate and insufficient value chain analyses.

2.4.4 Basic model of a value chain

The value chain is a model that defines a series of value adding activities that links a company's supply side with its demand side (Rayport & Sviokla, 1995). "Value" defined by Porter and Millar (1985) is the amount customers are willing to spend for what a firm provides. Value chain analysis is used to understand socioeconomic and power relationships in the production chain from the raw material to a final product. It takes a financial viewpoint of the consecutive value creation process in a network of firms. The value chain can be used to strategize and enhance efficiency in industrial practices and operations. Furthermore, the value chain analysis which assist in the food industry cultivate and enhance the effectiveness, that aids a spectrum of consumers and producers and results in an improved demand management (Tippayawong *et al*., 2017).

2.4.5 Primary and secondary value adding activities

Porter (1985) argued that the value chain consisted out of nine "value added" activities operating within a firm. The firm's competitive position is determined by these activities (Stonehouse & Snowdon, 2007). These "value-adding" activities consist of primary activities, related directly to distribution, sales and manufacture. There are also secondary activities which support primary activities, such as finance, human resources, planning and research and development (Fearne *et* al., 2012). The primary activities consist of: inbound logistics, operations, outbound logistics, marketing and sales and service. The supporting secondary activities consist of: procurement, human resource management, technology development and infrastructure.

2.4.6 Profit margins

A profit margin is the value created by the company and equates to the value created and captured minus cost of creating the value. The margins are assorted across the producers, suppliers, distributors, customers and other role-players in the value system. Assigning margins for agriculture commodities at each stage in a value chain is straightforward. Firstly, a price is determined for each activity in a chain for a specific commodity. By using price spreads, one then evaluates how much value each activity adds to the product (Rieple & Singh, 2010). Fig. 2.3 represent the primary and secondary/support activities and margins typical for an agricultural commodity.

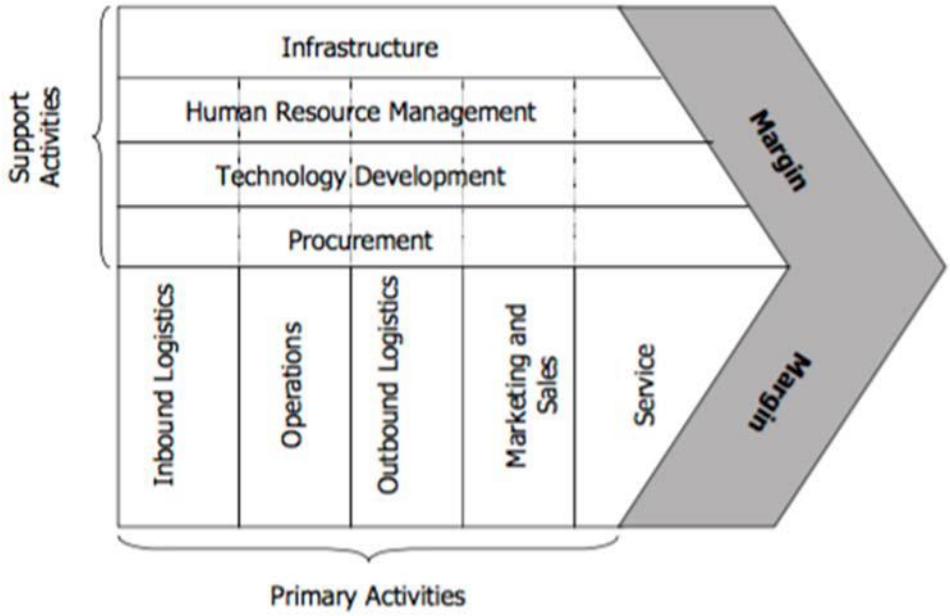

Figure 2.3 The Basic Model of Porter representing the primary and support activities (adapted from Porter, 1985).

2.4.7 Conception of value

Value is derived from customer needs, as it is important to define value from their perspective (Womack & Jones, 1996). Customer perceived value is defined by Monroe (1991) as the ratio between the perceived benefits (e.g. service attributes, technical support), and perceived sacrifice (e.g. cost of installation, purchase price, risk of failure). Creating 'value added' is probable through presenting the client with additional logistics services or by predicting their expectations. Gaining additional value will result in a higher profit and competing position in the market (Skowron-Grabowska, 2010). Thus, SCM "value added" is related with all the concepts such as the cost, quality, delivery flexibility, delivery times and innovation.

2.4.8 Value added time

The value-added time begins the moment the business buys raw materials and ends at the ultimate distribution. The time is signified by the amount of days that the inventory stays in the pipeline. This cycle time comprises of the process time, inspection time, move time and wait time. The inspection time move time and wait time are considered as a non-value adding process (time can be considered value-adding in situations such as maturation). Minimizing the time (also known as the cash-to-cash cycle) is a critical performance enhancer. Therefore, anything that can be done to minimize the length of this cash-to-cash cycle will reduce the cost and create more working capital. Thus, by assessing the cycle time, efficiency of the production line can be measured (My Accounting Course, 2018).

2.4.9 Value Chain Analysis in a developing country

The VCA offers a useful tool for considering competition in the farming section in a developing nation such as South Africa. It offers the basic understanding required for creating and implementing suitable development policies and programs to support market participation. Moreover, VCA is utilised by many development interventions for an important entry point and thus supports small engaging farmers in high value exports (Rich *et al*., 2011). A potential pathway out of poverty for many poor smallholders in the developing world are the livestock system. Most of the world's rural poor keep livestock and incorporate them in many ways that extend far beyond income generation (Randolph *et al.,* 2007). Indeed, the potential risk for food-security looms in developing countries and can be partly resolved through food chain analysis.

2.4.10 Definition and characteristics of Sustainable food value chain (SFVC)

The SFVC is defined according to FAO (2014) as "the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to a final consumer and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources." There are four unique characteristics that separate them from other value chains, namely 1) vulnerability of food production, 2) inclusivity, 3) dependence in developing nations, and 4) quality and control of food products. It is difficult to control both quality and control in terms of uniformity (mostly at the farming stage) and preservation. This observation highlights the need to upgrade the value chains technological, organizational and institutional sectors throughout the food value chain (e.g. good agricultural practises, standards, cold chains, information, certified seed, contracts and communication technology) (FAO, 2014).

2.4.11 Food loss and waste

According to Rezaei and Liu (2017) food loss and waste is defined as a decrease in the quality or quantity of edible food that is planned for human consumption. However, there is an important difference between food loss and food waste. Food loss takes place in the earlier stages of the food value chain such as during production, post-harvest and processing stages, and is primarily caused by failure of the supply chain and food production system such as in KNP. This issue is compounded by managerial and technical limitations, including insufficient storage facilities, infrastructure, cold chain maintenance, proper food handling practices, inefficient marketing systems or packaging. In comparison, food waste is the removal of food from the food supply chain that is still suitable for human consumption, e.g. due to visible defects, after the expiry date, or following food spoilage. Food waste take place in the later stages of the value chain and typically happens at the retail and consumer levels (Rezaei & Liu, 2017).

2.4.12 Difference between supply chain and value chain

According to Hopkins (2009) supply chain thinking is distinctive from value chain thinking (Table 2.4). A supply chain is considered a value chain when products and systems are developed primarily by consumer preference and by the chain acting in partnership causing the chain to be more difficult for competitors to replicate (Fearne *et* al., 2012). In common phrasing, demand chain and value chain are complementary understandings of an extended enterprise with integrated business processes that allows the stream of products and services in one direction, and of value as represented by demand and cash flow, in the other (Ramsay, 2005). Both chains overlap the same network of companies. Therefore, the predominant dissimilarity between a value chain and supply chain is an essential shift in emphasis from the supply base to the customer. Value chains focus downstream by creating value in the eyes of the customer, while supply chains focus upstream on integrating the supplier and producer processes, refining efficiency and reducing waste (Feller *et al.*, 2006). Since creating a profitable value chain necessitates an alignment amongst what a customer wants and what is produced via the supply chain, a supply chain focuses mainly on reducing cost and attaining operational superiority, value chains focus more on innovation in product development and marketing (Feller *et al*., 2006). Integrating these two chains may lead to a third-generation supply chain and create a leaner and more in sync process of product delivery and material flow. Therefore, financial flow, information and knowledge will be fully instantaneous and integrated (Feller *et al.*, 2006).

Table 2.4 Juxtaposition of supply chain thinking and value chain thinking (adapted from Fearne *et al.*, 2012)

	Objective	**Material Flow**	**Information**	**Relationships**
Supply chain thinking (Suitable for commodity markets and commodities)	Reduce costs, Increase market share and margins.	Emphasis on market access, improved distribution and effectiveness.	Exchange restricted to transactional data. Protected and apparent as a source of arbitrage.	Emphasis on supply chain effectiveness, market power and leveraging scale to secure advantageous terms of trade.
Value chain thinking (suitable for differentiated products and segmented markets)	Segment the market and add value with differentiated products designed to increase profitability at all stages of the chain.	Emphasis on service, quality and agility with distribution established by the consumer preference than capacity utilisation.	Perceived and shared as a source of competitive advantage. Strategic information disclosed with trusted partners.	Emphasis on supply chain pliability, shared risk, resource allocation and benefits.

2.5 Conclusions

In summary, there is vested interest and increasing pressure in facilitating greater engagement between the KNP and the many impoverished and previously displaced communities located along its borders. In this context, multiple committees/forums, etc. have been established towards compensating communities for damage caused by large herbivores including buffalo, as well as providing access to sustainable resources and development projects which empower communities and promote biodiversity conservation. Since KNP has a healthy buffalo population (>48000 animals), its sustainable use may serve to provide resulting animal products for human consumption (high-end cuts, stewing meat, mince, etc) in impoverished communities, which could allow the park opportunities for monitoring diseases and managing impacts. Selling expensive prime cuts to luxury restaurants and lodges helps make conservation more sustainable also helping to subsidise the cost of stew meat (source of protein) for adjacent communities.

Towards this goal the WPS was established to cater for damage causing animals and research purposes. What is required for the WPS to function efficiently and to meet the envisaged supply of subsidised meat to the local schools, is a Value Chain Analyses of the whole process. To develop such a VCA, knowledge is required of all the steps/processes that will be part of the value chain; one of the main focusses of this value chain will be the supplying of meat. However, little is known about the meat quality attributes of buffalo meat nor its yields. Scientists should have detailed knowledge of the physical properties, composition, storage life and quality of buffalo meat, to advise management, consumer, and retailers concerning aspects relating to healthiness and meat quality. This knowledge acquisition will also help formulate a value chain for the supply of game (with a focus on buffalo) meat.

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CHAPTER 3

THE CARCASS YIELDS AND COMPOSITION OF AFRICAN SAVANNA BUFFALO

3.1 ABSTRACT

In contrast to other game species and domestic livestock, there is a paucity of evidence concerning yields and thus meat obtained from buffalo. The aim of the present study was to investigate the effects of age and sex on African savanna buffalo carcass yields. Towards this goal, male (n=17) and female (n=13) as well as adult (n=23) and sub-adult (n=7) buffalo were slaughtered, and the weight of the carcass and various organs/offal and six major muscles [(*biceps femoris* (BF), *semimembranosus* (SM), *semitendinosus* (ST), *longissimus thoracis et lumborum* (LTL), *infraspinatus* (IS) and *supraspinatus* (SS)] determined. Buffalo had a high dressing percentage, calculated from the warm carcass weight, with the heaviest weights measured for the BF, SM and LTL muscles. Adults had a heavier muscle weight of 24 and 50 percent than sub-adults, and all parameters except the heart and IS muscle weight differed significantly between these age groups. In addition, the skin and head weight differed significantly between males and females. In summary, African savanna buffalo yields (~58%) compared favourably to other domestic animals, with the heavy weight of valuable muscles suggesting their commercial potential as a high-end value-added product.

3.2 Introduction

The consumption of game meat as an alternative protein source has a rich history in many African countries (Erasmus & Hoffman, 2017). In Southern Africa, there is increasing pressure on the Kruger National Park (KNP) to engage adjacent communities in biodiversity conservation efforts, ecological development and promotion of economic prosperity. In this setting, the use of game meat may provide a sustainable source of protein to optimize nutrition and improve health in these often-impoverished communities. Recent examples of resource use (e.g. mopane worms, thatch, medicinal plants) have provided valuable lessons (Swemmer & Mmethi, 2016), regarding the positive impact of facilitating access to tangible products from nature that address basic human needs and Kruger is looking for more options to enable access to basic natural resources. Therefore, involvement of the community in the processing and consumption of meat obtained from harvested animals including the African savanna buffalo may help create a sustainable income for local communities, while also ensuring food security.

Buffalo are still of high economic value, particularly in the scenario of eco-tourism and trophy hunting. Meat production is therefore still considered a secondary objective. However, in recent years, the price of buffalo meat has also come down due to breeding efforts, leading to greater availability for consumption as an alternative protein source. The private buffalo industry currently has more than 30 000 "disease free" buffalo on private land (Oberem & Oberem, 2016). National parks also have large natural buffalo populations (Ryan *et al.*, 2006). Utilization of some of these buffalo for meat may therefore have the potential to play an important role in benefit programs aimed at communities adjacent to national parks.

For game farming to become an alternative for domestic farming with the goal of amongst others, to produce meat, game species should be able to contend in terms of carcass composition and meat quality. To be considered for meat production, information is however needed in terms of carcass yield, nutritional composition and consumer acceptability for it to compete with domestic livestock (Hoffman *et al.,* 2005). Increased availability of information may therefore help accelerate expansion of the buffalo meat industry (Hildebrandt *et al.,* 2014). In particular, there is a need to explore the carcass yield and composition of African savanna buffalo. In this context, the aim of the present study was to describe carcass yield and organ weights obtained during slaughter of buffalo, as well as explore the effect of age and sex on these measurements. Information gathered as a result could help motivate the viability of buffalo meat as a suitable alternative to cattle rearing in the domestic market.

3.3 Materials and methods

3.3.1 Harvest and slaughter

In total, 49 buffalo were randomly harvested at the Pretoriuskop section in the KNP on four different occasions within a period of eleven days between May and June 2017. Since 19 carcasses were condemned or detained: typically, the reasons for detaining carcasses is when there is more than the norm (one or more) of beef measles (*Cysticercosis*) present in the secondary inspection from the four incisions in the shoulder muscles and on the majority of cut surfaces made by the veterinarian or meat inspector during the secondary inspection. Furthermore, carcasses can be partially condemned (e.g. bruising and abscesses) or totally condemned (e.g. tuberculosis and icterus). Affected areas are condemned due to reasons such as infections caused by systematic or generalised lesions. If only the red offal is affected, and the rest of the carcass is normal, then only the red offal (lungs, heart, liver, tongue and trachea) is condemned. However, if the intestines are tied to general diseases resulting in enlargement of the lymph glands, fever or hepatitis etc. the whole carcass is condemned (National Department of Agriculture, 2007). Therefore, a sample of thirty buffalo (Table 3.1) aged between 18 months and eight years were considered for the present study. In brief, after being darted with succinyldicholine chloride (SDC) from a helicopter and killed via a shot to the head, the animals were exsanguinated, hanged and eviscerated in the field and transported to the abattoir to be skinned, dressed (red pluck removed and trimmed) and quartered before undergoing health inspection by an independent Government veterinary official. At the abattoir some of the organs' weights were recorded. However, since evisceration took place in the field, some offal weights could not be recorded. Furthermore, the calibrated hanging scale broke during the weighing of "live" mass (undressed carcass weight, with a 3% fluid loss (Pienaar, 1969)) in the field, thus carcass yield information is limited. The quartered (between the 9th and 10th rib) carcass was then suspended in a chiller (0-5 °C) for 24 h. African savanna buffalo bulls reach sexual maturity at around four years of age. Therefore, adult buffalo were categorised as being four years and older according to tooth eruption (and horn/boss development) whereas the sub-adult category were buffalo younger than four years (Sinclair, 1977).

Table 3.1 The number of African savanna buffalo per sex and age category obtained

Sex	Adult	Sub-adult	Total
Male	12	5	17
Female	11	2	13

3.3.2 Processing and sampling

Muscle tissue was sourced from the right side of each carcass after approximately 24 h of cooling at the wildlife product section (WPS) of the Kruger national park. The *biceps femoris* (BF), *semimembranosus* (SM), *semitendinosus* (ST), *longissimus thoracis et lumborum* (LTL), *infraspinatus* (IS) and *supraspinatus* (SS) muscles were removed completely to be weighed and assigned to different trials and processed accordingly (Chapters 4 and 5).

3.3.3 Statistical analysis

The individual as well as the combined effects of age (adult vs. sub-adult) and sex (male/female) was analysed. Further, ANOVA was used between sexes with age as co-variant and one-way ANOVA was implemented to compare the age categories. Least squares mean (LSMeans) and standard error (se) were computed and a p-value of 5% was considered significant.

3.4 Results

Weights obtained from warm carcass measurements were compared between bulls and cows, as well as adults and sub-adults (Table 3.2). However, dressing percentage could not be calculated, since no "live" weight was recorded for sub-adults. The bull's heads were 33.8% and skins 25.8% heavier ($p \leq 0.05$) than that of the cows. Bulls also had a mean heavier "live" weights (p=0.499) and warm dressed carcass (p=0.071) weights than cows. The adult age category had a 39.79% heavier (p<0.001) mean warm carcass weight than the sub-adult category. Furthermore, the adult age category also had a significant heavier mean weight for the head (p=0.003), skin (p=0.005), lung (p=0.008) and liver (p<0.001) than the sub-adult age category (Table 3.2).

Table 3.2 Effect of sex and age on buffalo warm carcass measurements (LSMeans ± se)

	Sex		p-value	Age		p-value
	Male	Female		Sub-adult	Adult	
"Live" weight (kg)	478.6 ± 26.87	451.7 ± 26.87	0.499			
Warm carcass (kg)	277.2 ± 6.63	258.1 ± 7.59	0.071	206.1 ± 8.31	288.1 ± 10.01	<0.001
Dressing %	58.3 ± 0.99	58.9 ± 0.99	0.701			
Head (kg)	31.3 ± 1.07	23.4 ± 1.22	<0.001	20.5 ± 1.15	30.1 ± 1.59	0.003
Skin (kg)	48.8 ± 2.24	38.8 ± 2.67	0.009	31.4 ± 1.94	48.9 ± 3.18	0.005
Heart (kg)	2.0 ± 0.13	1.9 ± 0.15	0.469	1.8 ± 0.39	2.0 ± 0.09	0.285
Lungs + Trachea (kg)	6.3 ± 0.23	5.6 ± 0.27	0.089	4.8 ± 0.39	6.3 ± 0.26	0.008
Liver (kg)	5.4 ± 0.18	5.4 ± 0.20	0.953	4.3 ± 0.26	5.7 ± 0.18	<0.001

Measurements for cold carcass commercial cuts and muscle mass were obtained and compared between bulls and cows, as well as adults and sub-adults, after the end of the chilling period (Table 3.3). None of the weights of interest differed significantly between bulls and cows (p≥0.05). However, quarter weights, as well as the weights of the BF, ST, SM, SS and LTL differed significantly between the two age groups where all six muscles of interest were heavier in adults compared to sub-adults. The three heaviest of the six muscles were the BF, SM and the LTL in descending weights, respectively.

Table 3.3 Effect of sex and age on buffalo cold carcass and muscle weight measurements (LSMean ± se)

	Sex		p-value	Age		p-value
	Male	Female		Sub-adult	Adult	
Hindquarters mean (kg)	59.3 ± 1.99	59.7 ± 2.28	0.873	46.2 ± 2.21	63.5 ± 2.16	<0.001
Forequaters mean (kg)	59.0 ± 2.12	57.6 ± 2.42	0.668	44.3 ± 2.67	62.7 ± 2.40	<0.001
#*Muscle weights (kg)*						
BF	5.7 ± 0.23	5.3 ± 0.26	0.200	4.3 ± 0.25	5.9 ± 0.27	0.003
ST	1.7 ± 0.06	1.7 ± 0.07	0.536	1.2 ± 0.07	1.8 ± 0.06	<0.001
SM	4.6 ± 0.16	4.4 ± 0.19	0.409	3.5 ± 0.21	4.8 ± 0.18	0.001
IS	1.5 ± 0.08	1.5 ± 0.10	0.823	1.3 ± 0.27	1.6 ± 0.44	0.067
SS	1.1 ± 0.05	1.1 ± 0.06	0.477	0.8 ± 0.02	1.2 ± 0.06	0.005
LTL	3.0 ± 0.10	3.0 ± 0.12	0.693	2.5 ± 0.08	3.1 ± 0.10	0.004

LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus*.

3.5 Discussion

The African savanna buffalo is of high economic value, based on its role in eco-tourism and hunting. Therefore, meat production is likely to be a secondary objective in determining its contributions to economic development. To date, information on the carcass yield of buffalo remains insufficient. In particular, there is a need to determine the dressing percentage as a main determinant of cost (Fitzhenry, 2016). Interestingly, buffalo have a high dressing percentage with the prime muscles silverside (BF), topside (SM) and sirloin (LTL) being the heaviest (kg). These findings are in accordance with those previously reported by Hildebrandt and colleagues (2014). The maximum "live" weight obtained for this study was 630 kg for a bull and 596 kg for a cow, with a mean sample weight of 465.17 kg. This is however lower than what was reported by Pienaar in 1969 (745.3 kg, 618.2 kg and 475.51 kg, respectively) on 100 buffalo. This discrepancy in findings could be due to a smaller sample size, and lack of available data for "live" weights in the present investigation.

In a previous study on the "live" weight of buffalo, Pienaar (1969) recorded that sub-adult buffalo weights ranged from 81.3 kg to 422.0 kg and 485.2 kg to 696.8 kg for adult buffalo. The warm carcass weight from the present study corresponds to that noted by Grobler (1996), for buffalo with the sub-adult weight (206.15 ± 22.00 kg) lying within the 140-220 kg. The mean warm carcass weight for adult cow buffalo in the present study is 275.1 ± 10.12 kg and is in the parameter's range for adult cows (260-330 kg), whilst that for adult bulls in the present study (299.9 ± 16.30 kg), slightly lower than for the criteria for adult bulls (300-440 kg) of Grobler (1996).

In this study, the dressing percentage of African savanna buffalo was higher than that of domestic cattle such as Nguni, Angus and Bonsmara (50.3-53.8%) (Muchenje *et al.,* 2008), black wildebeest (*Connochaetes gnou*) bulls (53.1%) (Hoffman *et al.,* 2009a) and blue wildebeest (*Connochaetes taurinus*) adults (52.6%) (Van Heerden, 2018), but lower than impala (*Aepyceros melampus*) adult males (59.9%) (Hoffman *et al.,* 2009b). Although the bulls had heavier heads weights, the dressing percentage did not differ from that of the cows (p=0.701).

The head can be a major factor influencing the dressing percentage in buffalo; the male buffalo head is significantly heavier than that of female buffalo. Both sexes of African savanna buffalo have horns, although their shape and size vary. For sub adult males, the horns start off in the shape of a V, and then start to curve slightly outwards; however, the growth is still upwards, while the tips are widely parted. Later, the tips start to grow toward one another, and the horns complete much of the outward curve. After passing the sub-adult phase, the bull (adult) have a substantial thickening of the horns around the bases as the boss is being shaped. Cows (adult) horns begin their backward sweep and the horns continues to dip and widen, later the tips are widely separated with a wide flat span. Thus, the bulls' heads have higher mean weights, particularly after the bulls reach sexual maturity, mainly due to a thicker boss and thicker horn base (Pienaar, 1969; Nowak, 1991; Alden *et al.,* 1995). Adult bulls with large horns are normally kept specifically for trophy hunting and can reach prices between US$ 7500 (R 112 500) and US$ 14 500 (R 217 500) dependent on the trophy size, this is without any additional costs associated with the hunt (Omujeve, 2018; Wintershoek, 2018). However, in this present study this option does not exist since it is illegal to trophy hunt and sell carcasses in the KNP. Therefore, WPS sell the trophy worthy heads and collect, salt and process all the skins and sell to the highest bidder to help subsidise the operational costs.

Buffalo respond well to artificial feeding and have an increase in weight from 203 kg to 680 kg in a time span of the initial eight years and moreover, the meat is said to have no unpleasant odour and is comparable to beef (Van Zyl & Skead, 1964). Furthermore, buffalo have been reported to gain more weight faster than either exotic or indigenous cattle when the forage is insufficient (Harthoorn, 1958). According to Pienaar (1969), the maximum growth rate for African savanna buffalo is during the initial 12 months of life. Between the age of three to five years (maximum tooth replacement period) the growth rate is decelerated. However, during the fourth year of life, females attain their mature weight, as well as become sexually mature and normally calf for the first time. Male buffalo maintain their growth rate and weight gain even throughout old age.

Since game meat is usually sold as price per carcass weight, it is important to know the actual carcass weight of African savanna buffalo. This weight may include the skin, since game carcasses are often transported in chiller trucks with the skin on to minimize risk for bacterial infection and weight loss due to dehydration. In the present study, the average skin weight for an adult buffalo bull was 48.9 kg (Table 3.2).

In the present study the GIT (gastro-intestinal tract) was removed in the field where the field staff take it for home consumption. The GIT is usually cut up in small pieces and stewed in curry sauce and served over rice as it is a popular dish among South African cultures (Erasmus & Hoffman, 2017). It is therefore important that more information around the various offal weights and their nutritional properties be determined as it does form an important component of local cuisine (Alao *et al.,* 2018; Hoffman *et al.,* 2013).

As pertaining to the carcasses, larger mammals including beef are frequently quartered, particularly in older abattoirs where carcasses are moved manually on the overhead rails. The differences between the forequarter and hindquarter weights were slight, since buffalo have relatively heavy forequarters (Van Zyl & Skead, 1964). Mature female animals are known to have a higher hindquarter to carcass percentage than male animals (Ledger, 1963), this correlates with the present study where the females had ~2 kg heavier hindquarters than forequarters (Table 3.3). The larger difference between the hindquarter and fore quarter for the sub-adult group is indicative that there is still development to come in the neck, shoulders and chest regions for both sexes (Ledger, 1963).

As pertaining to the individual muscles, no significant differences were observed between the weights of the two sexes, however as expected, the adults' muscle weights were significant heavier than the muscles of the sub-adults (Table 3.3). The BF (silverside), SM (topside) and LTL (sirloin) muscles are regarded as high value cuts and are thus of economic importance (Ledger, 1963). Within the KNP's social outreach strategy, were buffalo meat will be provided as a sustainable source of protein to impoverished local schools and is part of the sustainable resource programmes. In this setting, the use of game meat may provide a sustainable source of protein to optimize nutrition and improve health in these often-impoverished communities, more importantly it provides an opportunity for a positive engagement with local schools about biodiversity conservation. The high value cuts will typically be aged and sold as steaks to offset the cost of the lower value muscles which are cooked and given to the schools in the schools' outreach program. These muscles had the heaviest weights (kg) for both sexes which is promising for offsetting the costs of meat production/sourcing in the KNP. The BF and SM muscle primary functions are for locomotion and jumping, therefore these two muscles developed throughout time and increased in size, in ratio to other muscles (Frandson *et al.,* 2009). The increase in size of these two muscles result in a coarser grain due to thicker muscle fibres (Herring *et al.,* 1965; Klont *et al.,* 1998), factors that will influence their eating quality. On the other hand, the IS and SS muscles form part of the forequarter and are the smallest and lightest (kg) of all the muscles in the present study. These smaller muscles serve in propulsion; primarily the IS and SS muscle acts as a shoulder joint ligament (Frandson *et al.,* 2009). However, these small muscles form part of the lower valued shoulder muscles and are normally processed to value added products such as mince or used in the production of sausages (fresh and droëwors) or as stewing meat.

In the present study, 38.8% of the buffalo were condemned or detained due to infection by Sarcocystis or beef measles (*Cysticercosis*). This value is higher than that previously reported by Sachs (1969) who reported an infection rate of 30% in the Serengeti. All the condemned and partially condemned carcasses, non-trophy worthy heads and offal not destined for human consumption are processed in a rendering plant at WPS, to create a bone and carcass meal product that can be used as fertilizer. However, all the detained carcasses are split frozen for at least 72 h with an air temperature of at least -18 °C, to kill the "measles" parasite (National Department of Agriculture, 2007). This freezing will influence the potential meat quality of the defrosted meat (Leygonie *et al.,* 2012) and therefore alternative uses for these muscles/cuts, such as drying into biltong need to be investigated (Chapter 6).

3.6 Conclusions

Yields obtained from African savanna buffalo compare favourably to those previously reported for other domestic species and game animals. The high weights obtained from the BF, SM and LTL muscles in particular suggest their potential use as value-added products such as aged steaks thereby increasing the profit margin, however research is required to determine the optimum ageing period. Future studies should also include cold carcass weights and evaluate dressing percentage in sub-adults to provide further insight towards understanding the commercial potential of buffalo in the domestic market. This information will also be important in determining the fixed and running costs per unit weight to evaluate the financial viability of the envisaged resource use strategy. Also, research should be conducted on the value of the offal, although there could be logistic challenges associated with the transport (weight and bloating) of carcasses containing the GIT within the KNP scenario.

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CHAPTER 4

EFFECTS OF AGE AND SEX ON THE PHYSICAL CHARACTERISTICS AND PROXIMATE COMPOSITION OF AFRICAN SAVANNA BUFFALO SKELETAL MUSCLE TISSUE

4.1 ABSTRACT

There is increasing interest in the commercial potential of African savanna buffalo game meat as an alternative to farmed meat products, based not only on its nutritional value, but potential source of protein for impoverished communities situated along the borders of the Kruger National Park. The aim of the present study was to explore the effects of age, sex and muscle type (six muscles) on the physical characteristics (ultimate pH, drip and cooking loss, tenderness, colour) and proximate composition (moisture, protein, intramuscular fat and ash content) of buffalo meat. There was an interaction between age and muscle type for intramuscular fat content ($p=0.01$). In adults, a similar distribution of IMF between muscle types was evident as for the total group, with the highest values noted for the LTL (*Longissimus thoracis et lumborum*) muscle, and lowest for the SM (*Semimembranosus*) muscle. In contrast for sub-adults, the highest IMF was noted for the SS (*Supraspinatus*) muscle and lowest for the BF (*Biceps femoris*) muscle. The physical and proximate characteristics of buffalo meat differed significantly between the six muscles of interest, with the SS muscle being most tender with least amount of protein content whereas the BF muscle was the toughest, and the LTL had the highest protein content. Compared to adult specimens, sub-adults had a higher moisture content, as well as lower muscle pH_U, shear force and protein content ($p \leq 0.05$). Sex had no influence ($p>0.05$) on the muscle parameters measured. In conclusion, findings from the present study indicate that African savanna buffalo meat is suitable for consumption based on nutritional and quality aspects.

4.2 Introduction

An acute shortage of usable game meat in Africa contributes to a lack of viable protein sources which affects impoverished communities in sub-Saharan countries (Pollock, 1969; Asibey, 1974; Hoffman & Cawthorn, 2013). In South Africa, there is a growing interest in the use of African savanna buffalo meat as a sustainable, nutritional protein source (Hoffman *et al.,* 2018), as game meat is considered a healthier alternative to meat obtained from intensive farming practices, while possessing pleasing aromatic characteristics and taste (Hoffman & Wiklund, 2006). In particular, there is interest in the use of sustainably harvested buffalo meat to supply communities adjacent to the Kruger National Park (KNP) (SANParks, 2017) while also supporting sustainable conservation efforts (Berry, 1986). Since the number of buffalo (>48000 animal) in the Kruger National Park (KNP) have significant impacts on both biodiversity inside the park and on subsistence agriculture on the park borders (SANParks, 2017), the utilization of game meat for consumptive (in which wildlife is killed as a source of products or alternative protein source) purposes is garnering increasing attention as a means of improving nutrition in adjacent communities, with additional opportunities for economical return and sustainable conservation efforts (Berry, 1986). Thus, buffalo utilised for the engagement with local schools for the outreach program may provide a sustainable source of protein to the undernourished school children and a positive (in some cases first) experience with the National Park.

However, concerns have been raised over the practicality and financial benefits of using harvested buffalo as a source of meat and meat by-products in South Africa, where buffalo are not normally utilised for their meat (Robertson, 2007). In addition, little is known about the quality and composition of African savanna buffalo meat, in addition to the effects that habitat, diet, age and sex could have on its physical characteristics and proximate composition. There is also a paucity of evidence on the best approach to sustainable harvesting and utilization of buffalo meat for its introduction into broader markets. This lack of available knowledge contributes to poor strategic planning and limited access of safe consumptive products produced in a sustainable, cost-effective environment from wild animals (Hoffman *et al.,* 2005).

In this context, there is a need to develop an effective value chain for the processing and handling of buffalo meat for consumptive purposes. Towards this goal, the aim of the present study was to explore the effects of age and sex on the physical qualities (ultimate pH, moisture loss, Warner-Bratzler shear force and surface colour) and proximate composite (moisture, protein, intramuscular fat and ash) of tissue samples of six major muscles *(Longissimus thoracis et lumborum, Biceps femoris, Semimembranosus, Semitendinosus, Infraspinatus* and *Supraspinatus*) obtained from the African savanna buffalo. Insight gathered as a result of this study may help elucidate whether African savanna buffalo meat has suitable quality attributes for consumptive purposes and could be considered as an alternative protein source.

4.3 Materials and methods

4.3.1 Harvest and slaughter of African savanna buffalo

In total, 49 buffalo were randomly harvested at the Pretoriuskop section in the KNP on four different occasions within a period of eleven days between May and June 2017. Since 19 animals were condemned or detained during meat inspection, a sample of thirty buffalo (17 bulls, 13 cows) aged between 18 months and 8 years were considered for the present study (this was part of proactive sustainable removals during the drought). In brief, after being darted with succinyldicholine chloride (SDC) from a helicopter and killed via a shot to the head, the animals were exsanguinated, hanged and eviscerated in the field and transported to the abattoir/wildlife product section (WPS) to be skinned and quartered (see Chapter 3 for more detail on the slaughter and dressing procedures). The quartered carcass was then suspended in a chiller (0-5 °C) for 24 h. African savanna buffalo bulls reach sexual maturity at about four years of age, thus adult buffalo in this study were categorised according to their tooth eruption (and horn/boss development) as being four years and older whereas the sub-adult category were buffalo younger than four years (Sinclair, 1977).

4.3.2 Sampling of skeletal muscle tissue

Muscle tissue was sourced from the right side of each carcass after approximately 24 h of cooling at the WPS in the KNP. The *biceps femoris* (BF), *semimembranosus* (SM) and *semitendinosus* (ST) muscles were removed in their totality and subsamples thereof used for the physical and chemical measurements. The *longissimus thoracis et lumborum* (LTL) muscle was removed from between the last lumbar vertebra and the natural termination of the muscle at the cervical vertebra and a subsample used for analyses. The *infraspinatus* (IS) and *supraspinatus* (SS) muscles were also removed to assess the physical characteristics and proximate composition of the tissue. For all the muscles, steaks (~1.5 cm thick) were cut from the centre of each whole muscle, perpendicular to the length of the muscle fibres. Remaining portions of the BF, SM and LTL muscles were used to assess the effects of refrigeration ageing on the meat quality attributes (Chapter 5).

4.3.3 Physical analysis

4.3.3.1 Ultimate pH (pH_u)

The ultimate pH (pH_U) of the muscles were measured approximately 24 h post-mortem by utilizing a calibrated (pH standard buffers at pH 4.0 and pH 7.0) portable Crison pH25 meter with a glass electrode (Lasec SA, Cape Town, South Africa). The pH of each muscle steak was measured as close to the core as possible and the electrode was washed with distilled water between each measurement.

4.3.3.2 Surface colour

The surface colour of the muscles were determined via five randomly placed colour measurements per steak on the cooking and drip loss steaks (Honikel, 1998). After 30 min of blooming, the Color-guide 45°/0° colorimeter (BYK-Gardner GmbH, Gerestried, Germany) was used to determine the CIE L*a*b* colour. The CIE L* (lightness), CIE a* (green-red) and CIE b* (blue-yellow) ordinates were then determined and the chroma value (saturation/colour intensity) and hue-angle (colour definition) calculated:

Hue-angle (°) = tan-1 (b*/a*)

Chroma (C*) = (a*2 + b*2)0.5

4.3.3.2 Drip loss

One thick steak (~1.5 cm) of each of the six muscles was used to determine the drip loss. The muscle steaks were initially weighed to determine the preliminary weight (W_1) and were then suspended in an inflated polyethylene bag (without touching any side of the polyethylene bag) for 24 h at ≈4°C. The steaks were removed and patted dry using absorbent paper. The final weight (W_2) was then determined. The drip loss calculation was as follows (Honikel, 1998):

Drip loss (%) = W1 – W2 / W1 x 100%

4.3.3.4 Cooking loss

One thick steak (~1.5 cm) of each of the six muscles was weighed (W_1) and then placed in a polyethylene plastic bag before being immersed in a preheated water bath at a constant temperature of 80°C for 60 min. The steak in the polyethylene plastic bag were then cooled overnight at ≈4°C. After the cooling process, the sample was removed from the polyethylene plastic bag and patted dry using absorbent paper. The final weight (W_2) was then determined. The cooking loss calculation was as follows (Honikel, 1998):

Cooking loss (%) = W1 – W2 / W1 x 100%

4.3.3.5 Warner-Bratzler shear force

For determination of the tenderness of the meat, the cooked samples were used; six 1.27 cm diameter cylindrical cores were taken whilst excluding any visible collagen tissue and sheared perpendicular to the fibres' longitudinal orientation with a Warner-Brazler blade (Universal Testing Machine, Model 4444, Apollo Scientific, South Africa, fitted with a Warner-Bratzler blade, 1.2 mm thick with a triangular opening, 13 mm at the widest point and 15 mm high). The blade moved at a cross speed of 3.33 mm/s and is connected to an electric scale to compute the maximum weight (force) in kg per 1.27 cm Φ diameter required to shear the samples. The mean of the six readings was calculated in kg/1.27 cm Φ diameter and then converted into newton (N) to uphold a uniform unit and allow for a more straightforward comparison with other reported values. The calculation for the conversion was as follows:

Shear force (N) = kg per 1.27 cm Φ * 9.81 / Area of core

Where area = $\pi\ (1.27/2)^2$

4.3.4 Proximate analysis

Proximate analysis determines the nutritious content of the meat by measuring the amount of moisture, protein, intramuscular fat (IMF) and ash content in the muscles. Each sample was assessed through a duplicate analysis and the mean was taken for the ultimate measurement, additional analyses were conducted when the duplicate readings differed more than 5%.

Portions from the six different muscles of all animals were weighed before and after being dehydrated for four days at 60°C in Skukuza to terminate the FMD virus and then vacuum sealed. Muscle tissue was then inspected by a veterinarian for safety purposes and sent to Stellenbosch University laboratory where it was stored in a dry room for two weeks. The samples were homogenised into a powder to ensure homogeneity. These samples were then, allocated to appropriate chemical analysis bags and sealed to avoid oxidation and moisture absorption. These samples were stored in the dry room until analysed.

The residual moisture content (g/100g) of the dried samples was determined by using a 2.5 g sample of each muscle at 100°C (24h) according to the AOAC official method 934.01 (AOAC, 2002c). The ash percentage was determined according to AOAC method 942.05 by using the moisture free sample and placing it for six h in a furnace at 500°C (AOAC, 2002a). The Intramuscular fat content (IMF) was determined from a 5 g sample by using chloroform/methanol (2:1 v/v) via a rapid solvent extraction method (Lee *et al.,* 1996). The 5 g sample consisted of a homogenised muscle sample and distilled water at a 1:3 ratio so as to ensure that the samples dehydrated in Skukuza were hydrated before solvent extraction. The crude protein content (g/100g) was determined according to the Dumas combustion method 992.15 (AOAC, 2002b). A 0.15 g sample of each muscle encapsulated in a LecoTM foil sheet was analysed using the LECO combustion method (Leco Fp-528, Leco Corporation) to obtain a nitrogen (% N) concentration for each sample. Determining the crude protein content (g/100g), the % N was multiplied by 6.25. Preliminary to the analysis of each batch of samples, an EDTA calibration sample (Leco Corporation, 3000 Lake View Avenue, St. Joseph, HI 49085- 2396, USA, Part number 502-092, lot number 1038) was used for ensuring the accuracy throughout the testing. After the laboratory chemical analyses had been performed, all values were recalculated to a wet (as is) basis taking into account the moisture determinations at Skukuza and in the laboratory. Values are thus given as g/100 g meat or as percentage.

4.3.5 Statistical analysis

A three-factor factorial layout was used for this trial with a completely randomized design. Mixed model ANOVA was used for the statistical analysis with sex, muscle and age as fixed effects. The animals were treated as random effect.

Main effects, interactions and correlations with $p \leq 0.05$ were regarded as being significant. Values are reported as the LSMeans ± the standard error (se). For post hoc testing, Fisher least significant differences (LSD) was used.

4.4 Results

4.4.1 Physical analysis

The individual as well as combined effects of age (adult vs. sub-adult) and sex (male/female) on the physical characteristics of African savanna buffalo muscles are depicted in Table 4.1. No interactive effects between age and sex and muscles were found, thus the main effects are discussed. No effects were noted for sex as a determinant of pH_U, drip loss, cooking loss, WBSF or colour ($p>0.05$). However, pH_U was higher in adults (5.9 ± 0.02) compared to the sub-adult group (5.6 ± 0.01) ($p=0.013$; Fig. 4.1), while age did not have a significant effect on drip loss and a trend ($p=0.057$) was noted towards lower cooking loss (%) in adults (40.8 ± 0.34) compared to sub-adults (42.5 ± 0.48). WBSF (N) was significantly ($p \leq 0.05$) higher in the adult group (40.6 ± 0.52) compared to sub-adults (32.9 ± 0.54) (Fig. 4.2). However, age did not influence the colour parameters.

There were differences ($p<0.001$; Table 4.1) between the six muscles (LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus*) for all the physical characteristics (pH_U, drip loss, cooking loss, WBSF and colour) as depicted in Table 4.2. The IS muscle had the highest pH_U (5.8 ± 0.04) whereas ST had the lowest (5.7 ± 0.04). Drip loss percentage was the lowest for the IS muscle (2.0 ± 0.16%) and highest for the SM muscle (5.9 ± 0.37%). The lowest cooking loss percentage was reported for the IS muscle (37.9 ± 0.78%) and the highest for the ST muscle (43.7 ± 0.36%). The WBSF (N) was highest for the BF muscle (45.9 ± 1.67 N) and lowest for the SS muscle (31.0 ± 0.82 N). The highest CIE L* value was observed for the ST muscle (42.8 ± 0.36), while the SM muscle (17.4 ± 0.16) had the highest CIE a* value. The CIE b* value was highest for the SM muscle (13.5 ± 0.20). Chroma values were highest for the SM muscle (22.0 ± 0.21) and lowest for the LTL muscle (18.8 ± 0.17). The hue angles were highest for the ST muscle, while the IS and SS muscles had the lowest values.

Table 4.1 Individual and interactive effects of age, sex and muscle type on physical characteristics of skeletal muscle tissue obtained from African savanna buffalo

Effects	**P values**								
	pHu	**Drip loss**	**Cooking loss**	**WBSF**	**Colour ordinates**				
					L*	**a***	**b***	**Hue**	**Chroma**
Sex	0.907	0.417	0.594	0.959	0.886	0.825	0.893	0.727	0.932
Age (cat)	0.013	0.214	0.057	0.002	0.147	0.489	0.782	0.340	0.736
Muscle	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sex*Age(cat)	0.894	0.930	0.653	0.745	0.772	0.861	0.600	0.725	0.698
Sex*Muscle	0.841	0.478	0.849	0.675	0.645	0.580	0.945	0.769	0.783
Age(cat)*Muscle	0.882	0.418	0.114	0.120	0.518	0.213	0.409	0.615	0.217
Sex*Age(cat)*Muscle	0.894	0.601	0.251	0.802	0.093	0.975	0.463	0.247	0.897

Table 4.2 The differences between the muscle physical qualities of the six selected buffalo muscles (Data is presented as the LSMeans ± se)

	Muscle type					
	LTL	**BF**	**SM**	**ST**	**IS**	**SS**
pH_u	$5.7^{c} \pm 0.04$	$5.8^{b} \pm 0.04$	$5.8^{b} \pm 0.04$	$5.7^{c} \pm 0.04$	$5.8^{a} \pm 0.04$	$5.8^{ab} \pm 0.04$
Drip loss (%)	$3.8^{bc} \pm 0.24$	$3.0^{c} \pm 0.30$	$5.9^{a} \pm 0.37$	$4.0^{b} \pm 0.30$	$2.0^{d} \pm 0.16$	$2.1^{d} \pm 0.27$
Cooking loss (%)	$39.6^{b} \pm 0.56$	$42.9^{a} \pm 0.48$	$43.0^{a} \pm 0.59$	$43.7^{a} \pm 0.36$	$37.9^{c} \pm 0.78$	$43.0^{a} \pm 0.36$
WBSF (N)	$37.1^{bc} \pm 0.71$	$45.9^{a} \pm 1.67$	$34.3^{bc} \pm 0.72$	$36.9^{b} \pm 0.85$	$35.4^{bc} \pm 0.62$	$31.0^{c} \pm 0.82$
L*	$37.6^{c} \pm 0.26$	$39.1^{b} \pm 0.31$	$40.0^{b} \pm 0.32$	$42.8^{a} \pm 0.36$	$37.1^{c} \pm 0.30$	$37.4^{c} \pm 0.27$
a*	$15.3^{d} \pm 0.14$	$16.1^{b} \pm 0.14$	$17.4^{a} \pm 0.16$	$15.1^{cd} \pm 0.18$	$15.4^{cd} \pm 0.16$	$15.7^{c} \pm 0.13$
b*	$10.9^{c} \pm 0.16$	$12.1^{b} \pm 0.16$	$13.5^{a} \pm 0.20$	$12.6^{b} \pm 0.13$	$10.9^{c} \pm 0.15$	$10.7^{c} \pm 0.15$
Chroma	$18.8^{c} \pm 0.17$	$20.2^{b} \pm 0.16$	$22.0^{a} \pm 0.21$	$19.7^{b} \pm 0.18$	$19.0^{c} \pm 0.17$	$19.1^{c} \pm 0.14$
Hue-angle	$35.4^{cd} \pm 0.41$	$36.8^{bc} \pm 0.36$	$37.6^{b} \pm 0.35$	$39.9^{a} \pm 0.35$	$35.2^{d} \pm 0.44$	$34.2^{e} \pm 0.41$

Abbreviations: LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus.*
LSMean: least square mean; se: standard error of the mean
$^{a\text{-}d}$LSMeans with different superscripts within rows differs significantly at $p \leq 0.05$

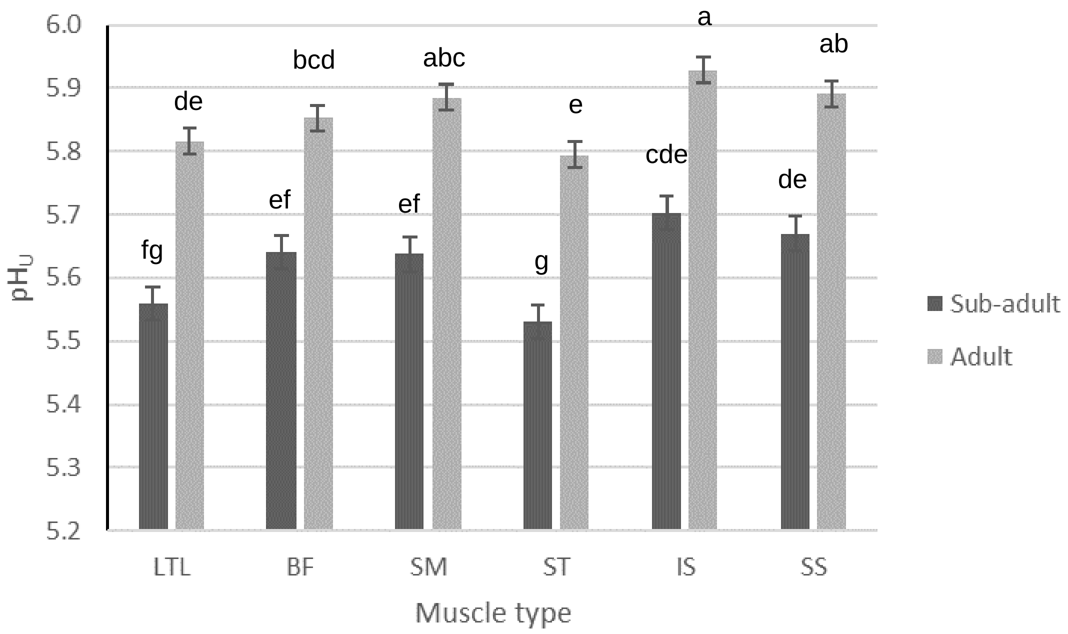

Figure 4.1 The ultimate pH of sub-adult and adult buffalo muscles (LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus).* [a-g]letters that differ indicate significant differences (p≤0.05).

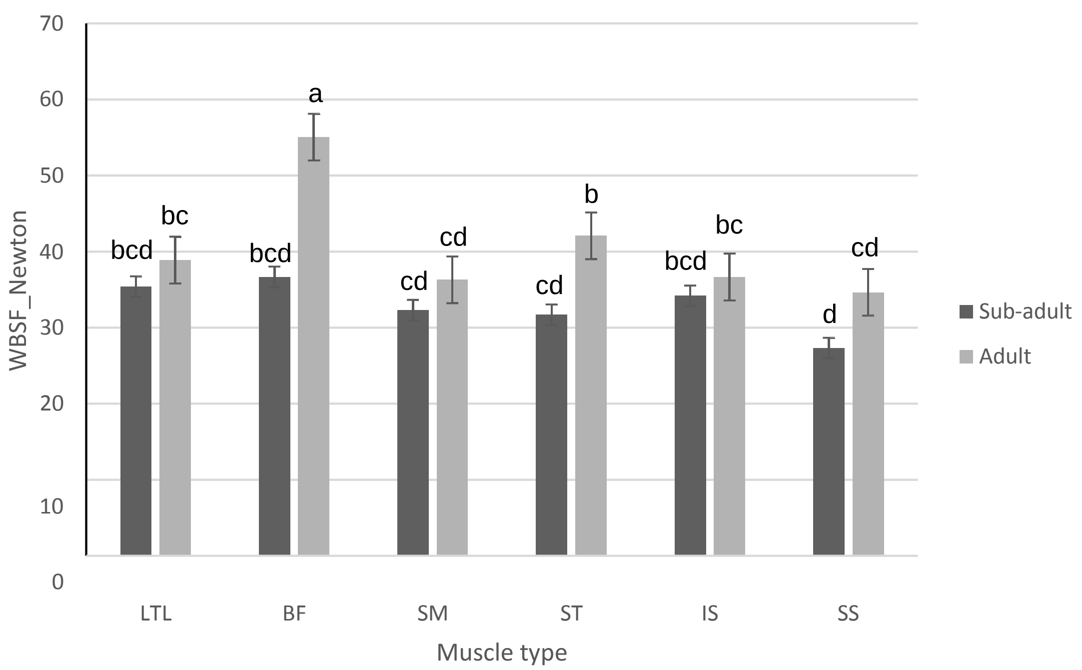

Figure 4.2 The Warner-Bratzler shear force of sub-adult and adult buffalo muscles (LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus).* [a-d]letters that differ indicate significant differences (p≤0.05).

4.4.2. Proximate analysis

The individual as well as combined effects of age (adult vs. sub-adult) and sex (male/female) on the proximate composition of African savanna buffalo muscles are depicted in Table 4.3. No interactive effects between age, sex and muscles were significant, thus the main effects and second order interactions were studied further. There was a significant interaction effect between Age and muscle type for IMF content (p=0.015). In adults, a similar distribution of IMF between muscle types was evident as for the total group, with the highest values noted for the LTL muscle, and lowest for the SM muscle (Fig. 4.3). In contrast for sub-adults, the highest IMF was noted for the SS muscle and lowest for the BF muscle.

No effects were noted for sex as a determinant of moisture, protein, IMF or ash content (p>0.05). However, moisture content was higher (p<0.001) in sub-adults (76.1 ± 0.13%) compared to adults (74.9 ± 0.10%) as depicted in Table 4.4. In addition, protein content was higher (p=0.005) in adults (22.8 ± 0.08%) compared to sub-adults (22.0 ± 0.13%). Ash content did not differ between adults and sub-adults (p=0.729).

There was a significant difference (p<0.001; Table 4.3) between the six muscles (LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus*) for all proximate characteristics (moisture, protein, IMF, ash) as depicted in Table 4.5. Protein content was highest in the LTL muscle and lowest in the SS muscle. Moreover, mean ash content was highest for the SS muscle and lowest for the IS muscle.

Table 4.3 Individual and interactive effects of age, sex and muscle type on proximate composition of skeletal muscle tissue obtained from African savanna buffalo

Effects	**P values**			
	Moisture	**Protein**	**IMF**	**Ash**
Sex	0.897	0.479	0.787	0.808
Age (cat)	<0.001	0.005	0.087	0.729
Muscle	<0.001	<0.001	0.002	0.007
Sex*age(cat)	0.508	0.647	0.528	0.647
Sex*Muscle	0.428	0.818	0.475	0.721
Age(cat)*Muscle	0.790	0.899	0.015	0.396
Sex*age(cat)*Muscle	0.985	0.767	0.874	0.731

Table 4.4 Proximate analysis of buffalo muscles as influenced by age

Parameter	Age category		p-value
	Sub-adult	Adult	
Moisture (%)	76.1 ± 0.13	74.9 ± 0.10	**<0.001**
Protein (%)	22.0 ± 0.13	22.8 ± 0.08	**0.005**
IMF (%)	2.0 ± 0.09	2.5 ± 0.10	0.087
Ash (%)	1.1 ± 0.01	1.1 ± 0.01	0.729

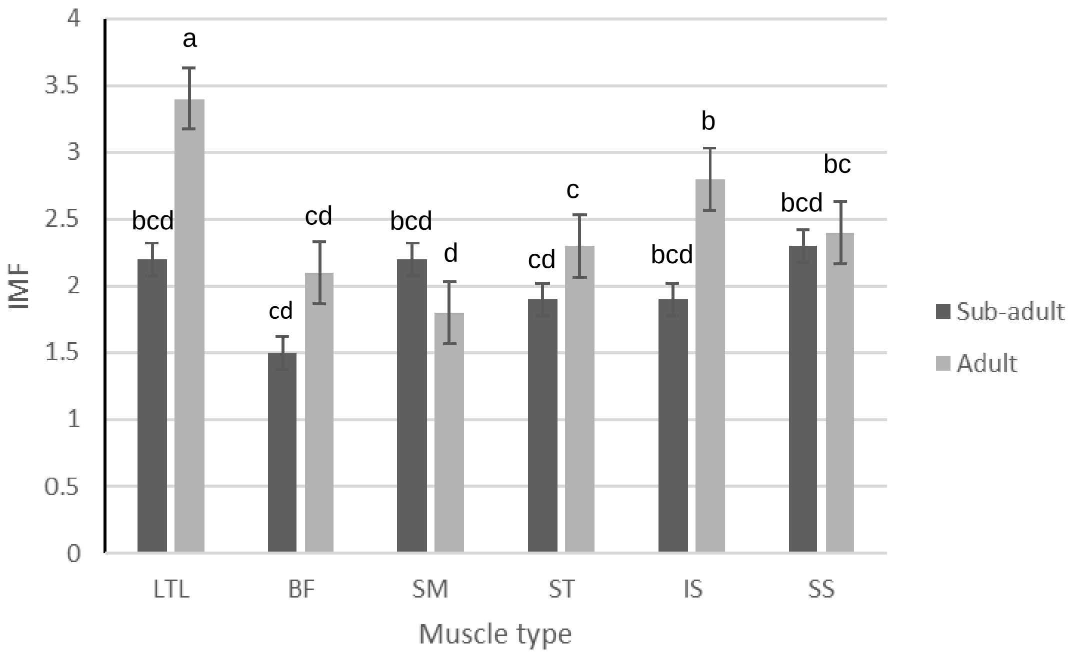

Figure 4.3 The distribution (and interaction) of IMF between the six major muscles of interest for adults compared to sub-adults (LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus)*. [a-d]letters that differ indicate significant differences (p≤0.05).

Table 4.5 Muscle proximate analysis (% as is) of six selected buffalo muscles (LSMeans ± se)

	Muscle type					
	LTL	**BF**	**SM**	**ST**	**IS**	**SS**
Moisture (%)	$74.7^{c} \pm 0.24$	$75.8^{ab} \pm 0.18$	$75.7^{ab} \pm 0.21$	$75.3^{b} \pm 0.20$	$75.5^{ab} \pm 0.23$	$76.0^{a} \pm 0.16$
Protein (%)	$22.7^{a} \pm 0.17$	$22.6^{a} \pm 0.19$	$22.5^{ab} \pm 0.18$	$22.6^{ab} \pm 0.16$	$22.0^{bc} \pm 0.13$	$21.8^{c} \pm 0.13$
IMF (%)	$2.8.^{a} \pm 0.27$	$1.8^{b} \pm 0.16$	$2.0^{b} \pm 0.11$	$2.1^{b} \pm 0.17$	$2.4^{ab} \pm 0.21$	$2.4^{b} \pm 0.18$
Ash (%)	$1.1^{bc} \pm 0.01$	$1.1^{ab} \pm 0.01$	$1.1^{ab} \pm 0.01$	$1.1^{bc} \pm 0.01$	$1.1^{c} \pm 0.01$	$1.2^{a} \pm 0.03$

Abbreviations: LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; IS: *Infraspinatus*; SS: *Supraspinatus.*

LSMean: least square mean; se: standard error of the mean

$^{a\text{-}c}$LSMeans with different superscripts within rows differs significantly at $p \leq 0.05$

4.5 Discussion

4.5.1 Physical analysis

In the present study, the effects of age, sex and muscle type on the physical characteristics and proximate composition of six major muscles based on tissue samples obtained from African savanna buffalo were evaluated. While there was an interactive effect between age and muscle type for IMF content (p=0.015), no significant interactions between age, sex and muscle type on the physical or proximate characteristics were evident. However, WBSF and pH_U were significantly higher in adults compared to sub-adults. In addition, all characteristics measured differed significantly between the six muscles.

The pH_U of meat products influences tenderness, colour, flavour, water-holding capacity and shelf life (Honikel, 2004), with meat having a high pH (>6.3) being considered more tender, followed by meat with a low pH (< 5.8) and lastly meat with an intermediate (5.8 – 6.3) pH (Yu & Lee, 1986). In the present study, a significant difference in pH_U was noted between the six muscles, consistent with variation in function, muscle fibre composition, glycogen storage and activity level. The IS muscle had the highest pH_U, whereas the ST muscle had the lowest. The slightly overall high ultimate pH can be explained by the harvesting procedure which entails the herding and moving of the buffalo to a suitable "working zone" by means of a helicopter, which results in physical effort being executed by the buffalo after being darted with an excess dosage of succinyldicholine chloride (SDC) (Lawrie & Ledward, 2006a). The latter also causes short-term stress, low glycogen levels and high pH as it is a neuro blocker (Hoffman, 2001). Despite the pH_U being in the higher range, particularly for adults (Fig. 4.1), overall values obtained still fall within the optimum range and the meat would not be classified as DFD (Shange *et al.,* 2019).

Drip loss is thought to originate from gaps amongst fibre bundles and the perimysium network in conjunction with the gaps amongst muscle fibres and the endomysium network (Offer & Cousins, 1992). A high drip loss (high amount of fluid in packaging) is correlated with a negative aesthetic impact on the consumer. Therefore, the meat industry focuses on keeping the drip loss as low as possible (Troy & Kerry, 2010) so as to help keep the final weight of the product high (Den Hertog-Meischke *et al.*, 1997). In the present study, drip loss percentage was highest for the SM muscle (5.9 ± 0.37%) and lowest for the IS muscle
(2.0 ± 0.16%). The finding that drip loss was highest in the SM muscle is consistent with previous studies in common eland (Laubscher, 2018) and blue wildebeest (Van Heerden, 2018). In contrast, studies on smaller antelope species reported low drip loss for the SM muscle (Neethling *et al.*, 2014). High drip loss was also evident for the ST muscle, which, due to its deeper position in the buffalo carcass, would have a slower cooling rate and higher

glycolysis rate, contributing to a high drip loss percentage (Vautier *et al.,* 2005). Another explanation for the higher drip loss in the ST and SM muscles (Fig. 4.1) may lie in the high percentage of glycolytic fibres and glycolytic activity within these muscles, which results in an augmented rate of post-mortem pH decrease (Troy & Kerry, 2010). High rates of pH decline with a low ultimate pH have been associated with an increase in drip loss percentage (Lawrie & Ledward, 2006a). Also, the lower drip loss percentages could be due to the higher pH_U that exceeded the isoelectric point ($pH_U \geq 5.4$) of meat, which results in improved ability to retain water with a resultant lower drip loss (Huff-Lonergan & Lonergan, 2005). This observation is in accordance with the finding of drip loss being lowest in the IS muscle, which had the highest pH_U (r=-0.14 between pHu and drip loss for all samples). Moreover, cooking loss was highest in the ST muscle and lowest in the IS muscle (Table 4.2) with similar results reported for blue wildebeest (Van Heerden, 2018). A higher cooking loss is normally associated with drier meat and is thus perceived as being less juicy (Warriss, 2000).

Meat tenderness is an essential aspect of overall quality influenced by the interaction between connective tissue, myofibrils and collagen (Sacks *et al.,* 1988). Collagen is one of the main components of muscle connective tissue and is a major determinant of the texture and toughness of the meat. According to Bailey & Light (1989), the variations in the texture of meat are reliant on the quality of the collagen rather than the quantity. In this study, WBSF differed significantly between muscles (Table 4.2), as expected, since skeletal muscles differ in their collagen content and composition, as well as location, activity and function (Lawrie & Ledward, 2006a), all factors that influence the WBSF. The mean WBSF values were in the tender range of 36.82 N for females and 36.70 N for males. However, as depicted in Fig. 4.2, the mean WBSF was higher ($p=0.002$) in adults compared to sub-adults, with the shear force noted for the BF muscle in adults (55.04 N) exceeding the desirable limit of 52.68 N as defined by Destefanis *et al.* (2008). The higher meat toughness noted for the adult group may be explained by higher collagen content which increases and also, more importantly, becomes more insoluble with age due to an increase in cross-links between polypeptide chains making the collagen more thermal stable (Bailey, 1972). Another explanation could lie in the higher pH_U noted for adults in the study (Table 4.2), which could also indirectly contribute to the toughness as reflected by the WBSF in this subgroup (Yu & Lee, 1986). Furthermore, the BF, SM and ST have intramuscular tenderness and muscle fibre orientation variations (Senaratne *et al.*, 2011). Thus, the WBSF values measured may have been influenced by the muscle fibre orientation within individual muscles and their steaks resulting in an influence on the buffalo muscle comparison.

Meat colour is known to influence consumer purchasing patterns, as it is considered a reflection of quality, wholesomeness and freshness. Consumers associate a bright red colour with a long shelf-life and high meat quality (Hood & Mead, 1993; Lawrie & Ledward, 2006b). Due to lower IMF levels and greater myoglobin content (Young & West, 2001; Kritzinger *et al.,* 2003; Hoffman *et al.*, 2005) game meat usually has a darker colour compared to domestic species (Hoffman *et al.,* 2005) which may negatively influence customer purchasing behaviour (Jeremiah *et al.,* 1972). In this context, consumers may prefer the lighter meat colour of larger game species, including buffalo, as compared to smaller game species, such as springbok and impala (Von La Chevallerie, 1972). A desirable dark red colour in game meat is reflected by several parameters, including low L* values (<40), high *a** values and low *b** values (Volpelli *et al.*, 2003). However, Shange *et al*. (2019), further specified the colour coordinates for game meat and described the typical colour coordinates for normal pH meat as L* >33, a* > 13, b* ~ 10 resulting in Chroma >17 and hue angle of >36.

In the present study the colour parameters of Table 4.2 is similar to beef (*Bos taurus*), as the mean L* value (38.54) fell between 33.2 and 41.0, the mean a* value (15.94) between 11.1 and 23.6, and mean b* value (11.75) just above the range of 6.1 to 11.3, indicating a light red colour that is perceived as attractive for consumers (Naveena & Kiran, 2014). Overall, the L* values were higher than found for springbok or impala (Hoffman *et al.,* 2007a; Hoffman, 2000) and even Cara-beef (*Bubalus bubalis*) also known as water buffalo (Naveena & Kiran, 2014). Also, the ST muscle had the highest L* value, followed by the SM muscle. This finding may be explained by the lower pH evident for ST muscle (Table 4.2), which is associated with the absorption characteristics of myoglobin (Winkler, 1939) and an increase of free water content between muscle fibres. Another explanation could be that the ST is known to contain high percentage of glycolytic fibres which primarily metabolize glycogen and have very few mitochondria (O'Keeffe & Hood, 1982). In contrast, the low L* value noted for SS muscle may reflect signs of DFD development. Nonetheless, this value (37.38) is still higher than that previously reported for eland (Laubscher, 2018), blue wildebeest (Van Heerden, 2018) and blesbok (Neethling *et al.,* 2014). In addition, the SM and ST muscles had high b* values associated with higher amounts of metmyoglobin rather than the concentration of myoglobin (Mancini & Hunt, 2005; Neethling *et al.,* 2016) and an unfavourable yellow/brown colour. In keeping with previous studies which analysed game meat, the LTL muscle had the lowest a* value (Laubscher, 2018). However, the value was still higher than the acceptable minimum of 12 reported by Wiklund, Stevenson-Barry, Duncan and Littlejohn (2001). Findings from the present study suggest that buffalo meat may be attractive to consumers based on a favourable colour profile. However, further research is required to establish consumer preference to buffalo meat based on colour preferences for fresh red meat.

4.5.2 Proximate analysis

In the present study the interaction between age*muscle type influenced the IMF with the SM being responsible for the interaction; in this muscle the IMF was higher in the sub-adults, whilst for all the other muscles, the adults were fatter. Age also influenced moisture and protein content, whilst muscle type significantly influenced moisture, protein IMF and ash content on the proximate composition of African savanna buffalo meat. However, sex did not have any influence on the proximate composition.

The proximate composition of African savanna buffalo meat (Table 4.4) is comparable to that previously reported (Hildebrandt, 2014) for the LTL, SM and BF muscles, although there was a slightly higher moisture and ash content in the present study. In addition, protein content and LTL muscle IMF values were higher than those previously reported (Hildebrandt, 2014). However, in the latter study there were a shortage of feed for the buffalo and the harvested buffalo had a very low body condition score of <2.5 whereas the buffalo in this study were in a good condition with some even showing some subcutaneous fat.

In the present study, moisture and protein content was negatively correlated (r=-0.71) in the total group, with the highest protein content (22.7 ± 0.17) for the LTL muscle as well as the lowest moisture content (74.7 ± 0.24). The interrelation between moisture and protein content (Doornenbal & Murray, 1982; Keeton & Eddy, 2004; Lawrie & Ledward, 2006a) was previously confirmed in studies on eland (Laubscher, 2018) and blesbok (Neethling *et al.,* 2014). In addition, the LTL muscle had a low moisture content but high IMF content (Table 4.4). The inverse correlation (r = -0.65) between moisture and IMF content although not as strong as that between moisture and protein contents, was also evident and has been demonstrated for other ungulates found in Africa such as impala, kudu and springbok (Hoffman *et al.,* 2007b; Hoffman *et al.,* 2009). However, the SS had the highest moisture but not the lowest IMF content; this was partly explained by Van Schalkwyk and Hoffman (2016) that due to the lack of high levels of IMF in game species, there is a stronger negative correlation between protein and moisture content in these ungulates; as described above.

Multiple intrinsic factors, including species, breed, age, sex nutritional status and exercise levels, influence the proximate composition of skeletal muscle tissue in animals (Lawrie & Ledward, 2006c). In particular, age (as was also noted in this study) is known to affect muscle composition, since the proportion of IMF increases, and muscle mass decreases, over time (Warriss, 2000). However, in the present study, sex did not influence the proximate composition of buffalo meat. This finding was unexpected, as previous studies have reported higher IMF content for female buffalo (Hildebrandt, 2014), and other wildlife species such as eland (Laubscher, 2018), blesbok (Neethling *et al.,* 2014), kudu and impala (Hoffman *et al.,* 2009).

However, in the present study, the IMF and protein contents were higher in adults, whilst the moisture content was higher in the sub-adults, both these findings were also observed for Cara-beef (Kiran *et al.,* 2016). In particular, IMF differed (p≤0.05) between the two age groups for the LTL muscle (Fig. 4.3). In a previous study, age had a significant effect on IMF, moisture and protein content in LTL muscle specimens from Springbok antelope (Hoffman *et al.*, 2007b). These findings are in agreement with the observation that the LTL muscle develops later and is subject to later IMF deposition (Lawrie & Ledward, 2006a). Overall, the present study indicates that protein, IMF and ash content for African savanna buffalo meat is higher than Cara-beef, with higher moisture, protein and ash content than beef (Naveena & Kiran, 2014). These findings are encouraging, as Cara-beef has a low fat and cholesterol content compared to other beef breeds (Valin *et al.,* 1984; Kesava Roa & Kowale, 1991).

4.6 Conclusions

The present study demonstrated differences between different muscles in the physical and proximate composition of African savanna buffalo meat. Also, age was shown to influence tenderness (WBSF), muscle ultimate pH, protein and moisture content. These findings indicate that due to the differences in the quality (physical and chemical) of the different muscles and ages, the muscles may not all be suitable for a specific use, e.g. as fresh steaks and as such, research is required to see how the larger muscles change with ageing to see which might be suitable for the high-end market as fresh steaks. None the less, these findings indicate that the quality of African savanna buffalo meat for consumptive purposes, particularly that obtained from younger animals is of acceptable standard. The present study provides valuable preliminary data supporting the commercial potential of African savanna buffalo meat, which compared favourably to other game animals. This study did not consider the effects of habitat and climate conditions on muscle composition and characteristics. In conclusion, the overall findings support the commercial potential of buffalo meat as a lean source of protein. The organic production system combined with the high protein low fat ratio make it an attractive meat product for health-conscious consumers.

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CHAPTER 5

DEVELOPING A STANDARD PROTOCOL FOR AGEING PERIOD TO ACHIEVE OPTIMAL TENDERNESS IN AFRICAN SAVANNA BUFFALO MEAT

5.1 ABSTRACT

This study aimed to develop a standard protocol to achieve optimal tenderness for chilled African savanna buffalo (*Syncerus caffer caffer*) *Longissimus thoracis et lumborum* (LTL), *semimembranosus* (SM) and *Biceps femoris* (BF) muscles, derived from different buffalo sexes and age categories. These muscles were obtained from thirty buffalo and portioned and aged under vacuum for 1, 5, 9, 13, 17, 21, 25, 29 and 32 days at ± 4˚C. The tenderness increased significantly for both SM and LTL muscles by 5 days post- mortem (PM) and increased substantially further, however, a decrease in tenderness was observed for the BF muscle over the ageing period. Furthermore, the cumulative purge loss increased from 4.0% to 9.3% over the 32-day ageing period. Cooking loss decreased significantly from day one PM to day five PM and then plateaued over the ageing period with a slight increase from day 13 PM onwards. This finding was anticipated, since cumulative purge loss influences the total moisture loss. Furthermore, the colour coordinates changed significant over the ageing period, with the CIE L* values increasing till day 13, and the SM muscle having the highest value, CIE a* values increased significantly from day five till day nine, and then decreased until day 32. CIE b* values increased significantly up to day nine and reached a plateau by day 21, after which it decreased significantly up to day 25, then reach a second plateau. The variation in BF tenderness over time indicates that this muscle is not necessarily suitable for ageing and consumption as a fresh steak. The present study found that ageing the LTL and SM muscle for 25 days gave optimum tenderness. Therefore, a longer ageing period resulting in increased storage costs and substantial increase in mass loss will exceed the benefit of further ageing.

5.2 Introduction

The lack of available protein sources is an important contributor to malnutrition and starvation in Sub-Saharan Africa (FAO, 2015). New methods are required to increase protein production in an environmentally friendly and sustainable fashion to meet food requirements and ensure optimal nutrition in lower to middle income countries (Tscharntke *et al.,* 2012; Cawthorn & Hoffman, 2014).

Game animals can survive in harsh conditions and place a lesser burden on resources and natural vegetation compared to cattle, resulting in lower input cost to farmers (Cole, 1990). In recent decades, professional hunting has surpassed meat production as an income opportunity in game ranching (Carruthers, 2008). However, there is increasing interest in revisiting the economic potential of game meat as a protein source towards establishment of a local market. Furthermore, there is pressure on the Kruger National Park (KNP) to engage with adjacent communities in a positive and meaningful way, and the school outreach programme where a targeted environmental education message is coupled with sharing a meal together is a great way to build conservation constituency.

There is growing interest in assessing the efficacy and sustainability of procedures used across meat production and processing, as well as determining the characteristics of meat obtained from game animals. In particular, it is important to enhance meat quality in a sustainable and cost-effective manner. Importantly, the meat market is largely consumer-driven, with greater demand for healthier food products that have the necessary nutritional composition. Indeed, game meat in South Africa is largely pesticide, steroid and hormone "free", due to limited application of intensive farming methods (Radder & Le Roux, 2005). However, both the supply and demand aspects of meat production need to be improved in order to facilitate greater availability of game meat to the South African consumer (Hoffman *et al.,* 2005) which may ultimately add potential value to the market. A careful balance must therefore be established between customer demand and a sustainable supply of high-quality game meat products from animal to consumer.

Juiciness, flavour and tenderness all contribute to the perceived quality of meat products, including game meat (Strydom *et al.,* 2016). In particular, tenderness is one of the main aspects considered by consumers when purchasing meat products, necessitating optimizing of meat tenderness in the game meat industry (Grunert *et al.,* 2004). The ageing of meat at ideal temperatures has emerged as a major factor which promotes tenderization (Dransfield, 1994), i.e. favourable changes in myofibrillar and cytoskeletal changes in tissue proteins consistent with good meat texture for consumptive purposes (Chriki *et al.,* 2013; Jeremiah *et al.,* 2003). In particular, vacuum ageing is a preferred technique in the meat industry sector due to the convenience and extended shelf-life and food safety this process provides (Hodges *et al.*, 1974). However, optimal ageing procedures and methods for game meat, including that obtained from African savanna buffalo, are lacking.

Therefore, the aim of the present study was to assess the change in physical characteristics of African savanna buffalo skeletal muscle tissue over a chilled vacuum ageing period of 32 days. Towards this goal, steaks were obtained from three different muscles: i.e. *Biceps femoris, Longissimus thoracis et lumborum* and *Semimembranosus*. The ultimate goal was to establish the optimal ageing period for buffalo meat prime cuts.

5.3 Materials and methods

5.3.1 Harvest and slaughter

In total, 49 buffalo were randomly harvested at the Pretoriuskop section in the KNP on four different occasions within a period of 11 days between May and June 2017. Since 19 animals were condemned or detained during meat inspection, a sample of thirty buffalo (Table 5.1) (17 bulls, 13 cows) aged between 18 months and 8 years were considered for the present study. In brief, after being darted with succinyldicholine chloride (SDC) from a helicopter and killed via a shot to the head, the animals were exsanguinated, hanged and eviscerated in the field and transported to the abattoir to be skinned and quartered. The quartered carcass was then suspended in a chiller (0-5 °C) for 24 h (for more details on the slaughter and dressing procedures, see Chapters 3 and 4). African savanna buffalo bulls reach sexual maturity at about four years of age, thus adult buffalo in this study were categorised according to their tooth eruption (and horn/boss development) as being four years and older whereas the sub-adult category were buffalo younger than four years (Sinclair, 1977).

Table 5.1 The number of African savanna buffalo per sex and age category

Sex	Adult	Sub-adult	Total
Male	12	5	17
Female	11	2	13

5.3.2 Sampling of skeletal muscles

Muscle tissue was sourced from the right side of each carcass after approximately 24 h of cooling at the wildlife product section (WPS) in the KNP. The *biceps femoris* (BF) and *semimembranosus* (SM) muscles were removed in their totality and *M. longissimus thoracis et lumborum* (LTL) was removed from between the last lumbar vertebra and the natural termination of the muscle at the cervical vertebra. All three muscles were trimmed of epimysium and subcutaneous fat and then cut perpendicularly to the longitudinal axis of the skeletal muscle tissue to separate the muscle into nine equal steaks (~1.5 cm thick). These nine steaks were then randomly assigned to one of the nine ageing periods. Each of the nine steaks per muscle were individually weighed and vacuumed packed (Multivac, Model C200; Sepp Haggenmuller, Wolfertschwenden, Germany) in a composite plastic (70 µm polyethylene and nylon; moisture vapour transfer rate of 2.2 g/m^2 per 24 h at 1 atm, O2 permeability of 30 cm^3/m^2 per 24 h at 1 atm and a CO2 permeability of 105 cm^3/m^2 per 24 h at 1 atm) bag and kept in the refrigerator (2-4 °C) for the assigned ageing period.

5.3.3 Sample preparation

At every time plot of the ageing period, the steaks of that time plot were taken from the refrigerator and removed from the vacuum packaging. The steaks were patted dry with a paper towel to remove surface moisture and weighed afterwards to determine purge loss. Each steak was used for determining the ultimate pH, cooking loss, tenderness and CIE L*a*b* surface colour. The muscle samples for day 1 formed part of the physical analysis on the six main muscles (Chapter 4) although their data is also included in this Chapter.

5.3.4 Physical analysis

5.3.4.1 Ultimate pH (pH_U)

The ultimate pH (pH_U) of the muscles were measured approximately 24 h post-mortem (PM) for day 1 by utilizing a calibrated (pH standard buffers at pH 4.0 and pH 7.0) portable meter Crison pH25 with a glass electrode (Lasec SA, Cape Town, South Africa). The pH of each muscle steak was measured as close to the core as possible and the electrode was washed with distilled water between each measurement. Thereafter, at each ageing period the ultimate pH was measured after the samples were removed from their individual vacuum package and patted dry.

5.3.4.2 Cumulative purge loss

The cumulative purge loss was determined by weighing the steaks before vacuum packaging to determine the initial mass of the steak. The steaks were then removed from the vacuum packaging at each ageing period and patted dry with absorbent paper towels to remove any additional surface moisture. The dry patted steaks were then weighed to establish the amount of purge loss. The purge loss measurement is expressed as a percentage of the initial weight.

5.3.4.3 Cooking loss

One steak of each of the six muscles was weighed (W_1) and then placed in a polyethylene plastic bag before being immersed in a preheated water bath at a constant temperature of 80°C for 60 min. The steak in the polyethylene plastic bag were then cooled overnight at ≈4°C. After the cooling process, the sample was removed from the polyethylene plastic bag and patted dry using absorbent paper. The final weight (W_2) was then determined. The cooking loss was expressed as a percentage of the initial weight (Honikel, 1998).

5.3.4.4 Surface colour

The surface colour of the muscles were determined via five randomly placed colour measurements per steak (Honikel, 1998). After 30 min of blooming, the Color-guide 45°/0°

colorimeter (BYK-Gardner GmbH, Gerestried, Germany) was used to determine the CIE L*a*b* colour. The CIE L* (lightness), CIE a* (green-red) and CIE b* (blue-yellow) ordinates were then determined and the chroma value (saturation/colour intensity) and hue-angle (colour definition) calculated:

Hue-angle (°) = tan-1 (b*/a*)

Chroma (C*) = (a*2 + b*2)0.5

5.3.4.5 Warner-Bratzler shear force (WBSF)

For determination of the tenderness of the meat, the cooked samples were used; six 1.27 cm diameter cylindrical cores were taken whilst excluding any visible collagen tissue and sheared perpendicular to the fibres' longitudinal orientation with a Warner-Brazler blade (Universal Testing Machine, Model 4444, Apollo Scientific, South Africa, fitted with a Warner-Bratzler blade, 1.2 mm thick with a triangular opening, 13 mm at the widest point and 15 mm high). The blade moved at a cross speed of 3.33 mm/s and is connected to an electric scale to compute the maximum weight (force) in kg per 1.27cm Φ diameter required to shear the samples. The mean of the six readings was calculated in kg/1.27cm Φ diameter and then converted into newton (N) to uphold a uniform unit and allow for a more straightforward comparison with other reported values. The calculation for the conversion was as follows:

Shear force (N) = kg per 1.27 cm Φ * 9.81 / Area of core

Where area = $\pi (1.27/2)^2$

5.3.5 Statistical analysis

A four-factor factorial layout was used for this trial with a completely randomized design. Mixed model ANOVA was used for the statistical analysis with sex, muscle type, animal's age and ageing period as fixed effects. The animals were treated as random effect.

Main effects, interactions and correlations with $p \leq 0.05$ were regarded as being significant. Values are reported as the LSMeans ± the standard error (se).

5.4 Results

Interactive effects between age, sex, muscle type and days post-mortem were found (Table 5.2). Firstly, there were significant interactions between muscle type*days PM ($p=0.001$) (Fig. 5.1) and age*days PM ($p<0.001$) (Fig. 5.2) for change in pH. In addition, a sex*days PM interaction for cumulative purge loss ($p=0.025$) was evident (Table 5.2). A significant fourth order interaction was observed for WBSF for age*sex*muscle type*days PM ($p<0.001$), as shown in Table 5.2. The individual as well as the combined effects of age (adult vs. sub-adult) and sex (male/female) and days PM on the physical characteristics of African savanna buffalo muscles are outlined in Tables 5.3 and Table 5.4.

Table 5.2 Individual and interactive effects of age, sex, days post-mortem and muscle type on physical characteristics of skeletal muscle steaks obtained from African savanna buffalo

Main experimental effects	**P-values**								
	pHu	Cumulative purge loss	Cooking loss	WBSF	Colour ordinates				
					L*	a*	b*	Hue	Chroma
Age	0.027	0.466	0.155	0.024	0.084	0.232	0.489	0.138	0.625
Sex	0.866	0.914	0.913	0.578	0.794	0.736	0.689	0.971	0.681
Muscle type	0.022	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Day	<0.001	<0.001	<0.001	0.792	<0.001	<0.001	<0.001	<0.001	<0.001
Age(cat)*Sex	0.696	0.544	0.928	0.756	0.490	0.945	0.458	0.515	0.721
Age(cat)* Muscle type	0.828	0.788	0.926	0.060	0.391	0.619	0.597	0.782	0.585
Age(cat)*Day	<0.001	0.767	0.076	0.338	0.098	0.321	0.250	0.011	0.472
Sex*Muscle type	0.802	0.613	0.939	0.734	0.911	0.837	0.416	0.767	0.540
Sex*Day	0.942	0.025	0.789	0.679	0.365	0.603	0.754	0.101	0.913
Muscle type*Day	0.001	0.460	0.873	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Age(cat)*Sex*Muscle type	0.845	0.246	0.880	0.998	0.533	0.556	0.179	0.917	0.284
Age(cat)*Sex*Day	0.962	0.387	0.272	0.728	0.415	0.742	0.822	0.665	0.823
Age(cat)*Muscle type*Day	0.990	0.820	0.938	<0.001	<0.001	0.001	0.006	0.252	<0.001
Sex*Muscle type*Day	0.933	0.147	0.918	0.033	0.081	<0.001	0.172	0.015	0.001
Age(cat)*Sex*Muscle type*Day	0.999	0.844	0.392	<0.001	0.036	0.560	0.014	0.122	0.153

Table 5.3 Physical qualities (LSMeans ± se) of three selected buffalo muscles as per age, sex, muscle and ageing period

Main effects		**pH**	**Cumulative purge loss (%)**	**Cooking loss (%)**	**Total moisture loss (%)**	**Warner Bratzler shear force (N)**
Age	**Sub-adult**	5.6 ± 0.01	7.8 ± 0.20	40.7 ± 0.20	48.5 ± 0.28	34.2 ± 0.39
	Adult	5.6 ± 0.01	7.3 ± 0.12	39.8 ± 0.12	47.2 ± 0.17	40.5 ± 0.31
Sex	**Female**	5.6 ± 0.01	7.6 ± 0.16	40.2 ± 0.15	47.8 ± 0.22	38.1 ± 0.41
	Male	5.6 ± 0.01	7.5 ± 0.14	40.3 ± 0.14	47.8 ± 0.20	36.6 ± 0.32
Muscle type	**LTL**	5.6^{b} ± 0.01	6.9^{b} ± 0.14	38.0^{c} ± 0.16	44.9^{c} ± 0.22	31.4^{b} ± 0.23
	SM	5.6^{ab} ± 0.01	9.2^{a} ± 0.17	41.1^{b} ± 0.15	50.3^{a} ± 0.22	29.7^{b} ± 0.21
	BF	5.6^{a} ± 0.01	6.6^{b} ± 0.17	41.8^{a} ± 0.13	48.3^{b} ± 0.22	50.9^{a} ± 0.53
Ageing period (days PM):	**1**	5.7^{a} ± 0.02	4.2^{f} ± 0.22	41.8^{a} ± 0.36	46.0^{e} ± 0.46	39.1^{a} ± 0.71
	5	5.7^{a} ± 0.02	5.9^{e} ± 0.28	40.3^{bc} ± 0.30	46.2^{de} ± 0.43	36.0^{a} ± 0.67
	9	5.6^{b} ± 0.01	7.3^{d} ± 0.28	39.9^{cd} ± 0.28	47.2^{cd} ± 0.41	37.2^{a} ± 0.72
	13	5.6^{b} ± 0.01	7.7^{cd} ± 0.28	39.2^{d} ± 0.27	46.9^{cde} ± 0.39	36.5^{a} ± 0.75
	17	5.6^{b} ± 0.07	8.0^{bc} ± 0.27	39.4^{d} ± 0.27	47.4^{c} ± 0.40	38.1^{a} ± 0.80
	21	5.6^{bc} ± 0.02	7.9^{cd} ± 0.24	40.0^{cd} ± 0.30	47.9^{c} ± 0.41	37.5^{a} ± 0.73
	25	5.6^{cd} ± 0.01	8.5^{b} ± 0.27	40.5^{bc} ± 0.25	49.0^{b} ± 0.43	37.2^{a} ± 0.72
	29	5.5^{d} ± 0.01	9.2^{a} ± 0.28	40.5^{bc} ± 0.35	49.7^{ab} ± 0.48	37.4^{a} ± 0.80
	32	5.5^{d} ± 0.01	9.3^{a} ± 0.26	40.9^{b} ± 0.31	50.2^{a} ± 0.41	37.0^{a} ± 0.93

Abbreviations: LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus*; PM: post-mortem

LSMean: least square mean; se: standard error of the mean

$^{a-f}$LSMeans with different superscripts within main effects differ significantly at $p\leq0.05$

Table 5.4 Colour parameters (LSMeans ± se) of the three selected buffalo muscles as per age, sex, muscle and ageing period

Main effects		**L***	**a***	**b***	**Hue**	**Chroma**
Age	**Sub-adult**	42.1 ± 0.12	14.8 ± 0.07	13.0 ± 0.06	41.3 ± 0.17	19.8 ± 0.08
	Adult	39.8 ± 0.07	15.5 ± 0.04	12.7 ± 0.04	39.4 ± 0.09	20.1 ± 0.05
Gender	**Female**	40.8 ± 0.08	15.2 ± 0.06	12.9 ± 0.05	40.4 ± 0.11	20.1 ± 0.07
	Male	41.1 ± 0.09	15.1 ± 0.05	12.8 ± 0.04	40.4 ± 0.11	19.8 ± 0.05
Muscle type	**LTL**	39.3^{c} ± 0.09	14.9^{b} ± 0.06	11.7^{c} ± 0.05	38.2^{c} ± 0.12	19.0^{c} ± 0.07
	SM	42.4^{a} ± 0.10	15.6^{a} ± 0.07	14.2^{a} ± 0.05	42.5^{a} ± 0.14	21.2^{a} ± 0.07
	BF	41.2^{b} ± 0.11	14.9^{b} ± 0.07	12.6^{b} ± 0.05	40.4^{b} ± 0.14	19.6^{b} ± 0.07
Ageing period (days PM):	**1**	38.9^{c} ± 0.18	16.3^{ab} ± 0.10	12.2^{c} ± 0.11	36.6^{f} ± 0.22	20.4^{cd} ± 0.13
	5	40.8^{b} ± 0.19	16.1^{b} ± 0.10	12.9^{b} ± 0.11	38.5^{e} ± 0.20	20.7^{bc} ± 0.13
	9	40.9^{b} ± 0.22	16.8^{a} ± 0.09	13.5^{a} ± 0.10	38.6^{e} ± 0.19	21.6^{a} ± 0.12
	13	41.6^{a} ± 0.18	16.1^{b} ± 0.09	13.6^{a} ± 0.10	40.1^{d} ± 0.20	21.1^{ab} ± 0.11
	17	41.6^{a} ± 0.18	15.1^{c} ± 0.10	13.20^{ab} ± 0.10	41.2^{c} ± 0.22	20.1^{d} ± 0.12
	21	41.3^{ab} ± 0.18	14.9^{c} ± 0.11	13.0^{b} ± 0.09	41.2^{c} ± 0.23	19.8^{d} ± 0.12
	25	41.0^{b} ± 0.17	14.1^{d} ± 0.10	12.5^{c} ± 0.09	41.5^{bc} ± 0.24	18.9^{e} ± 0.11
	29	41.2^{ab} ± 0.18	13.7^{de} ± 0.11	12.4^{c} ± 0.09	42.3^{b} ± 0.27	18.6^{ef} ± 0.11
	32	41.3^{ab} ± 0.17	13.2^{e} ± 0.10	12.4^{c} ± 0.09	43.4^{a} ± 0.27	18.2^{f} ± 0.10

Abbreviations: LTL= *Longissimus thoracis et lumborum*; BF: *Biceps femoris*; SM: *Semimembranosus* PM: post-mortem

LSMean: least square mean; se: standard error of the mean

[a-f]LSMeans with different superscripts within main effects differs significantly at $p \leq 0.05$

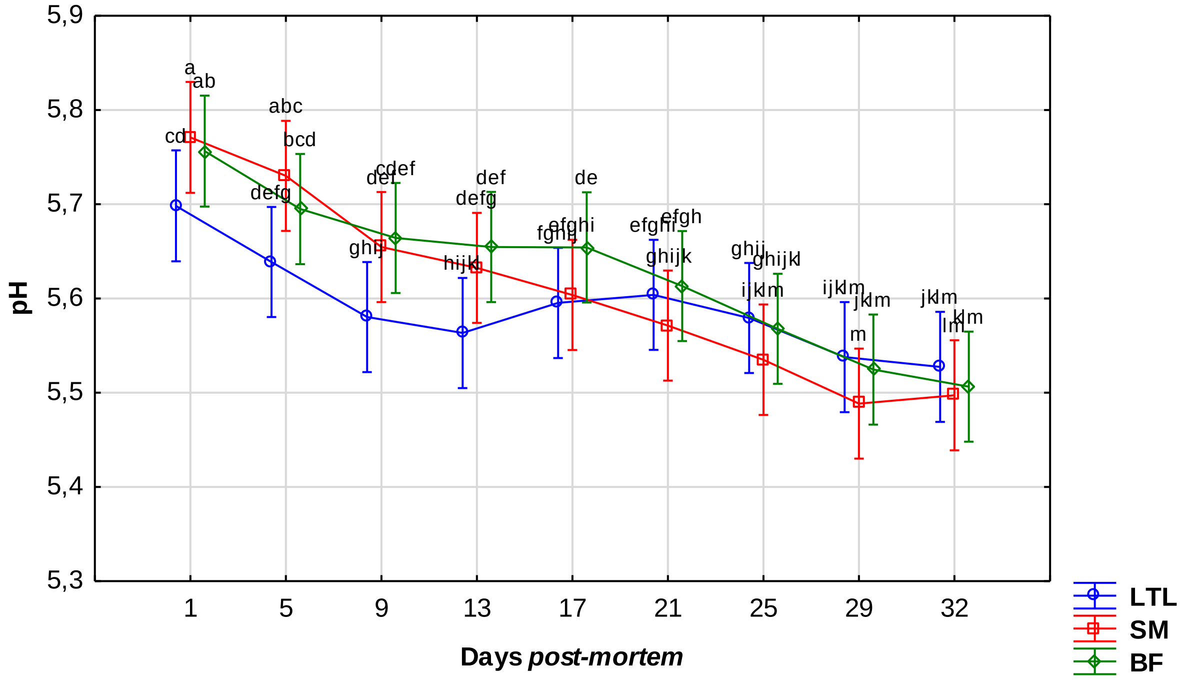

Figure 5.1 The change in pH of buffalo muscles, *Longissimus thoracis et lumborum* (LTL), *Semimembranosus* (SM) and *Bicep femoris* (BF) during ageing up to 32 days post-mortem. [a-m]Different letters indicate significant differences (p≤0.05) between the mean values. Error bars indicate standard error of the mean of each group.

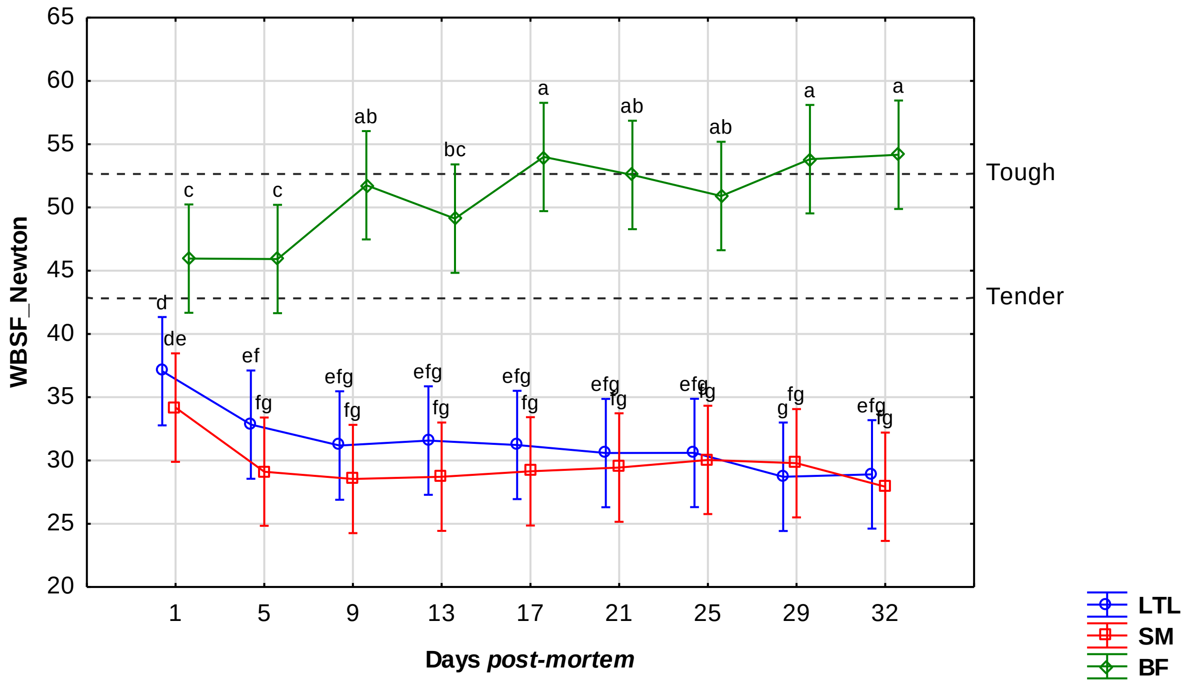

Figure 5.2 The Warner Bratzler shear force (N) of buffalo muscles, *Longissimus thoracis et lumborum* (LTL), *Semimembranosus* (SM) and *Bicep femoris* (BF) during ageing up to 32 days post-mortem. [a-g]Different letters indicate significant differences (p≤0.05) between the mean values. Error bars indicate standard error of the mean of each group (Destefanis *et al*., 2008).

For the colour measurements, there was a fourth order interaction observed between age*sex*muscle type*days PM for both CIE L* (p=0.036) and CIE b* (p=0.014) (Table 5.2) values. Third order interactions were also found between sex*muscle type*days PM for CIE a* (p<0.001), hue (p=0.015) and Chroma (p=0.001) values and between age*muscle type*days PM for CIE b* (p=0.006) and Chroma (p<0.001) (Table 5.2).

To better understand these interactions, the individual effects of age, sex and muscle type on change in the physical characteristics of interest are described in Table 5.3. Firstly, change in pH (p=0.027) and WBSF (p=0.024) was greater in adults compared to sub-adults. Cooking loss and cumulative purge loss did not differ significantly between adults and sub-adults (p>0.05). Sex did not have a significant individual effect on change in pH, WBSF, cooking loss or cumulative purge loss (p>0.05). Lastly, change in pH (p=0.022), cooking loss (p<0.001), cumulative purge loss (p<0.001) and WBSF (p<0.001) and for all colour measurements (CIE L*a*b*) differed significantly between the three muscles of interest. Days PM had a significant effect on all physical characteristics except WBSF (p=0.792) (Table 5.3).

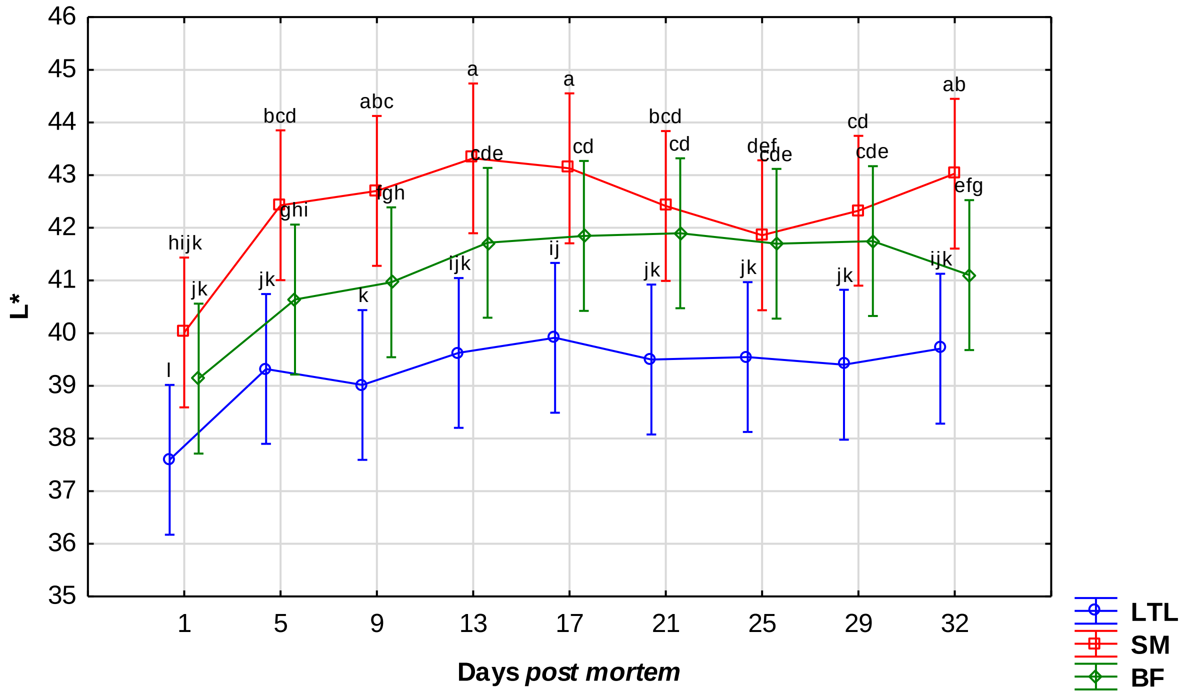

Figure 5.3 The change in CIE L* value colour co-ordinate of buffalo muscles, *Longissimus thoracis et lumborum* (LTL), *Semimembranosus* (SM) and *Bicep femoris* (BF) during ageing up to 32 days post-mortem. [a-k]Different letters indicate significant differences (p≤0.05) between the mean values. Error bars indicate standard error of the mean of each group.

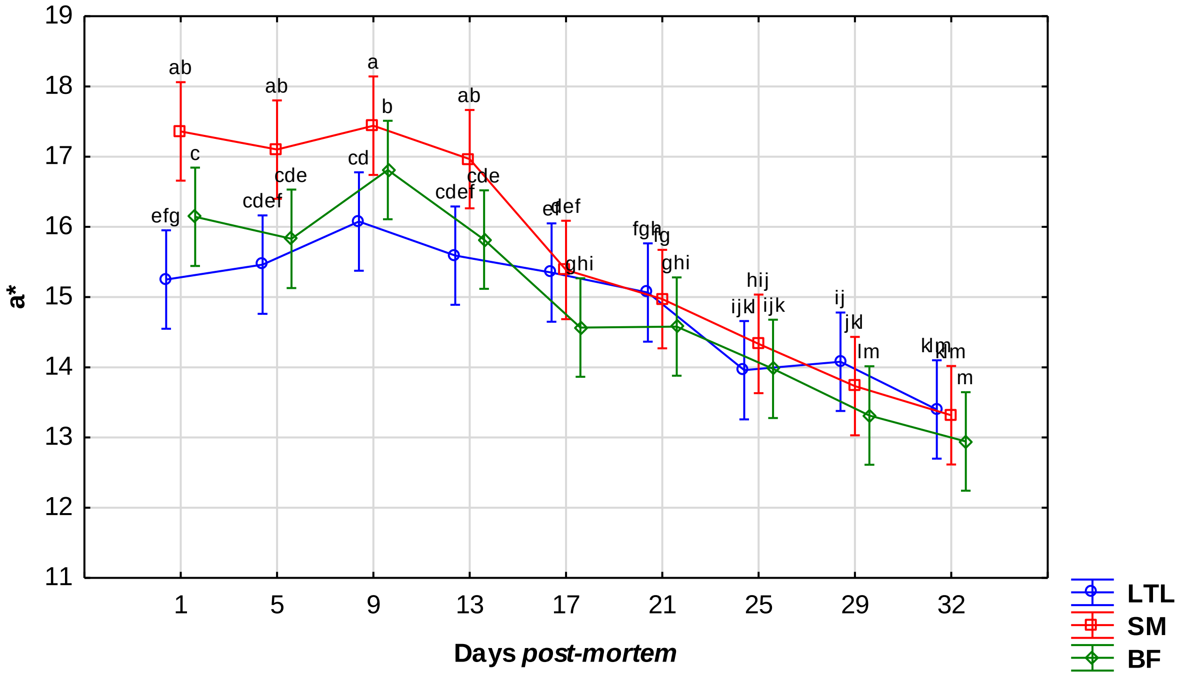

Figure 5.4 The change in CIE a* value colour co-ordinate of buffalo muscles, *Longissimus thoracis et lumborum* (LTL), *Semimembranosus* (SM) and *Bicep femoris* (BF) during ageing up to 32 days post-mortem. [a-m]Different letters indicate significant differences (p≤0.05) between the mean values. Error bars indicate standard error of the mean of each group.

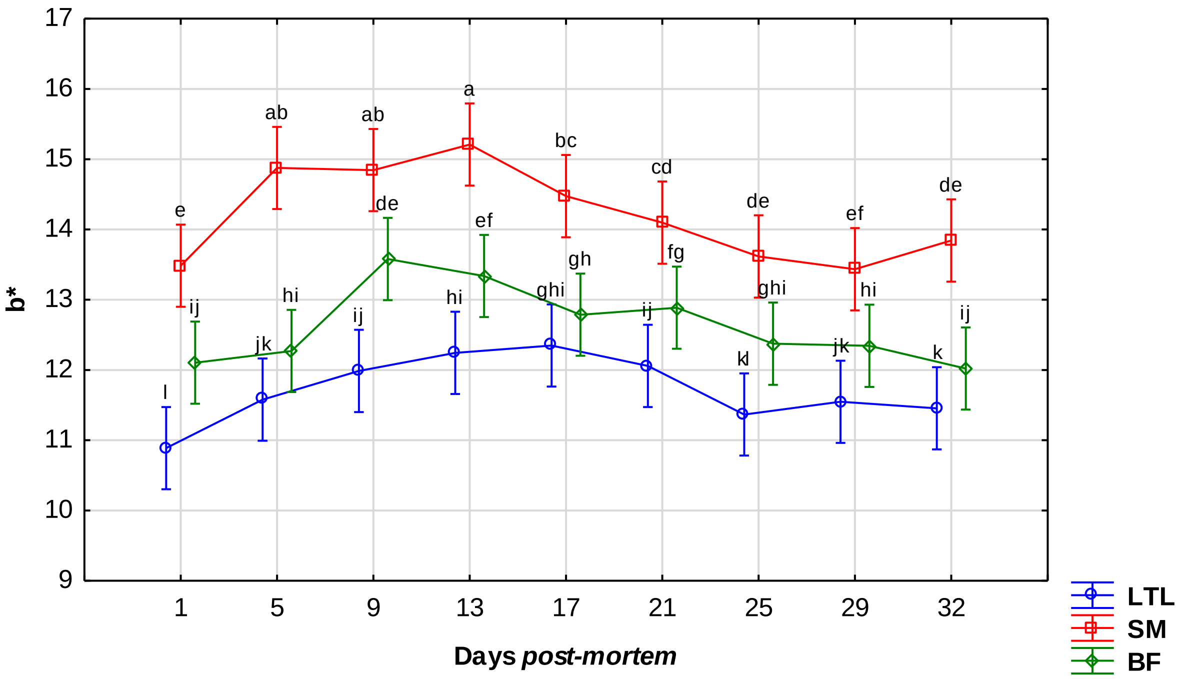

Figure 5.5 The change in CIE b* value colour co-ordinate of buffalo muscles, *Longissimus thoracis et lumborum* (LTL), *Semimembranosus* (SM) and *Bicep femoris* (BF) during ageing up to 32 days post-mortem. [a-k]Different letters indicate significant differences (p≤0.05) between the mean values. Error

bars indicate standard error of the mean of each group.

The ageing process had a significant effect on change in pH, purge loss, cooking loss and colour measurements ($p<0.001$) over 32 days. Briefly, there was a significant decrease in pH ($p<0.001$) with a linear decreasing trend found with the increase in the ageing period. A similar trend was noted for cooking loss ($p<0.001$) except the decreasing trend started increasing again from day 13 PM (Table 5.3). Mean purge loss increased significantly in a linear manner from day one to day nine and plateaued to day 21 and thereafter increased significantly to day 29 where after it plateaued till day 32.

The mean WBSF of all three muscles (LTL, BF and SM) were not significant over the ageing period (Fig. 5.2), although they differed individually ($p<0.001$). For the LTL muscle, the lowest WBSF was reached at an ageing period of 29 days, with a significant decline from days one to five, and again from days 25 to 29. However, the decrease in WBSF for this muscle did not decrease between day five until day 25 for the time points, a phenomenon that could be described to the high variation within the different steaks. The SM muscle reached the lowest WBSF at day 13, with a significant decline from days one to five. In comparison, the BF muscle reached the lowest WBSF at day five, with toughness increasingly significantly until day nine, and again from days 13 to 17, after which it plateaus (Fig. 5.2).

The mean CIE L* values increased until day 13 and plateaued till day 32, with the SM muscle having the highest value (Fig. 5.3). The mean CIE a* values increase significantly from day five up to day nine and then decreased significantly in a linear manner, with the BF muscle having the lowest a* value (Fig. 5.4). Mean CIE b* values increased significantly till day nine and plateaued up to day 21, then decreased significantly till day 25 where it plateaued again, with LTL having the lowest b* value (Fig. 5.5). Mean hue values increased in a linear manner up to day 32, with the SM muscle having the highest hue values. Lastly the mean Chroma values increased up to day five and then decreased in a linear manner up to day 32 with the LTL muscle having the lowest Chroma values (Table 5.4).

5.5 Discussion

The high overall ultimate pH observed in this study can be explained by the harvesting procedure which entails the herding and moving of the buffalo to a suitable “working zone” by means of a helicopter, which results in high physical effort being executed by the buffalo before and after being darted with an excess dosage of succinyldicholine chloride (SDC) (Lawrie & Ledward, 2006a). The latter also causes short-term stress, low glycogen levels and high pH as it is a neuro blocker (Hoffman, 2001a). In fact, Hoffman (2001b) has reported that the use of SDC in the harvesting of buffalo has a strong negative effect on meat quality and even led to the pale, soft and exudative (PSE) phenomenon normally experienced in pigs suffering from acute ante mortem stress. A similar phenomenon is also described during acute stress experienced during the capture of various ungulates and is commonly known as white muscle capture myopathy (Hattingh *et al.,* 1984; Hoffman & Wiklund, 2006).

Cumulative purge loss in fresh meat can be influenced by the pH and the spacing of the myofibrillar as water in meat is either bound to free water, entrapped by steric affects or bound to proteins (Huff-Lonergan & Lonergan, 2005). Thus, the moisture lost is most affected by the rigor process since, the decrease in pH throughout the process is the result of anaerobic conversion of glycogen to lactic acid allowing the net charge of proteins to be reduced (Strydom *et al.*, 2016; Huff-Lonergan & Lonergan, 2005). This normally occurs when the pH reaches the muscle's iso-electrical point of ~5.4. In the present study the mean pH drops from day one PM (5.7 ± 0.02) to 5.5 ± 0.01 on day 32 PM. Although the pH remained above the iso-electrical point (highest was observed on day 25 PM), it was still inversely correlated (r=-0.47) with the cumulative purge loss (Table 5.3). Vacuum packaging also has an influence on cumulative purge loss due to the physical compression of the meat caused by the vacuum (Payne *et al.,* 1998). Individually, the cumulative purge loss percentage increase from 4.2% to 9.3% over the 32-day ageing period with the SM muscle having a significant higher (Table 5.3) cumulative purge loss. This finding can be due to the size (cut surface area to volume ratio) of the muscles' steaks that allows for greater variability in the meat quality attributes, such as purge loss, colour and tenderness of the muscle (Sawyer *et al.,* 2007); this variation in most of the measured parameters could also be a reason for the lack of distinct differences between the parameters over ageing time. None the less, purge loss plateaued from day 29 PM, given a limited amount of water in the meat sample, in accordance with findings reported North *et al.* (2015). Moreover, the purge loss increased by nearly 60% over the ageing period, in accordance with values previously reported (Laubser, 2018; Hoffman *et al.*, 2009).

Cooking loss decrease significantly from day one PM to day five PM (Table 5.3) and then plateaued over the ageing period with a slight increase from day 13 PM onwards. This finding was anticipated, since cumulative purge loss has an effect on the total moisture loss. It is also possible that this increase was caused by proteolytic fluctuations taking place PM and achieving an acute point at which stage the water bounded in the meat could be freed during cooking (North *et al.,* 2015). Increase in cooking loss percentage has been correlated with a decrease in tenderness (Silva *et al.,* 1999) as evidence from the present study supports, with the BF muscle having a significant higher cooking loss and a significant higher WBSF (Table 5.3). Higher cooking loss for the BF muscle can also be the result of the physical shrinkage of the insoluble collagen throughout the heating process causing the meat matrix to force out water molecules (Rhee *et al.,* 2004; Colle *et al.,* 2015) also resulting in more collagen per core sheared, thus explaining the higher WBSF.

Tenderness is an essential aspect of overall meat quality, and influenced by the interaction between connective tissue, myofibrils and collagen (Sacks *et al.*, 1988). The collagen content establishes the background or muscle toughness as measured by the WBSF (Sentandreu *et al.,* 2002; Purslow, 2005). In this study, the BF muscle WBSF differed significantly from the LTL and SM muscle over the ageing period (Fig. 5.2). This was expected, since skeletal muscles differ in their collagen content and composition, as well as location, activity and function (Lawrie & Ledward, 2006a). The remaining structural proteins also affect the physical characteristics of muscles, leading to a dissimilarity in toughness (Koohmaraie *et al.*, 2002). However, ageing cause proteins to be broken down, resulting in an increase in tenderness observed over the ageing period (Ouali, 1992). Another reason for an increase in tenderness lies in degradation of muscle structure that reduces myofibrillar strength (Ouali, 1990). In this study, there was little change in WBSF of buffalo meat observed past five days of ageing. A higher rate of tenderisation have been found in venison compared to beef due to an increased proteolytic enzyme activity and more effective proteolytic systems (Hutchison *et al.*, 2010; North *et al.*, 2015). However, the short period could be related to the long-time taken between killing and chilling as the higher the carcass temperature, the more active the proteolytic enzymes. Furthermore, the high pH enhances the activity of proteolytic enzymes therefore meat having a high pH (>6.3) being considered more tender, followed by meat with a low pH (< 5.8) and lastly meat with an intermediate (5.8 – 6.3) pH being the toughest (Yu & Lee, 1986).The same plateau in tenderization has been observed after eleven to fourteen days of ageing in beef (Koohmaraie *et al.*, 1991; Smith *et al.,* 1978; Sentandreu *et al.,* 2002; Nowak, 2011). This finding can be an indication that buffalo meat has relatively high enzyme activities, an aspect that warrants further research.

Meat toughness can be distinguished by consumers: when the WBSF is higher than 52.68 N, the meat will be regarded as tough and, lower than 42.87 N it will be experienced as tender meat and between these values it will be observed as intermediate (Destefanis *et al.,* 2008). In this study, the lowest WBSF for the LTL muscle was obtained after 29 days PM with a shear force value of 28.71 N. The SM muscle obtained its lowest WBSF value of 27.92 N after 32 days PM, while the BF muscle reached its lowest WBSF value of 45.92 N after five days PM. Therefore, at the most tender time period (29-32 days PM) of the meat, both LTL and SM would be regarded as tender meat and the BF muscle as intermediate, by consumers. However, throughout the ageing period, mean WBSF values for the LTL (31.41 N) and SM (29.66 N) muscles were lower than 42.87 N and these muscles can therefore be considered as tender throughout the ageing period. In addition, the BF muscle WBSF increase over the ageing period and should be sold before it surpasses the toughness parameter of 52.68 N, i.e. before day 17 PM, or processed into value-added products such as biltong. Moreover, steaks from the LTL and SM muscles can go through ageing for 25 days and sold to restaurants (restaurants normally keep the meat in the chiller for few days before selling depending on the stock turnover rate since ageing continues) to be served as quality and tender steaks.

The BF muscle had significantly higher shear force values throughout the ageing period compared to the LTL and SM muscles and as mentioned, it might be more suitable to be processed into value added products such as biltong rather than being sold for consumption as steaks. These finding are also in accordance with those reported by Van Heerden (2018) in aged blue wildebeest (*Connochaetes taurinus*) meat, and by North *et al.* (2015) in aged springbok (*Antidorcas marsupialis*) meat, where the BF muscle was tougher than the LTL muscle. This phenomenon is said to be the result of higher total collagen content in the BF muscle as well as lower collagen solubility in the BF (Rhee *et al.*, 2004; North *et al.,* 2015). Also, with ageing, soluble and insoluble collagen content in the muscle does not alter, resulting in an absence of improvement for the BF muscle shear force over the ageing period (Fig. 5.2), since there is already a large baseline toughness produced by excessive levels of insoluble collagen (Silva *et al.,* 1999; Sentandreu *et al.,* 2002; Colle *et al.,* 2015). In the first five days PM, the SM had the highest decline (5.07 N) in WBSF, whilst the LTL had a decline of 4.22 N, and BF a decline of 0.04 N (Fig. 5.2). Muscles such as the LTL have little connective tissue and an improved response to ageing than high connective tissue containing muscles such as the BF (Thompson, 2002).

Also, cooking and cumulative purge loss both result in moisture loss, since protein bonds and proteins are degraded and therefore release water that was bound into the extracellular space; a piece of meat with less moisture will have a higher shear force.

The colour of the meat is the main factor for consumer acceptability at the time of purchase and discolouration of meat when packaged under aerobic conditions results in loss of sales (McKenna *et al.,* 2005). Ageing can result in change of colour due to the oxidative processes and enzymatic reducing systems that controls the metmyoglobin levels of the meat. Metmyoglobin is the cause for the brown discolouration, however metmyoglobin is reduced to myoglobin via the metmyoglobin reducing activity (Neethling *et al.*, 2016). Once the meat is exposed to oxygen (removing meat from vacuum packaging) the oxygenation of myoglobin results in oxymyoglobin and this gives the meat the cherry red colour that is attractive to most consumers, which they correlate with quality and freshness (Lawrie & Ledward, 2006b). According to Volpelli and colleagues (2003), a desirable dark red colour in game meat is reflected by several parameters, including low L* value (<40), high a* values and low b* values. However, Shange *et al.* (2019), further specified the colour coordinates for game meat and described the typical colour ordinates for normal pH game meat as L* >

33, a* > 13, b* ~ 10 resulting in Chroma ordinates > 17 and a hue angle of > 36.

In the present study, desirable values were demonstrated for all muscles of interest over the ageing period after blooming (Table 5.4). Furthermore, the colour parameters compared favourably with beef (*Bos taurus*), as the mean L* value (40.38) fell between (33.2 - 41), the mean a* value (15.30) between (11.1 – 23.6), and mean b* value (12.77) just above the range of (6.1 – 11.3), indicating a light red colour that is perceived as attractive for consumers (Naveena & Kiran, 2014). The L* value increased from day 1 PM to day 13 PM and then plateaued, with the highest L* value observed on day 13 PM, with subtle changes in the LTL muscle. These results are similar to those previously reported for beef (Boakye & Mittal, 1995; McKenna *et al.,* 2005). However, the L* value differs significantly between the different muscles that do not correspond with a previous study on blue wildebeest (Van Heerden, 2018). The increase in L* value could be due to increased retention of oxygen due to vacuum packaging of the samples, since the oxygen-consuming enzymes in the deep skeletal muscle tissue become less activated over the ageing period (Boakye & Mittal, 1995). Furthermore, an increase in protein denaturation over the ageing period and the cumulative purge loss also has an effect on the scattering of light (Colle *et al.,* 2015).

The mean a* values as well as the chroma values for the different muscles increased significantly from day five PM to day nine PM and then decreased linearly. The SM muscle had a significantly higher a* value than the LTL and BF muscles. Furthermore, all the a* values observed were above the cut-off point of 12 established for consumer acceptability of venison (Wiklund *et al.*, 2001). The same pattern was reported by Colle and colleagues (2015) for change in a* value over the ageing period for beef. In the present study, the meat would have the optimum colour on day nine PM since, the a* value is normally positively correlated with the concentration of myoglobin and Chroma with the saturation of the meat colour (Vestergaard *et al.,* 2000).

The b* values differed significantly between the different muscles with LTL having the lowest b* values. However, the mean b* value increased significantly from day 1 PM up to day 9 PM and then plateaued till day 13 PM and decrease up to day 25 PM and then plateaued further over the ageing period. The meat became a more yellow/brown colour up to day 13 PM as a result of oxidation that changed oxymyoglobin to metmyoglobin (Wiklund *et al.,* 2010). Also, the lower pH could have resulted in lower oxygen consumption which led to a faster browning due to a higher oxygen penetration (Faustman & Cassens, 1990). Furthermore, the hue angle increased linearly over the ageing period, which indicates an increase in redness. The colour measurement for the three muscles indicate that the SM will have a more saturated red colour as well as more yellow/brownish colour than the BF and LTL. Overall the highest values were observed for the SM.

5.6 Conclusions

The present study demonstrated the effects of chilled ageing on the physical characteristics of African savanna buffalo meat in relation to animal age and sex; the latter two factors having less impact than muscle type and days aged. In particular, rapid tenderization of the LTL and SM muscles was observed as early as five days PM. In contrast, while the BF muscle reached optimal tenderness at day five, tenderization decreased again with a longer ageing period. Therefore, an ageing period of 25 days is recommended based on the present findings for the LTL and SM muscle, with a longer ageing period resulting in a storage/chiller cost that will exceed the benefit of further ageing. Furthermore, ageing longer than 25 days PM will result in a substantial increase in mass loss as cumulative purge as well as increased cooking losses and decolourisation. In conclusion, the physical characteristics of African savanna buffalo meat show early changes over the ageing period, including increased tenderness for LTL and SM, and in relation to colour parameters, the evolution observed during ageing was in accordance with results in beef. Due to the BF muscles' high WBSF, it should be considered for alternative uses such as drying for biltong as is the norm for this muscle in beef in South Africa. Results of this study could serve to inform buffalo product suppliers to local restaurants on the ageing period to ensure maximum tenderness to satisfy consumer demands for tender meat. Selling these aged muscles at a premium price will help offset the costs to the KNP when assisting the adjacent communities with provision of cheaper stew meat obtained from African savanna buffalo. Future research to more accurately determine the optimum ageing period for buffalo meat should evaluate different chilling rates (of which the speed of getting the carcasses to the WPS should be a factor for evaluation) as well as increasing the sample size from different age categories for both sexes. Also, further research is suggested to assess the textural changes as well as the sensory attributes such as flavour and aroma of the meat over the ageing periods. Also, alternative uses for the BF muscle should be investigated.

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CHAPTER 6

EFFECT OF FREEZING AFRICAN SAVANNA BUFFALO CARCASSES ON BILTONG QUALITY

6.1 ABSTRACT

The effects of freezing on salting, drying weight loss, physico-chemical and textural properties were determined on biltong made from African savanna buffalo muscles. Fifteen frozen (detained) and fifteen chilled African savanna buffalo carcasses were utilised in the present study. Five muscles typically used for biltong were removed (BF= *Biceps femoris*; SM: *Semimembranosus*; ST: *Semitendinosus*; LTL: *Longissimus thoracic et lumborum*; RF: *Rectus femoris*) and cut along the grain into biltong strips. Raw biltong strips was treated with spices, salt and vinegar and dried in a biltong cabinet dryer at 26°C till 45-50% weight loss. Compared to chilled meat, frozen-thawed muscles had a significantly higher salt, protein and ash content with a lower ($p \leq 0.05$) moisture, water activity (a_w), pH and fat content. The RF muscles had the highest salt content, whereas the BF muscle had the lowest salt content. Fat content and pH were highest for the BF muscle. Overall, frozen-thawed biltong had a higher hardness as well as lower springiness compared to fresh muscle tissue. The LTL and RF muscles had higher springiness compared to the BF, SM and ST muscles. Thus, frozen carcasses (detained carcasses) can be utilised the same as chilled carcasses for value-added products such as biltong.

6.2 Introduction

The importance of establishing the composition and patterns of consumption of fresh African savanna buffalo meat, which remains poorly described, is based on several factors. Buffalo meat is reported to have a high production potential, with a live carcass having 40% lean mass and 5.6% fat mass (Du Toit, 2003). In addition, buffalo meat can be processed to a variety of value-added products (Naveena & Kiran, 2014). Moreover, studies on similar buffalo species suggest that their meat is comparable to beef, with high protein and low-fat contents. (Ummary, 1986; Juárez *et al.,* 2010; Petridis *et al.*, 2015).

In South Africa, ranchers commonly use buffalo meat for biltong (a salted dried meat snack food similar to specialty dried meat products such as beef jerky (North America) and charqui (Brazil)). Biltong can also be processed on a commercial level or at home by the consumer (Strydom & Zondagh, 2014; Jones *et al.,* 2017). Moreover, the production process is a very simplistic process, were meat is cut in desirable sizes, salted, and spiced using an acidic-liquid spice mix or a dry salt method (Jones *et al.,* 2017) The most common muscles for biltong production include silverside (*biceps femoris*), eye of the round (*semitendinosus*), topside (*semimembranosus*), thick flank (*rectus abdominus*) and fillets (*longissimus dorsi*) (Van Wyk, 2007; Jones *et al.,* 2017).

Importantly, some buffalo in the KNP are affected by Sarcocystis or beef measles (*Cysticercosis*) and are then detained and need to be frozen for at least 72 h with an air temperature of at least - 18 °C (National Department of Agriculture, 2007). Alternative uses for the meat are needed to add more value to the meat than just stew meat or mince since the prime cuts cannot be sold as such due to the aesthetics of the measles in the meat as well as the damage to the meat quality caused by the ice crystal formation (Leygonie *et al.,* 2012). Therefore, use of skeletal muscles for biltong processing is of particular interest in maximizing value while also limiting the potential for foot and mouth disease on the end-product (National Department of Agriculture, 2014). Biltong can then be sold out of the FMD buffer zone and thus have a larger customer basis.

Skeletal muscles differ in shape, size, location, and biochemical functioning (Listrat *et al.,* 2016; Zochowska-Kujawska *et al.*, 2009). Internal muscles therefore also differ with regards to fibre type, connective tissue content and intramuscular fat, which contributes to variation in the properties of biltong derived from skeletal muscles. Buffalo meat is often frozen and then thawed before processing, leading to the formation of ice crystals and loss of water which physically damages the fibre and myofibrillar structure of muscle tissue (Ngapo *et al.,* 1999; Gambuteanu *et al.*, 2013; Leygonie *et al.*, 2012). These changes may affect salt diffusion and water loss during processing (Deng, 1977; Akköse, 2017; Picouet *et al.,* 2013; Retz *et al.,* 2017), which affects the physical and chemical properties of biltong.

There is limited information available on the quality characteristics of buffalo biltong, and no studies have investigated the composition of biltong processed from frozen-thawed buffalo meat. Therefore, the aim of the present study was to determine the effect of carcass freezing on weight loss of biltong strips during salting and drying, as well as the physico-chemical and textural properties of biltong derived from different buffalo muscles (BF: *biceps femoris*, SM: *semimembranosus*, ST: *semitendinosus*, RF: *rectus femoris*, LTL: *longissimus thoracic et lumborum*).

6.3 Materials and methods

6.3.1 Harvest and slaughter of African savanna buffalo

In total, 49 buffalo were randomly harvested at the Pretoriuskop section in the KNP on four different occasions within a period of eleven days between May and June 2017. For the present study a sample of thirty buffalo aged between 18 months and 8 years were considered. In brief, after being darted with succinyldicholine chloride (SDC) from a helicopter and killed via a shot to the head, the animals were exsanguinated, hanged and eviscerated in the field and transported to the abattoir to be skinned and after health inspection by a veterinarian, quartered. The quartered carcass was then suspended in a chiller (0-5 °C) for 24 h whilst the detained carcasses were frozen at -30°C for 72 h. Afterwards, the frozen carcasses were thawed at 4°C for 72 h. Thereafter the muscles from 15 thawed and 15 fresh carcasses were compared.

6.3.2 Biltong production

The BF, SM, ST, LTL and RF muscles were removed in their entirety from the buffalo carcasses. Visible connective tissues and fat were trimmed off, and the muscles were cut along the grain into biltong strips weighing 248 ± 8.9 g, ~1.2 cm thick, retaining the muscle sample identity at all times. Afterwards, 4% (by weight) of Freddy Hirsch's commercial biltong spice mixture with a formulation of salt, coriander, white pepper, dextrose, sucrose, ascorbic acid, MSG (flavour enhancer), cereal (wheat flour), flavourings and 1.5% vinegar with 5% acidity (Freddy Hirsh, Maitland, Cape Town) was added by lightly sprinkling the mixture over the meat strips which were then left to absorb the salt for 12 h under refrigerated conditions. The biltong strips from each muscle per treatment were randomly divided into five replicates. A total of five Hilco biltong cabinet driers (Freddy Hirsch) were utilised, with each replicate containing the same number of biltong strips dried in cabinet drier at a temperature of 26°C. One strip per replicate was weighed at regular intervals during drying till 50% of the sample's initial weight was attained when the biltong was deemed dry and ready for consumption.

6.3.3 Sample preparation

Representative samples from each replicate (biltong strips) were randomly sampled (from the larger batch of biltong slices) and cut into smaller pieces before homogenising for one minute using a knifetec™ 1095 MB (FOSS, Höganäs, Sweden) grinder.

6.3.4 Physico-chemical analysis

Salt content was determined in duplicate by weighing a 0.3g sample (closed container) and stirred for two hours with 50mL of 0.3M nitric acid. A 926 Chloride analyser (Sherwood Scientific, Cambridge, UK) was used to determine the chloride concentration. Furthermore, the a_w was measured in duplicate at 25 °C using an Aqualab Series 4 water activity measurement system (Decagon Devices Inc., Washington USA). The pH was determined using a Crinson25 pH meter with a glass electrode (Lasec (Pty) Ltd, Cape Town, South Africa) after homogenization of a three-gram sample in 27mL distilled water for 30 min. The proximate chemical analysis was determined as described in section 4.3.4.

6.3.5 Textural properties

Texture instrumental measurements of biltong were carried out using an Instron: two cylindrical cores (1.27 cm diameter) with a height of 20mm per biltong sample from five strips were cut parallel to the orientation of muscle fibres. Texture profile analyses was performed using a 25mm compression plate with a 500 N load cell at a speed of 60mm/min. The samples were compressed to 50% its original height in two cycles. Hardness is the maximum peak force during the first compression cycle, cohesiveness is the ratio between the positive force area through the second compression cycle and that of the first compression cycle. Springiness is measured as the height that the food recovers during the time elapsed between the first compression and the start of the second compression. The chewiness is the energy required to chew a solid sample to a state of steady swallowing and is expressed as hardness x cohesiveness x springiness (Ruiz De Huidobro *et al.,* 2005). The Warner-Bratzler shear force (WBSF) was measured according to the method of Retz *et al.* (2017) using the Instron machine (3344 model equipped with Bluehill software). Five strips per replicate, were cut in to six sub samples utilising a 1x1cm double bladed scalpel. A compression load cell (500 N) with a V-shaped blade was utilised at a speed of 200mm/min to cut the samples perpendicular to the fibre orientation. The shear force was recorded in Newton.

6.3.6 Statistical analysis

Data were analysed using Statistica version.13.2 (Statsoft 2016). Both the effects of freezing versus chilled and muscle type on mass transfers, textural properties and physico-chemical properties of the biltong were analysed utilising analysis of variance (ANOVA) of 2 x 5 factorial in a completely randomized design. Fisher's LSD test was used to separate the means. A value of $p \leq 0.05$ was used to indicate statistical significance.

6.4 Results

The individual and interactive effects for treatment and muscle type on physico-chemical properties of African savanna buffalo biltong are shown in Table 6.1. There was a significant interaction between treatment and muscle type for drying time ($p=0.011$), springiness ($p=0.004$; Fig. 6.1) and salt content ($p<0.001$; Fig. 6.2), where the ST muscle from fresh muscles had the longest drying time, and ST from frozen-thawed muscles had the shortest drying time (Fig. 6.3).

Drying time, moisture, fat, NaCl, pH, chewiness and springiness differed between the muscles of interest, as shown in Tables 6.2 and 6.3. Moisture content was lowest for the LTL and RF muscles, while fat content and pH were highest for the BF muscle. The RF muscle also had the highest salt content, chewiness and springiness (Tables 6.2 and 6.3).

There were significant differences between the treatment effect for all the physico-chemical properties except cohesiveness and chewiness (Table 6.1). Frozen-thawed meat had significantly higher weight gain during the salting process, faster drying rate, higher protein, ash and salt contents, as well as higher WBSF and hardness values. In comparison, chilled muscles have a significantly higher moisture, fat, a_w, pH content as well as springiness compared to the frozen thawed muscles.

Table 6.1 Individual and interactive effects of muscle type and treatment (fresh and frozen-thawed) on the physico-chemical properties of African savanna buffalo biltong

Parameter	**P values**		
	Muscle	**Treatment**	**Muscle*Treatment**
Salt weight loss	0.83	0.029	0.459
Drying Time (hrs)	<0.001	0.048	0.011
Moisture (%)	<0.001	<0.001	0.288
Protein (%)	0.542	<0.001	0.14
Ash (%)	0.663	0.033	0.642
Fat (%)	0.004	<0.001	0.13
Water activity (a_w)	0.011	<0.001	0.18
NaCl (%)	<0.001	<0.001	<0.001
pH	0.049	0.005	0.243
WBSF (N)	0.185	0.003	0.292
Hardness (N)	0.609	0.009	0.217
Cohesiveness (ratio)	0.65	0.153	0.588
Chewiness (N)	<0.001	0.454	0.08
Springiness (mm)	<0.001	0.026	0.004

Table 6.2 Differences (LSMeans ± se) between the muscle physico-chemical properties of five selected African savanna buffalo muscles

Muscle type	Treatment	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	a_w	pH	NaCl (%)
BF	Frozen-thawed	$43.8^{bc} \pm 0.36$	$47.2^{ab} \pm 0.42$	$7.7^{ab} \pm 0.23$	$2.5^{bc} \pm 0.29$	$0.9^{cd} \pm 0.00$	$5.3^{bc} \pm 0.02$	$5.4^{bcd} \pm 0.14$
	Chilled	$46.6^{a} \pm 0.72$	$43.5^{bc} \pm 0.80$	$6.9^{ab} \pm 0.41$	$3.8^{a} \pm 0.42$	$0.9^{a} \pm 0.00$	$5.5^{a} \pm 0.08$	$4.3^{f} \pm 0.26$
SM	Frozen-thawed	$45.3^{ab} \pm 0.81$	$47.2^{ab} \pm 0.66$	$7.3^{ab} \pm 0.20$	$1.8^{cd} \pm 0.25$	$0.9^{abc} \pm 0.01$	$5.2^{c} \pm 0.04$	$5.2^{cde} \pm 0.23$
	Chilled	$46.6^{a} \pm 0.33$	$45.2^{ab} \pm 0.34$	$6.8^{b} \pm 0.18$	$2.6^{bc} \pm 0.24$	$0.9^{a} \pm 0.00$	$5.3^{bc} \pm 0.02$	$4.9^{def} \pm 0.19$
ST	Frozen-thawed	$44.9^{ab} \pm 0.56$	$46.1^{ab} \pm 0.49$	$7.8^{a} \pm 0.71$	$1.9^{cd} \pm 0.09$	$0.9^{bcd} \pm 0.01$	$5.3^{bc} \pm 0.03$	$5.4^{bcd} \pm 0.20$
	Chilled	$46.8^{a} \pm 0.97$	$45.1^{ab} \pm 0.86$	$6.9^{ab} \pm 0.27$	$2.2^{cd} \pm 0.24$	$0.9^{a} \pm 0.01$	$5.4^{ab} \pm 0.03$	$4.6^{ef} \pm 0.16$
RF	Frozen-thawed	$41.0^{d} \pm 1.00$	$48.8^{a} \pm 0.93$	$7.6^{ab} \pm 0.22$	$2.4^{bcd} \pm 0.39$	$0.9^{d} \pm 0.01$	$5.3^{bc} \pm 0.03$	$8.3^{a} \pm 0.26$
	Chilled	$45.3^{ab} \pm 0.99$	$40.1^{c} \pm 4.59$	$7.6^{ab} \pm 0.38$	$2.6^{bc} \pm 0.31$	$0.9^{ab} \pm 0.00$	$5.3^{bc} \pm 0.04$	$5.8^{b} \pm 0.40$
LTL	Frozen-thawed	$42.4^{cd} \pm 0.50$	$48.5^{a} \pm 0.57$	$7.5^{ab} \pm 0.14$	$1.7^{d} \pm 0.19$	$0.9^{cd} \pm 0.00$	$5.3^{bc} \pm 0.04$	$5.6^{bc} \pm 0.16$
	Chilled	$43.5^{bc} \pm 1.23$	$45.8^{ab} \pm 0.89$	$7.3^{ab} \pm 0.25$	$3.1^{ab} \pm 0.21$	$0.9^{bcd} \pm 0.01$	$5.3^{bc} \pm 0.04$	$5.7^{bc} \pm 0.16$

Abbreviations: BF: *biceps femoris*, SM: *semimembranosus*, ST: *semitendinosus*, RF: *rectus femoris*, LTL: *longissimus thoracic et lumborum.*

LSMean: least square mean; se: standard error

$^{a\text{-}f}$LSMeans with different superscripts within main effects differ significantly at $p \leq 0.05$

Table 6.3 Differences (LSMeans ± se) between the muscle textural properties of five selected African savanna buffalo muscles

Texture	Treatment	Muscle type				
		BF	SM	ST	RF	LTL
Hardness (N)	**Frozen-thawed**	$172.4^{abc} \pm 14.26$	$221.9^{a} \pm 33.31$	$222.7^{a} \pm 40.05$	$215.5^{a} \pm 20.88$	$186.4^{ab} \pm 15.66$
	Fresh	$150.5^{bc} \pm 21.55$	$166.6^{abc} \pm 16.29$	$114.9^{c} \pm 21.50$	$132.3^{bc} \pm 15.66$	$163.7^{abc} \pm 14.99$
Cohesiveness (ratio)	**Frozen-thawed**	$1.3^{ab} \pm 0.00$	$1.3^{ab} \pm 0.01$	$1.3^{ab} \pm 0.01$	$1.3^{a} \pm 0.01$	$1.3^{ab} \pm 0.01$
	Fresh	$1.3^{b} \pm 0.01$	$1.3^{ab} \pm 0.01$	$1.3^{ab} \pm 0.01$	$1.3^{ab} \pm 0.01$	$1.3^{ab} \pm 0.01$
Springiness (mm)	**Frozen-thawed**	$0.5^{b} \pm 0.02$	$0.5^{b} \pm 0.02$	$0.3^{b} \pm 0.08$	$0.6^{b} \pm 0.05$	$0.5^{b} \pm 0.03$
	Fresh	$0.5^{b} \pm 0.08$	$0.4^{b} \pm 0.02$	$0.5^{b} \pm 0.03$	$1.2^{a} \pm 0.22$	$0.5^{b} \pm 0.05$
Chewiness (N)	**Frozen-thawed**	$111.4^{bcd} \pm 7.93$	$130.1^{bc} \pm 19.37$	$96.6^{bcd} \pm 23.65$	$144.7^{b} \pm 16.57$	$122.0^{bcd} \pm 14.80$
	Fresh	$96.9^{bcd} \pm 8.01$	$93.2^{bcd} \pm 7.31$	$73.4^{d} \pm 14.00$	$197.7^{a} \pm 33.12$	$94.2^{cd} \pm 10.59$
WBSF (N)	**Frozen-thawed**	$146.9^{a} \pm 11.91$	$120.6^{abc} \pm 6.28$	$144.4^{a} \pm 5.22$	$131.9^{ab} \pm 20.46$	$130.0^{ab} \pm 3.17$
	Fresh	$105.8^{bc} \pm 9.66$	$119.9^{abc} \pm 7.16$	$134.4^{ab} \pm 13.84$	$94.9^{c} \pm 12.11$	$111.1^{bc} \pm 6.88$

Abbreviations: BF: *biceps femoris*, SM: *semimembranosus*, ST: *semitendinosus*, RF: *rectus femoris*, LTL: *longissimus thoracic et lumborum* muscles
LSMean: least square mean; se: standard error
$^{a-f}$LSMeans with different superscripts within main effects differ significantly at $p \leq 0.05$

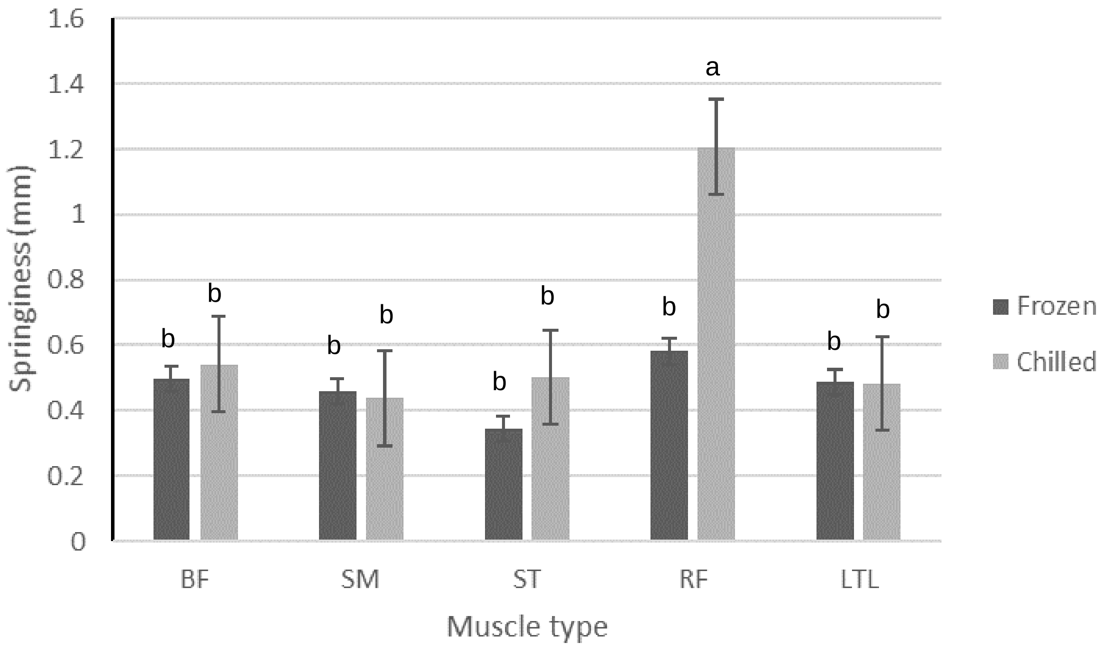

Figure 6.1 The Springiness (mm) between the five major muscles of interest for frozen-thawed compared to chilled muscles (BF: *Biceps femoris*, SM: *Semimembranosus*, ST: *Semitendinosus*, RF: *Rectus femoris*, LTL: *Longissimus thoracic et lumborum*). [a-d]Letters that differ indicate significant differences ($p \leq 0.05$).

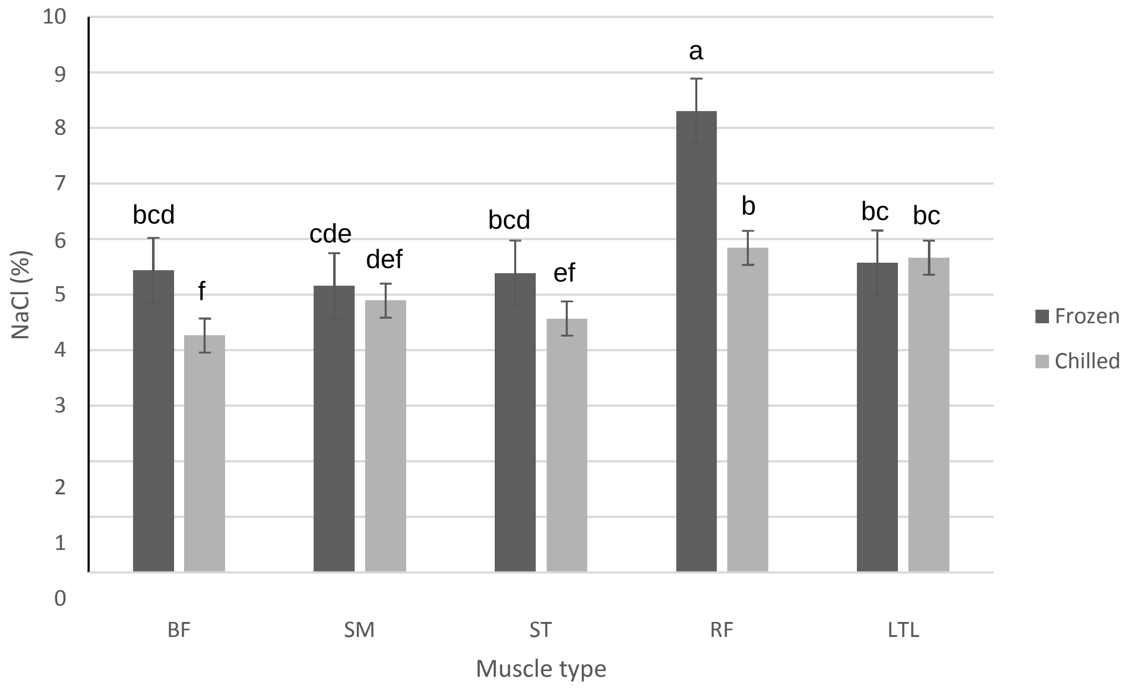

Figure 6.2 The NaCl % between the five major muscles of interest for frozen-thawed compared to chilled muscles (BF: *Biceps femoris*, SM: *Semimembranosus*, ST: *Semitendinosus*, RF: *Rectus femoris*, LTL: *Longissimus thoracic et lumborum*). [a-f]Letters that differ indicate significant differences ($p \leq 0.05$).

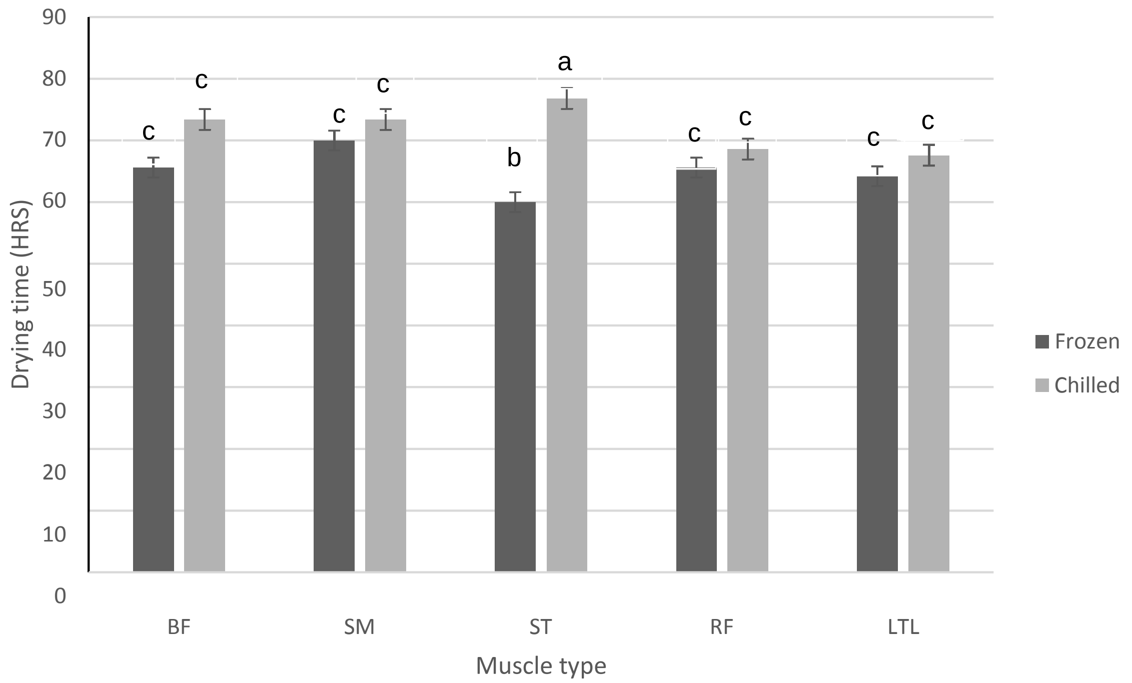

Figure 6.3 The drying time between the five major muscles of interest for frozen-thawed compared to chilled muscles (BF: *Biceps femoris*, SM: *Semimembranosus*, ST: *Semitendinosus*, RF: *Rectus femoris*, LTL: *Longissimus thoracic et lumborum*). [a-d]Letters that differ indicate significant differences ($p \leq 0.05$).

6.5 Discussion

There was a significant interaction between muscle type and chilled vs frozen muscles on drying time and salt content; biltong made from chilled muscle dried slower compared to that from frozen-thawed muscle, with the frozen-thawed ST muscle having the shortest drying time, and chilled ST muscle the longest (Fig. 6.3). In addition, frozen-thawed biltong had a higher salt content compared to that made from chilled muscle; in particular, the RF muscle had the highest salt content. The frozen muscle lost more moisture (thus concentrating the salt) than the chilled muscles, since salt content and moisture content are negatively correlated (r=-0.69) in the present study. This finding is due to structural damage caused by the ice crystals (Gambuteanu *et al.,* 2013; Leygonie *et al.,* 2012). In addition, frozen-thawed muscles gained significantly more weight compared to fresh muscle tissue during salting. Akköse (2017) also reported higher salt diffusion in frozen compared to fresh beef muscles; this phenomenon is explained by the formation of ice crystals which promotes salt dispersion through destroying the myofibrillar structure of meat.

The different treatments as well as muscle type also had a significant effect on the moisture content, while treatment also influenced the a_w values. Moisture content and a_w were significantly higher in biltong made from chilled muscles compared to frozen-thawed muscle tissue, with the lowest moisture content observed for biltong made from the RF (43.1 ± 0.98%) and LTL (42.9 ± 0.66%) muscles. These findings are in accordance with previous findings reported for beef biltong (Engez *et al.,* 2012; Retz *et al.,* 2017) and could be explained by formation of ice crystals during freezing leading to structural damage and increased water loss. Moreover, protein and ash content were both affected by the different treatments, with frozen-thawed biltong having a significantly higher protein content, as they lost more moisture resulting in an increase in the other chemical proportions. The frozen- thawed protein content of 48% was similar to that of frozen-thawed beef (Engez *et al.,* 2012). Furthermore, fat content was significantly affected by treatment and muscle type, since meat from different treatments was sources from different animals. A higher fat content was observed for fresh muscle biltong (2.9%) compared to frozen-thawed biltong (2.1%). Fat content differed significantly between the muscle types, with highest content for BF muscle and lowest for the ST muscle. These findings concur with those reported by Engez *et al*. (2012) for beef. This finding could be due to the differences between the different muscle's intramuscular fat (Table 4.5 from Chapter 4) (Grau *et al.,* 2008).

Treatment as well as muscle type affected the pH of the biltong, with chilled muscle biltong having a significantly higher pH (5.37) compared to biltong from frozen-thawed muscles (5.29). Since frozen-thawed muscles had higher moisture and weight loss, there is a higher percentage of vinegar and salt absorbed into the biltong, the former resulting in a lower pH

(Jones *et al.,* 2017). Freezing meat also results in an imbalance in ionic strength initiated by the loss of proteins and minerals which causes a lower pH (Leygonie *et al.,* 2012). The pH also differed between the individual muscles, with the BF muscle biltong having the highest pH, and the SM the lowest (Table 6.2). The high pH evident for the BF muscle can be due to a high fat content which could result in lower vinegar absorption compared to the other muscles.

In the present study, WBSF (134.7 ± 5.02 N) and hardness (203.8 ± 10.95 N) were significantly higher in the frozen-thawed muscles compared to the chilled muscles (113.2 ± 5.01 N) (145.6 ± 8.34 N) respectively. High WBSF and hardness are linked to water loss during thawing, increase in myofibrillar filament shrinkage, and protein coagulation (Shanks, 2002; Leygonie *et al.,* 2012). In the present study, a negative correlation was observed between the moisture content and the WBSF (r=-0.36) and hardness (r=-0.28). Furthermore, chewiness differed significantly between the muscles, with the highest chewiness noted for the RF muscle and lowest for the ST muscle. A significant interaction was observed between muscle type and treatment for springiness, with the ST and RF having the highest values for chilled muscles, and RF and BF for frozen-thawed muscles. Chilled muscles also had a higher (p=0.026) springiness than frozen thawed muscles. Springiness is also slightly correlated to the moisture content (r=0.01) and a_w (r=0.03) in dried meat products such as kumpiwozia and ham (Ruiz-Ramirez *et al.*, 2005; Wesierska *et al.*, 2014). These results were expected, since frozen-thawed muscles had a higher moisture loss which will result in a lower springiness.

Furthermore, casual observation of the dried biltong from frozen (detained carcasses) muscles did not show any of the parasite cysts (measles) and thus there should not be a visual defect observed by the consumers. However, this needs further research.

6.6 Conclusions

In summary, the different treatments and muscle types significantly influenced mass transfers and the physico-chemical properties of African savanna buffalo muscle tissue during biltong processing. The frozen-thawed biltong had greater weight gain during salting, lower moisture, fat content, water activity as well as pH, and significantly higher, salt, protein and ash content compared to biltong made from chilled muscles, resulting in a higher hardness and lower springiness for frozen-thawed muscles. For frozen muscles to be considered for biltong production, the drying time should be decreased to acquire higher moisture and springiness as well as prevent hardening. In conclusion, frozen-thawed carcasses can be utilised in the wildlife product section (WPS) to produce biltong from detained buffalo carcasses. Although, the BF muscle was identified as not being suitable for fresh steaks (Chapter 4 and 5), it is ideal for making biltong. Therefore, use of buffalo skeletal muscle tissue could add financial value thereby offsetting the cost of supply of meat to school environmental engagements with local schools.

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CHAPTER 7

MANAGEMENT OF AFRICAN SAVANNA BUFFALO MEAT IN THE KRUGER NATIONAL PARK

7.1 ABSTRACT

This chapter describes the development of a standard operating procedure (SOP) for the management and processing of African savanna buffalo carcasses in the Kruger National Park. Grade A and AB (sub-adult) buffalo carcasses should ideally be used for primal cuts and processing for value-added products. Grade B, C (adult) and detained (frozen) buffalo carcasses can be used for some primal cuts, processed meats and value-added products. Primal cuts should be vacuum packed and matured for at least 25 days and sold to restaurants and lodges, with the LTL and SM muscles in particular identified as valuable cuts. BF muscle is ideal for biltong production, since shear force will not decrease over a more extended ageing period. The off-cuts and trimmings will be useful for value-added meat products, including biltong, droëwors, patties, boerewors (sausage), stew meat and mince. Furthermore, the hides, heads and the bone meal could be processed further (by local artisans) and sold at auction and local shops.

7.2 Introduction

Sub-Saharan Africa is severely affected by malnutrition and starvation compounded by a lack of available protein sources (FOA, 2015). With the human population reaching nine billion in the next few decades, agriculture scientists must find new ways of meeting food requirements (Tscharntke *et al.,* 2012; Cawthorn & Hoffman, 2014). In this context, there is a need to consider methods to increase the production of high-quality meat in a sustainable manner, particularly from non-traditional animals, for human consumption. Since the number of buffalo in the Kruger National Park (KNP) exceeds the threshold of potential concern, the utilization of game meat for consumptive purposes is receiving more attention as a means of improving nutrition in adjacent communities (Berry, 1986). In addition, harvesting of animals for various management reasons is an essential component of wildlife management, and there is interest in economic opportunities for game ranchers and eco-tourism. However, concerns have been raised over the practicality and financial benefits of using harvested buffalo as a source of meat by-products in South Africa, where buffalo are not normally utilised for their meat (Robertson, 2007).

In order for game meat products to be an alternative protein source to domestic animals, the physical characteristics and nutritive content is desired for the labelling of these products.

Unfortunately, low quality experiences and insufficient information on the nutritive quality and content of the meat contributes to poor acceptance of game meat among potential consumers (Hoffman *et al.,* 2005). Therefore, emphasis should be placed on development of optimized logistical networks and supply chains to increase quality and safety, as well as improving marketing and communication, to promote consumer interest in game meat (Cawthorn & Hoffman, 2014).

In the present chapter, the development of a standard operation procedure (SOP) for the management of African savanna buffalo carcasses from field operation through slaughter, deboning, production and marketing is described towards the goal of establishing a more efficient supply chain.

7.3 Management of buffalo meat

The harvesting and processing of African savanna buffalo meat in the KNP involves five stages, namely 1) **field operation**, 2) **slaughter**, 3) **deboning**, 4) **production of products** and finally

5) **marketing**, as outlined below (Fig. 7.1). Moreover, these logistical points (phases) will utilise a set of activities required to process a raw material in to a value-added product.

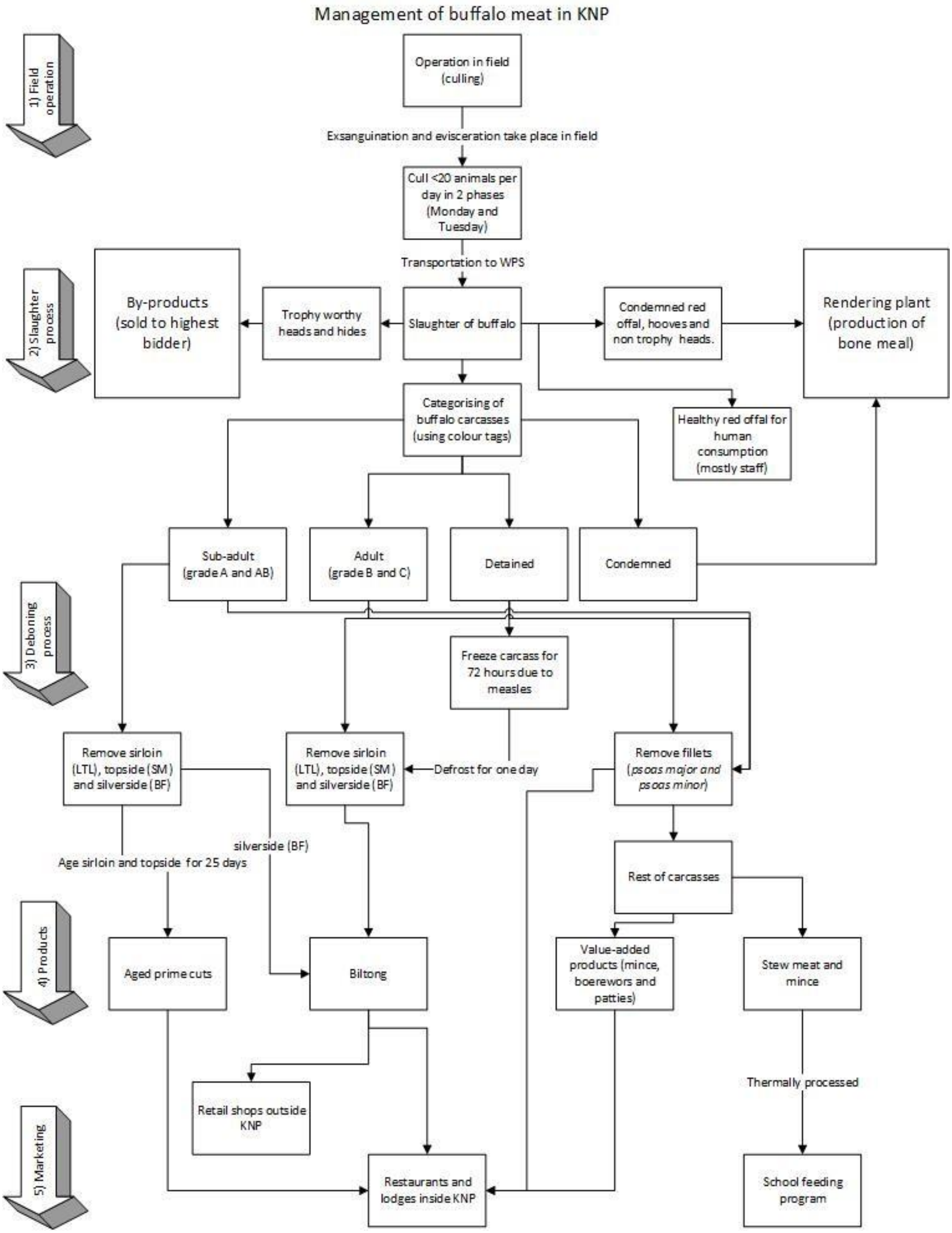

Figure 7.1 Standard operating system for the major logistical operational points to be considered in a typical buffalo harvesting scheme.

7.3.1 Field operation

Currently field operations usually takes place on Tuesdays and Thursdays when a helicopter is available for harvesting. The team manager and section ranger decide where the harvesting is to take place the day prior to harvesting, based on the information they receive from a fixed wing plane that locates the buffalo herd. The morning of the harvesting, all the vehicles (two high lift trucks for the transportation of the buffalo and the land cruisers for the transportation of scientist and field staff) drive to the chosen location and wait for the arrival of the helicopter. When the helicopter arrives, it lands and the pilot as well as the veterinarian discuss the final detail with the team leader on the ground, where after the helicopter seeks the buffalo herd as located by the fixed wing plane. After the herd is located, the helicopter attempts to move the herd to an open space close to a nearby road out of sight from all tourists. The pilot then informs the ground team when they can start moving closer, with the section ranger and state veterinarian in front, followed by the abattoir vehicle with butchers.

The veterinarian in the helicopter darts the buffalo with succinylcholine. Succinylcholine residues in meat are apparently considered acceptable by public health authorities, moreover cooking and digestion destroy Succinylcholine residues (Hoffman, 2001). The number of buffalo darted within an operation varies depending on the terrain and herd size, but usually ranges between four and eight. After the buffalo are darted, the helicopter pilot attempts to keep the darted animals bunched-up to facilitate the slaughter/loading process whilst waiting for the buffalo to go down (± 5 min from the first dart). When all darted buffalo are down, the helicopter so informs the ground crew and the section ranger, and the state veterinarian walk into the field and shoot all the darted buffalo in the head with a free bullet using a heavy calibre rifle to ensure that all the buffalo are dead. After ensuring that the number of buffalo that was darted and the number of buffalo shot in the head are the same, the state ranger signals for the abattoir team to exsanguinate the buffalo. Attention should be placed on not contaminating the neck slit area when transporting the carcass to the game abattoir (National Department of Agriculture, 2007). Thereafter, the bleeding proceeds, which could potentially be sped up by letting the buffalo bleed on a slope or whilst suspended by the high lift whilst blood samples are taken for the blood bank.

Trucks with a high lift then move in and hang the buffalo to further the bleeding process, which helps improve the quality and palatability of the meat. Game (category A-buffalo) must be bled within ten min of being shot and can be bled in laying position (National Department of Agriculture, 2007). In the KNP, there are currently two trucks partaking in this process: one truck can lift a maximum of four buffalo, whereas the other truck can only lift a maximum of two buffalo at one time. Although the helicopter attempts to keep the darted buffalo in a closed herd, the dead buffalo are normally spread out and need to be dragged closer to the trucks by using a land cruiser that is equipped with a conveyer belt whereupon the buffalo carcasses are placed; this helps to speed up the time between exsanguination and the hanging process and results in faster bleeding. After bleeding, evisceration, which refers to the removal of the internal organs from the carcass takes place (National Department of Agriculture, 2007). Evisceration take place in the field to ensure that there is no bloating of the carcass, as it can take up to two hours or more for the carcasses to be transported from the field to the abattoir. Bloating will increase the risk of contamination (micro absorbance) within the abattoir during the dressing procedures. It should be remembered that wild ungulates normally have a full stomach as they have not stood in lairage and had time to decrease the stomach contents as is the scenario with livestock. The necessary facilities for knife sterilisation and hand cleaning are available in the field (National Department of Agriculture, 2007). The primary meat inspection is conducted by an independent State veterinarian and includes inspecting the head, pluck, feet, abdominal and reproductive organs of a partially dressed game carcass with the pluck (red offal) and carcass then being sent to a registered game abattoir. Most of the white offal is left in the field for predators or vultures (Department of Agriculture, 2010). However, some of the rough offal will be cleaned and taken for own consumption by the staff such as the plies (third stomach) and set of tripe (weasand, first, second and fourth stomach and rectum).

The eviscerated buffalo carcasses are loaded onto a truck with the high lifts and covered up with a tarpaulin, ensuring that tourists will not see the carcasses but also protects against contamination of opened abdomen. The buffalo are transported to the game abattoir within two hours of being bled. The first truck drives back to the abattoir with the first phase of harvested buffalo, and some of the abattoir crew start the slaughter process. The next group is culled after the truck with the previous phase has departed for the abattoir and everyone is back in their vehicles, where after the helicopter starts locating the buffalo herd again and moves them to an open space were the harvesting continues until the required number (±15) of buffalo is reached. The whole slaughter procedure is repeated as described. After the required number of buffalo are slaughtered, the second truck drives back to the abattoir with the remaining abattoir crew and carcasses.

Suggested procedural changes:

Presently, the idea is that the buffalo killed on Tuesday will be deboned on the Wednesday (after chilling) with the next batch being killed on the Thursday and deboned on the Friday. The Friday then being set aside for further processing. It is also accepted that all the staff in the abattoir are involved in these activities. A recommendation is that the harvesting should be done at the start of the week before Wednesday, preferably on Monday and Tuesday, thus allowing sufficient time for cooling of the carcasses with the first carcases being deboned on the Wednesday (after at least 36 h of chilling). This will allow for the Friday to do further processing as well as selling of meat (see later). Therefore, all the carcasses can be deboned and stored before the weekend. Furthermore, a dedicated helicopter should be considered since, the present helicopter's main purpose is for anti-poaching and will therefore stop the harvesting process for any anti-poaching activities. Some causes for concern included inaccurate shots, the generation of excessive stress for the animals as well as inadequate bleeding (a chest stick could also be used to facilitate a better bleed-out), and cooling (the time from loading the buffalo to delivery at the abattoir should be minimised due to the high temperatures in KNP) potentially resulting in inferior quality of meat (Hoffman *et al.*, 2004). Also, care should be taken to ensure that not too many animals are harvested during the time period as this could result in carcasses lying on the delivery vehicle for an unnecessarily long time before being processed in the abattoir. Whilst lying on the vehicle they will be exposed to the external elements including high ambient temperatures and flies, to name but a few. However, as time progresses and the abattoir team become more efficient in the process, more animals can be processed per time unit, and the lower the fixed costs per unit become (efficiency is key).

7.3.2 Slaughter of African savanna buffalo

Game meat falls under the Meat Safety Act of 2000 (Department of Agriculture, 2000). More recently, a manual for game meat inspection was published by the Division of Veterinary Services (Section Veterinary Public Health) of the Department of Agriculture (National Department of Agriculture, 2007).

Following the field operation, buffalo typically arrive in two phases at the abattoir offloading section as seen in Fig. 7.2 which is a line-slaughter system. The carcasses are hoisted up and suspended from both Achilles tendons. Moreover, the carcass weights are taken so that the predictions can be made on the yields of not only the carcasses but also different cuts/products to ensure easier marketing and for control purposes. The head and feet are only removed at the abattoir, where the first meat inspection point (by an independent inspector) is situated (National Department of Agriculture, 2007). The heads are then hung on separate hooks on a different line, in the same order as the carcasses. Removal of the hides is performed using hygienic and clean techniques to ensure the quality of the hide as well as the meat. Contact between the exterior of the hide and meat should always be prevented. Removing the hide when the carcass is still warm is easier and preferred. All the cuts are made from the inside to the outside to prevent contamination of the meat using the two knife principles. The hides will be processed to be sold at auctions. All sexual organs are completely removed. The flaying knife should be used with care since damage cuts on the hide will lower their value. The quality of the hide does not start at the curing process, but it starts at the removal of the hide (National Department of Agriculture, 2007).

Red offal is preferably removed at the depot/abattoir and are hung on a separate line, in the same order as the carcasses and inspected when still fresh by the veterinarians. Abnormalities noted on the red offal will be correlated with the carcass by a tagging system or with a report attached to the carcass, for the meat inspector. The carcasses are then split in half with a saw blade without deviating from the centre line of the spinal column to prevent damage to any expensive cuts; this promotes chilling. The halved carcasses are then inspected and trimmed by the veterinarians/meat inspectors for approval. Lastly, the carcasses are washed with potable water to remove all blood and bone saw dust and quartered between the 9th and 10th rib and weighed before being dispatched to the cooling facility where it is refrigerated so that the core temperature of the carcass is chilled to lower than seven degrees Celsius (< 7°C) in less than 24 h to limit bacterial growth (National Department of Agriculture, 2007).

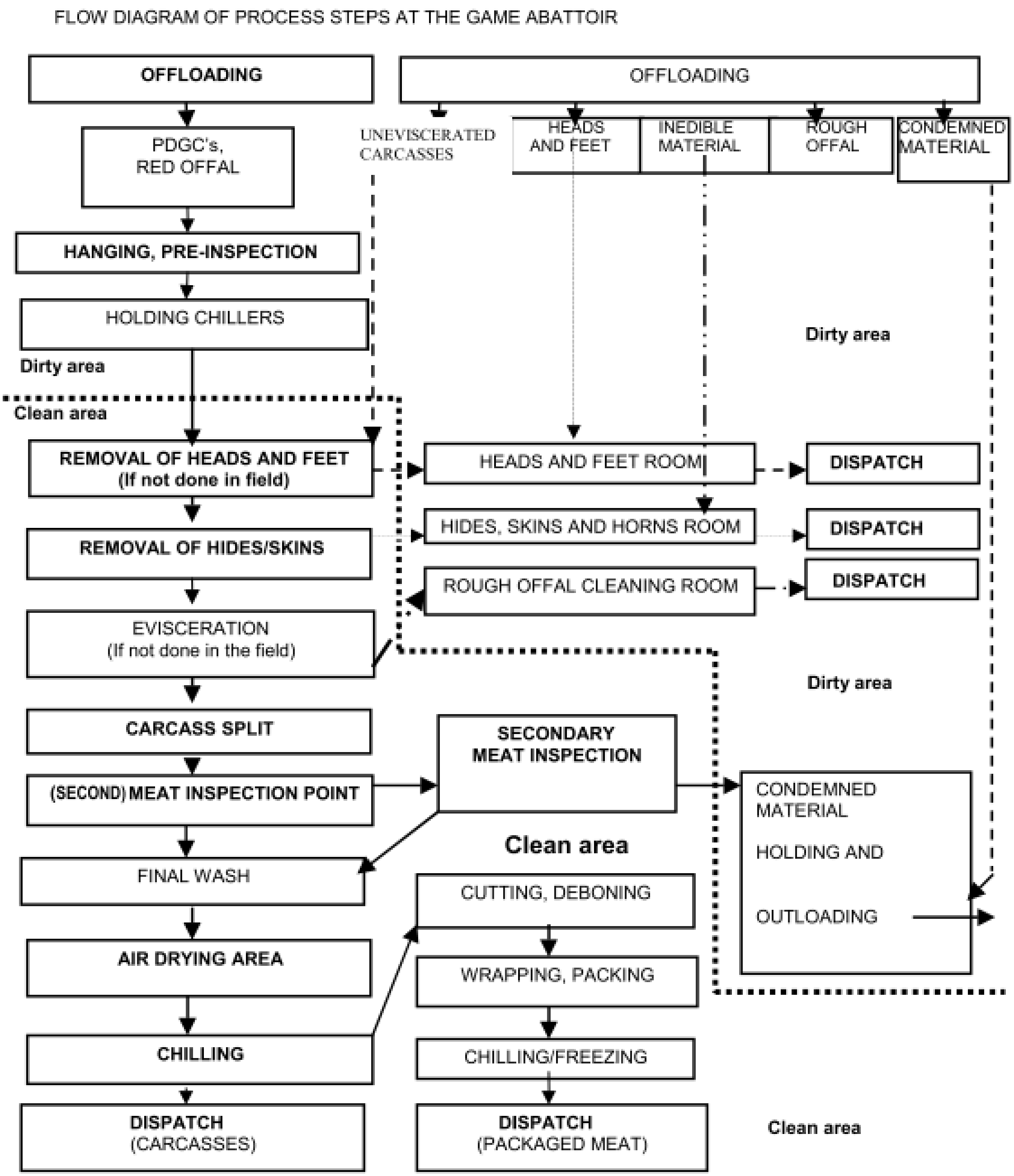

Figure 7.2 The representation of the process steps at a game abattoir (National Department of Agriculture, 2007).

The reasons for detaining carcasses include when there is more than the norm (one or more) Sarcocystis parasites (sarcocystis parasites are obligatory, two-host, intracellular, intestinal, coccidian parasites), or beef measles (*Cysticercosis*), present in the secondary inspection from the four incisions made in the shoulder muscles and on the majority of cut surfaces made by the veterinarian or meat inspector during the secondary inspection. These carcasses need to be frozen at -18°C for 72 h. The carcass/meat may be released for human consumption, after the deep bone or core temperature reach -6°C as confirmed by an authorised person. Carcasses can be partially or totally condemned. Affected areas are condemned due to various reasons, such as infections caused by systematic or generalised lesions. If only the red offal is affected, and the rest of the carcass is normal, only the red offal is condemned (lungs, heart and liver). However, if the intestines are linked to general diseases such as enlargement of the lymph glands, fever or hepatitis etc. the whole carcass is condemned (National Department of Agriculture, 2007). The condemned carcasses and condemned organs are sent to the rendering plant to create a by-product known as bone meal.

Suggested procedural changes:

It is suggested that a grading system be implemented. Application of a grading system helps to categorize buffalo carcasses, guiding the deboning team to know which carcasses will go for prime steaks, ageing, value added products and processed meat (Table 7.1). The grading of buffalo carcasses is of utmost importance for the abattoir and will help identify the different grades of meat by sorting the different grade buffalo in different lines in the cool rooms or by using different colour tags. Incorporating the grading of buffalo at the abattoir will help speed up the process and prevent adult/old buffalo meat being sold to restaurant and lodges as prime tender (and expensive) steaks. Grade A and AB meat should go for prime cuts whereas grade B and C will go for value added products and processed meats, creating a better flow in the supply chain. However, the fillets (*psoas major* and *minor* muscles of all the carcasses can be sold as primal steaks at the highest price). A brief analyses of the harvest data of the past number of years would seem to indicate that a larger proportion of older bulls have been selectively harvested rather than animals randomly killed; these older bulls have inferior meat quality which cannot be processed into prime tender steaks, thereby causing a loss of potential income.

Table 7.1 Suggested grading of African savanna buffalo (*Syncerus caffer caffer*) carcasses

Grade	Permanent incisors	Buffalo age	Category
A	0	< 2 years	Juvenile
AB	1-2	2.5; 3-3.5 years	Sub-adult
B	3-6	4; 4.5; 5; 5.5 years	Adult
C	7-8	6; 6-10; >12 years	Old

To evaluated and develop the grading system (Chapter 3), male (n=17) and female (n=13) buffalo were slaughtered; 23 were categorised as adult (grade B and C) and seven as sub-adult (grade A and AB). Sex only influenced the head and skin weight. The age category influenced all the parameters except for the heart and IS muscle weight. The muscle weight for the adult category was between 24 and 50 percent heavier than those of sub-adults, with heaviest weights measured for the BF (silverside), SM (topside) and LTL (sirloin) muscles. Findings from this study therefore suggests that only the different age categories/grades and the detained carcasses (Table 7.1) should be marked with different colour tags. Therefore, the deboning team know what they should produce from these different carcasses and will therefore help with the flow.

7.3.3 Deboning process

Deboning is the process whereby the fore and hindquarters of the carcass are taken and processed into various primal cuts (similar to those from beef carcasses). The primal cuts from the hindquarter are: silverside (*biceps femoris*), fillet (*Psoas major and Psoas minor*), sirloin (*longissimus thoracis et lumborum*), prime rump (*gluteus medius*), T-bone, topside (*semimembranosus*), knuckle (*vastus medialis* and other related muscles) and hind shin (*Peronaeus terius, extensor digitorum longus* and *extensor digiti terii proprius*). Some of these primal cuts are then vacuum sealed for an extended shelf life and maturation. The deboning process starts 24 h post-mortem after chilling at temperature as close to 0°C as possible, and the pH has gone from a physiological pH of 7.0-7.2 in the muscles to 5.3-5.8 pH_U post-mortem (Honikel, 2004). The quarters are then moved from the chillers via rails to be weighed and then move on to the primary block-man, where the muscles are excised from the quarters and moved to the table for further trimming and cleaning of the primal cuts.

Suggested procedural changes:

Currently most of the meat are cut up in to goulash and stewing meat and sold for the lowest price. However, with the implementation of the ageing of the prime cuts and the new value-added products. The deboning team will vacuum pack the prime cuts and age them according to the correct number of days thereby creating value added products from the different muscles excised.

The sanitation of the deboning room is a high priority and should commence immediately after each break and at the end of the production day, however all edible meat products should be removed before sanitation starts in the area. The new shift after the break may not start before all the areas and equipment have been cleaned and disinfected (National Department of Agriculture, 2007).

Block tests is a measure that was established during the time of the Meat Board for wholesalers and retailers to price a variation of cuts given a certain producer price (National Department of Agriculture, 2002). Therefore, block tests should ideally be conducted on a regular basis to help determine the number of different cuts that will be produced from a buffalo carcass. In the present study a block test was conducted by Jussy Mashele on the 01/06/2018 on a buffalo with a carcass weight of 277 kg (Table 7.2). By using the block test, the quantity of meat that will be produced could be predicted, and the price per carcass could be calculated: at the suggested (current price being paid by wholesalers for the equivalent beef cuts) price WPS can sell all these different cuts for a total of R11 765.51 per a carcass of 277 kg. Therefore, value added products should be considered to increase the value per carcass and help subsidise the cost of the stew meat for local schools.

By knowing the age category or if it is detained by observing the colour tags utilised in the slaughter process, the right procedure can be used for the next step. In the present study (Chapter 4), sex did not influence any physical characteristics (ultimate pH, drip land cooking loss, tenderness and colour) and proximate composition (moisture, protein, intramuscular fat and ash content) of fresh steaks. However, adult buffalo had a lower tenderness and moisture content with a higher pH_U and IMF than sub-adults. Furthermore, the physical and proximate characteristics of buffalo meat differed significantly between the six muscles of interest, with the SS muscle (blade or chuck tender) being most tender and the BF (silverside) the toughest, with the LTL (sirloin) having the highest amount of IMF and protein. In the present study, SM (topside) and LTL (sirloin) muscle aged for 25 days gave optimum tenderness and the variation in the BF (silverside) tenderness over time indicates that the muscle is not necessarily suitable for ageing and consumption as a fresh steak.

Table 7.2 Block test conducted on an African savanna buffalo (277 kg)

Retail cuts	Weight (kg)	% whole
Top side	11.4	4.11
Silverside	15.2	5.49
Rump steak	10.9	3.93
Thin Flank	8.5	3.07
Thick Flank	8.9	3.21
Short fillet	1.9	0.68
Soft shin	11	3.97
Shin	3.3	1.19
Tail	0.5	0.18
T-bone steak	15.8	5.7
Blade steak	13.7	4.94
Brisket	17.3	6.24
Short rib	6.3	2.27
Chuck/prime	22.7	8.19
Neck	11	3.97
Trimming	21	7.58
Stew	43.6	15.74
Goulash	3.1	1.12
Hump	4.5	1.62
Bones	34	12.27
Sinew & Fat	10.7	3.86
Band saw loss (SODAS)	1.7	0.67
Total	277	100

From the abovementioned, the adult category and detained carcasses (after defrosting for 24 h) with the tougher muscles should be deboned in value added products. SM (topside), BF (silverside) and LTL (sirloin) muscles should be removed for biltong production and the rest of the carcass utilised into stew meat, mince, boerewors, and patties, whereas the sub adult age category muscles, especially LTL (sirloin) and SM (topside) muscle should be aged in to steak and the BF (silverside) muscle utilised for biltong production.

7.3.4 Products

Meat consumers want convenient items that are cost effective, economical and have a superior shelf-life quality (Deogade *et al.,* 2008). Value adding to products is defined as: "to economically add value to a product by changing its current place, time, and form characteristics to characteristics more preferred in the marketplace". These days the consumers want a low-fat or organic product. Value can be added through packaging, shelf life stability and/or creating different products. Presently customers arrive and purchase meat mainly defined as steaks (Top side, Silverside, Rump steak, Fillet, T-bone) or products (mince, Boerewors or biltong sliced).

Suggested procedural changes:

Presently, all these products are currently sold at a very low price and thus, it becomes difficult, if not impossible, to cover the operational cost and to help subsidise the cost of the stew meat for the school outreach program. Therefore, new value-added products should be produced, with a larger profit margin. However, all these raw products can be sold in the KNP but cannot be sold raw outside the buffer zone that surrounds the KNP due to FMD. However, by using the value chain analysis to find out what the consumers want in KNP, products can then be adjusted accordingly and also create a larger profit margin for these value-added products.

The KNP is in an unique situation in that it has the final control on the meat that is sold at its restaurants and in its shops as well as to some of the private lodges/camps that are in the KNP. Casual observations during this investigation indicated that particularly the latter are aware of the quality meat being sold and are regular customers. However, there is a negative association to this “formal” selling of meat to the public in that customers arrive at any time ad disrupt the flow of work in the deboning plant. It is thus suggested that meat and meat products only be sold to the public on Fridays (if the program of Monday/Tuesday is applied for the harvesting of the buffalo).

The following buffalo products prices at the Wildlife Product Section (WPS) are compared to Karan beef (wholesaler) and Checkers supermarket (Table 7.3). Karan beef abattoir is equipped to process up to 2040 head of cattle per day as well as to debone 300 tons of product per shift, therefore, they’re in a whole different production level than WPS, however they still sell their bulk products at a higher price than WPS. Furthermore, in a large retail shop such as Checkers, the price is double for most of the products and for fillet it is almost four times the price. Therefore, WPS should increase the prices of the products that have a high demand and diversify in value added products especially in biltong, since it can be sold outside the buffer zone (KNP) to retail shops at a premium price.

Table 7.3 Prices for buffalo meat products at WPS (2018), compared to beef of Karan beef (abattoir) and Checkers (Stellenbosch) (20/10/2018)

Different products	Price (R/kg) WPS	Suggested selling price (R/Kg)	Price (R/kg) Karan Abattoir	Price (R/kg) Retail
Stew	39.22	60		98.99
Top side	59.23	70	66.00	89.99
Silverside	53.95	70	66.00	89.99
Rump steak	59.23	90	88	139.99
Fillet	59.23	200	147	249.99
T-bone	53.95	90	89	104.99
Mince	49.07	65		89.99
Boerewors*	57.40	70		89.99
Biltong sliced	147.20	240		299.99

* to make boerewors or droëwors, fat would need to be bought in from outside, as well as other spices and sausage casings. However, this product will most probably sell very well at the camping and lodging sites as it is perceived to be an ideal product for braaing by your average South African.

FMD are associated with all the buffalo that were harvested, therefore there are three approaches to sell the meat outside the buffer zone (Fig 7.3). The meat should be de-boned correctly, well-cooked or processed into break-dry biltong. However, for well-cooked meat there are more precise options such as inactivating the FMD virus by thermal process consisting of a conventional continuous cooking process followed by steam cooking of vacuum packaged products (Masana *et al.,* 1995). Thermal processing of beef cubes, ground beef or beef slices in commercially popular flexible pouches, effectively inactivated FMD virus in beef. Meat cooked in boiling water must reach a core temperature of 93 °C over a 16 min processing period to produce a FMD free product (Garcia-Vidal *et al.,* 1988).

Presently the whole detained carcasses (frozen carcasses) are utilised for stew meat and sold at the lowest price of R39.22 per kg, therefore, other utilisations of the carcasses should be considered, such as biltong production, since biltong is being sold at R147.20 per kg (although this price should be increased). In the context of biltong production (Chapter 6), compared to chilled buffalo meat, frozen thawed muscles had a significantly higher salt, protein and ash content with a lower moisture, pH, water activity and fat content. The BF muscle had the highest fat content and pH as well as the lowest salt content. Overall the frozen-thawed biltong had a higher hardness, with a lower springiness. However, the frozen carcasses (detained carcasses) can be utilised the same as chilled adult carcasses for value added products, especially biltong. The possibility should be evaluated of including brown sugar into the spice mixture (a commercial spice mixture was used) which should help minimise the hardening of the outside of the frozen-thawed biltong.

The effect of different drying methods were briefly evaluated; (1) ambient-air drying (average temperature of 22°C) where 3 fans (first fan: 160 Watt, Akira model: FP-18A spec 18inch, second fan: 150 Watt, logik 45cm high velocity floor fan model: HVF-45, third fan: 85 Watt, Kenwood model: IF450) and an extraction fan (130 Watt) were utilised and (2) a Hilco biltong cabinet drier (Freddy Hirsch) (average temp of 26°C) were also utilised. Both drying methods are suitable for biltong processing to produce biltong with similar properties (Nwabisa, 2017). However, the cost associated with the ambient air in the present study worked out 44.49% cheaper than that of the cabinet drying. In addition, ambient air drying will also reduce more costs since, the quantity produce per drying time of 60 h can exceed that of the cabinet dryers. Therefore, ambient air drying should be utilised at the WPS to help increase the production of biltong. However, further research is required to standardise the SOP with ambient air drying.

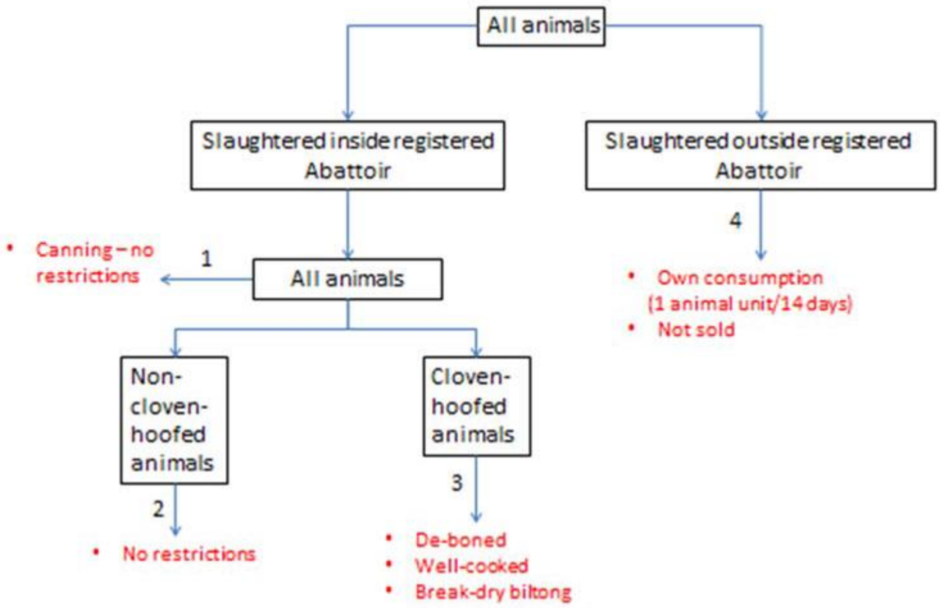

Figure 7.3. Veterinary regulations regarding animal slaughter and movement out of a Foot and Mouth (FMD) infection zone (Swemmer & Mmethi, 2016).

7.3.5 By-products

Trophy worthy heads are cleaned, dried in the sun to be sold as trophies, whilst the smaller heads and the condemned carcasses go to the rendering plant to produce an end product known as bone meal that can be sold as fertiliser. Further all the hides are cured at the WPS and sold to the highest bidder.

7.3.6 Marketing

Meat products are marketed in several ways and convenience to suit the consumer's choice. Meat has a high biological value and plays a special role in developing countries such as Africa, where protein deficiency and malnutrition are major problems (Deogade *et al.,* 2008). Consumers expect the meat products on the market to have the required freshness, tenderness, wholesomeness, leanness, flavour, satisfactory juiciness and a high nutritional value (Grunert *et al.,* 2004). Environmental customers are also more concerned about the environment and thus more interested in organic products and products farmed in systems that are close to natural production systems (Steenkamp, 1997). Consumers are also more aware of food issues and health concerns and thus game meat which has a lower fat content than pork, beef or mutton could be marketed as a premium health product (Hoffman *et al.,* 2005). Furthermore, tourists visiting Africa have indicated that they would like to try game meat as part of the whole Africa experience (Hoffman *et al.,* 2003). The best- known game meat products are steaks and biltong.

The South African game industry is a free-market enterprise and generates opportunities for game meat producers and individual game ranchers. However, this creates problems since there is no standardised cuts or quality standards for game meat (Hoffman & Bigalke, 1999). Any individual producer can sell any type of game meat quality or cut. This result in inferior quality meat such as dark, firm and dry (DFD) being sold on the market. The problem then is that the inferior quality meat is sold with the good quality meat. The meat products from WPS are currently only sold to the staff members of KNP at a very low price, too low to help subsidise the cost of the stew meat for their interactions with the adjacent communities. Trophy heads are sold to hotels and restaurant as decoration or to individuals, further the hides are sold at an auction to the highest bidder and the bone meal sold as fertilizer.

Suggested procedural changes:

The recommended marketing and outsource of products (Fig. 7.1) would be to sell all the sub-adult buffalo aged LTL (sirloin) and SM (topside) muscles as well as all the fillets (Chapter 5) to restaurants and lodges, as these will produce the highest quality steaks. Further all the adult category and frozen carcasses' BF (silverside), SM (topside) and LTL (sirloin) muscles can be processed in biltong and the rest of the carcass utilised as stew meat and value-added products such as mince and boerewors; thus most of the stew meat for the meat distribution can be processed from the detained carcasses and the forequarters of most of the buffalo (this is also the normal use in any beef carcass for these cuts) and utilised through thermal processing to inactivate FMD. Therefore, using the fresh carcasses for producing the high-grade value-added products for selling in the KNP to restaurants, lodges and to all the picnic stops (were all the products would be cooked and prepared by the staff, preventing the risk of someone trying to move the fresh meat outside the buffer zone) will help subsidise the feeding scheme.

7.4 Conclusions

In summary, findings from this study support the use of grade A and AB (sub-adult) buffalo carcasses for aged primal cuts as well as processing for value-added products. Grade B, C (adult) and detained (frozen) buffalo carcasses can be used for processed meats (mainly biltong) and value-added products. The tough meat from adult and detained carcasses can be successfully utilised for stew meat and development of palatable products (patties, sausage and droëwors). Primal cuts should be vacuum packed and aged for a minimum of 25 days under refrigerated conditions (should also be properly labelled on "day in" and suggested day to be sold) and sold to restaurants and lodges, with the LTL (sirloin) and SM (topside) muscles in particular identified as valuable cuts. The fillets of all the animals can be sold fresh as they are removed; due to their inherent nature/composition they need not be aged. In contrast, the BF muscle is ideal for biltong production, since toughness (shear force) will not decrease over a more extended ageing period and it will thus remain a tough muscle. The off-cuts and trimmings could be used for value-added meat products, including biltong, droëwors, patties, boerewors (sausage) and mince. Biltong can be produced from frozen-thawed (detained) carcasses using different drying methods; it is suggested that in summer use be made of the ambient air and only when time is of essence, the drying cabinet. This will ensure that less energy is used. Producing biltong from frozen carcasses creates a larger profit margin, since frozen carcasses can only be used for processing of biltong, stewing meat and mince. All stew meat and mince from the carcasses should be thermally processed before sending to the schools. In conclusion, the use of buffalo meat has potential as an alternative protein source in sub-Saharan Africa. In addition, further research is needed for other alternative protein sources for the school feeding scheme such as impala in KNP, due to this species being most populous.

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